CRANIOFACIAL SURGERY AND DISTRACTION OSTEOGENESIS

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Prof. Dr. S.M. Balaji
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From the Editor’s Desk . . .

My sincere thanks to His Excellency, Maumoon Abdul Gayoom, The President, Republic of Maldives, for all his support and encouragement to organize this scientific session at the beautiful islands of Maldives. I am also thankful to Hon’ble Ilias Ibrahim, The Minister of Health, and the Government of Maldives, whose enthusiastic support have always encouraged us to aim higher and to achieve the same.

I take great pleasure in acknowledging Prof. U.S. Nayak, the Organizing Chairman, who always encouraged us to vie our mission on international standards. A special thanks to Prof. Cesar Guerrero, Prof. Patrick Diner, Prof. Masaharu Mitsugi, Prof. Lim Cheung, Prof. Andrew Heggie, Prof. Tetsu Takashi, and every one of the ingenious, dedicated craniofacial surgeons and scientists. For their continuous work on research and their altruistic sharing of experiences.

Medicine as it is practiced today has evolved through the ages by evidence based research and careful documentation. It is necessary therefore for us practitioners to continuously look at each other and share our views and experience to whet our own skills in providing the best treatment to the patients, who trust our ability.

This book of transactions of the 3rd Asia Pacific Congress on Craniofacial Surgery and Distraction Osteogenesis is a collection of the meticulous and significant research work performed by colleagues around the world, printed to be preserved and referred to. The previous book had proved invaluable to me in many ways. Many of my colleagues expressed the same. Therefore we have taken some extra efforts to publish more research work in this volume, even though it proved to be very strenuous on the financial aspect.

A cursory look at the contents will show you that the book contains invaluable articles from the “pioneers” of craniofacial surgery and distraction osteogenesis. To name a few, Prof. Cesar Guerrero
has contributed three articles. Prof. Mitsugui has provided us an illustrious overview of all the craniofacial distraction procedures; Prof. Andrew Heggie has showed us many knick knacks of craniofacial surgery. It has many detailed experimental as well as clinical studies; long term results in addition to accounts on new devices and innovative techniques. If I start enumerating all the others, I’d run out of pages.

Veterans like Prof. Michael Carstens have given us detailed accounts of their exhaustive studies on embryogenesis, the very basics of our treatment procedures. Some of these, though important and exceptional could not be accommodated into the conference schedule for want of time, but I could not stop myself from including them in the published literature.

I hope this book too, like its predecessor, will be useful to all the surgeons like me, and stimulate us to look for answers for challenges yet to be surmounted. I hope you find this book worth the effort that has been taken to make it. If you do, please write to me at smbalaji@eth.net; it will provide mighty encouragement.

Thanking you,

Prof.Dr.S.M.Balaji
Organizing Secretary & Editor
Traditional versus rhBMP-2 Inducted Intraoral Bone Transport in Mandibular Reconstruction

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Summary: This study focuses on the evaluation of mandibular bone transport in 10 mongrel canines. Three groups consisting in 5 surgical sites each were operated to evaluate bone healing. In the control group a 12 mm defect was created and no reconstruction procedures were intended, in the second group bone transport by distraction osteogenesis was performed for reconstruction and in the third group bone transport with rhBMP-2 was employed to accelerate the distraction regenerate process. The distraction protocol consisted in 2mm intraoperative activation, 5 days latency period, 0.9mm per day activation for 10 days and 75 days of consolidation. The group 3 with rhBMP-2 showed excessive bony regenerate at the distraction area compared with group 2. Group 1 revealed poor bone formation throughout the defect.

Introduction: The use of intraoral distraction osteogenesis to reconstruct critical defects (12-30mm) of the mandible is the newest alternative, based on the excellent animal research and clinical results. During our previous reports on bone transport we have observed that long consolidation periods were needed to obtain stable results; this phase needs to be proportional to the amount of distraction
performed, taking from 3 to 12 months to show adequate mineralization on the radiographs, depending on the amount of distraction. Human recombinant bone morphogenetic protein (rhBMP-2) has been used successfully in the osseous reconstruction of large mandibulectomy defects in adult Macaca fascicularis monkeys to regenerate osseous defects. The purpose of this study was to radiographically evaluate and compare the bone healing process after a pure bone transport and bone transport with a molecule of TGF-beta superfamily (rhBMP-2) as a bone inductor to enhance or accelerate the bone healing and consolidation process.

**Material and method:** Three groups of mongrel dogs consisting on five surgical sites each were used in this study to evaluate the effects of rhBMP-2 in the healing process for intraoral bone transport. **First group** (control): An intraoral Marx’s reconstruction plate was utilized to maintain the proximal and distal segments in position; a 12 mm mandibular body resection was performed to create a critical size defect for spontaneous healing. **Second group** (Pure bone transport): Under general anesthesia and controlled vasoconstriction of the area, a large horizontal incision was made on the vestibule. A Marx’s reconstruction plate was fixed transmucosally in five surgical sites and 12 mm bony defects were created. Under abundant irrigation and minimal periosteal detachment a vertical osteotomy was performed to create a 1cm distraction disc and meticulous periosteal layer closure was accomplished. The Dynaform appliance’s anterior arms were bent to create a step for a straight A-P vector avoiding medial displacement of the transporting segment. The device was then screwed over the reconstruction plate, which served as a guide for the mandibular reconstruction during the activation period. The reconstruction plate was fixed with a minimum of three screws on both sides of the discontinuity defect leaving enough space for the distraction disc osteotomy and the distractor placement. The posterior arms of the appliance were fixed to the proximal segment with two bicortical screws and the anterior arms to the distraction bullet. The distraction protocol consisted in 2mm of intra-operative activation, five days after surgery.
without activation (latency period), and 0.9mm per day for 10 days (activation period), to complete the protocol with 75 days of consolidation period. After distraction was completed the appliances remained in place throughout the entire study. **Third group (Bone transport with rhBMP-2):** Following the same surgical technique indicated for the second group, five surgical sites underwent 12 mm bone transport. One month post-surgery, after the activation period was completed, the distraction chamber was approached extraorally through the skin and partially filled with 0.75mg of BMP-2 reconstituted with Lyophilized buffer mixed with Osteogen (synthetic non-ceramic form of resorbable pure hydroxiapatite osteoconductive 300-400 microns). All animals were sacrificed 90 days after surgery under sedation with perfusion technique for microangiographic studies, used in the evaluation of wound healing processes (modified after Rhinelander). The system consisted on cannulating both common carotid arteries for perfusion under Hg pressure with 10% buffer formalin, and both femoral arteries were used for exsanguinations and adequate perfusion of the entire head and neck region. Serial cephalometric radiographs, submento-vertex, lateral, periapicals and occlusals were taken in all animals before, immediately after surgery, at the end of distraction period, and 90 days post-surgery before necropsy. During the radiographic procedures the animals were kept sedated and their heads were positioned in a standardized setting and at the same distance against the x-ray cassette to minimize the error due to magnification.

**Results:** The first group showed intention of bridging the gap with an incomplete bony regenerate, leaving an important discontinuity defect. The second group demonstrated radio-opacity between the two bony segments of 90 and 100% range, 90 days after surgery, 1/5 had a major oral exposure allowing food and saliva contamination and major soft tissue contraction demonstrating a minimal 35% radio-opacity, with good inferior border continuity and vertical contraction at the alveolar bone level. The third group treated with rhBMP-2, showed as well consolidated radio-opacity of 90 to 100%, 90 days post-operatively. However, the occlusal radiographs
at the distraction chamber area revealed a more voluminous distraction regenerate after the consolidation period in group 3 than group 2 with no rhBMP-2. The second and third groups showed a radiopacity comparable to the contiguous bone in the distraction chamber site 90 days after surgery. Both groups showed on the radiographs, taken thirty days after surgery, the five zonal structures: the radiolucent fibrous interzone in the middle of the distraction area (FZ), radiodense mineralization zones on either side (MZ), and radiolucent zone of remodeling (RZ) adjacent to the residual host bone segment and to the distraction disc. The interfibrous zone disappeared 90 days after surgery, suggesting the beginning of the remodeling in the distraction area. The macroscopic samples in group 3 (rhBMP-2) showed a concentrically overgrowth at the site of rhBMP-2 injection, laterally to the mandibular inferior border compared to the samples in group 2 that conserved the regular mandibular anatomy. The mix of rhBMP-2 with osteogen conducted an excessive concentric bone proliferation in the distraction area. Docking site surgery was not considered for this study in any of the distraction groups, as a result, a bony defect or non-union problem between the distraction bullet and the docking bone was seen in the radiographs.

**Conclusions:** Bone transport by distraction osteogenesis showed outstanding radiographic healing characteristics in mandibular reconstruction. The radiopacity of the newly formed bone by the distraction regenerate was very comparable to the originating bone. The common vertical bony defect in the docking site area corresponds to the presence of sclerotic edges covered by mucosa without any osteoblastic activity; this indicates that a docking site surgery in this area should be accomplished in order to unite the transported and docking bone. It appears that the use of rhBMP-2 induced an enlarged bone regenerate at the distraction chamber and would probably prevent the hourglass deformity seen in major mandibular reconstruction by bone transport, and accelerate the bone mineralization process to reduce the long consolidation periods needed for large reconstructions. The use of rhBMP-2 along the
distraction chamber, while preserving the peristium layer and maintaining the collagen fibers intact, appears to augment the quantity of bone regenerate, and enhance the distraction regenerate when the principles of distraction osteogenesis are respected.

References:

An over view of CMF Distraction

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1. Maxillary Distraction
   Anterior and Inferior repositioning of the Maxilla in Patients with Severe Hypoplasia

Indications
1. Nonsyndromic patients with severe maxillary hypoplasia
2. Patients with orofacial clefts and associated severe maxillary hypoplasia
3. Patients with Binder syndrome or craniosinostosis syndromes affecting the maxilla

Patients
Ten patients (4 female, 6 male) between ages 15 and 28 years (mean age 20.3 years) with severe maxillary hypoplasia received combined surgical orthodontic treatment using distraction osteogenesis combined with a Le Fort I osteotomy without downfracture. Two patients received simultaneous surgically assisted maxillary expansion.

Presurgical Orthodontics
Orthodontic preparation before surgery is identical to that for routine maxillary and mandibular orthognathic surgery.
Unlike the original tooth borne Rigid External Device (RED), the new RED II can be attached to the maxilla using fixation plates known as Leipzig plates. If simultaneous maxillary expansion is planned, a palatal device should be adapted and cemented in place if a tooth borne expansion device will be used i.e. Hyrax.

**Surgical Technique**

After presurgical orthodontic treatment is completed, a prediction of the planned maxillary movement is obtained. The transverse plane is evaluated by positioning the dental models in Class I centric occlusion. If there is an absolute maxillary transverse deficiency, it may be addressed at the time of surgery by placement of a Hyrax expansion device, and adding the midpalatal and interdental bone cuts after the Le Fort I osteotomy is complete.

The maxillary expansion device is cemented before or during surgery, to allow simultaneous expansion and anterior and inferior repositioning of the maxilla.

To address the vertical and horizontal deficiencies, the vectors of distraction are determined using a lateral cephalogram prediction tracing or 3D CT prediction software if available.
Under general anesthesia, the halo portion of the Red II system (Martin, Tuttlingen, Germany) is adjusted and fixed. The nasotracheal tube is secured to the frame.
To decrease the negative soft tissue effects associated to maxillary surgery, the soft tissue incisions are done from canine to first molar in each side. The mucoperiosteal flaps are elevated and to minimize paranasal soft tissue dissection and release of the nasalis muscle, a 4 mm tunnel will extend from the canine area to the piriform rim.

The Le Fort I osteotomy is completed without down-fracture. The Leipzig retention plates (Martin, Tuttlingen, Germany) are fixated with monocortical screws to the lateral wall of the maxilla extending posteriorly to the zygomatic buttresses.
The Leipzig plate is connected to the carbon fiber rod attached to the halo, then the device is adjusted to reproduce the predicted vector of distraction. This is followed by an intraoperative trial distraction to ensure free movement of the segments.

Intraoperative distraction trial and RED II in place during the distraction phase.

Active distraction is started on the 5th post operative day with a distraction rate of 1.0 mm per day for the RED and the expansion device. After the distraction phase is complete, interarch elastics are used for 2 weeks to improve the occlusion. The RED II is removed 4 weeks after surgery and replaced by internal mini-plate fixation under IV sedation combined with local anesthesia. The expansion device is left in place and 3 months after surgery is changed to a transpalatal arch by the orthodontist.

**Distraction Protocol**

- Maxillary osteotomy and placement of device.
- Latency Period 4-5 days.
- Distraction rate of 1mm/day.
- Traction control with intermaxillary elastics 5 days before distraction is completed
- Removal of RED II and simultaneous plate fixation within 30 days after surgery.

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Lateral cephalogram superimposition comparing skeletal and soft tissue measurements before and after maxillary distraction.

Facial photographs before surgery, three months after distraction, and one year after distraction.
Occlusal photographs before distraction osteogenesis, and 1 year after distraction

Simultaneous correction of the transverse discrepancy

3-D CT frontal and lateral images before surgery, after finishing distraction and during consolidation using CT v-works imaging (Seoul, Korea) See fixation with plates and screws placed at the same time of removal of the RED II devices.
Results
The patients were followed with lateral cephalograms obtained before surgery, immediately after surgery and one year after distraction to evaluate vertical and horizontal stability. The maxilla was advanced an average of 10.4 mm (5.4mm - 15mm) and inferiorly repositioned 5.2mm (3.5mm - 8mm) as measured at “A” point.

A mean horizontal relapse of 0.2mm and a mean vertical relapse of 0.9mm were observed one year after distraction.

Simultaneous maxillary expansion was stable after one year as confirmed with dental models. No cross bite or excessive flattening of the curve of Wilson was noted.

The only complication was loosening of the Leipzig plate in a patient with very thin maxillary wall. This complication was treated by a second surgery for repositioning of the plate.

Advantages
1. This distraction technique obviates the need for extensive subperiosteal elevation around the piriform rim and dissection of the nasal mucosa shortening operation time, decreasing intraoperative blood loss and other potential vascular complications.
2. Avoids the need for autogenous bone graft decreasing the operating time and preventing donor site morbidity.
3. Mandibular setback will not be needed on a regular basis as a measure to prevent relapse associated to large maxillary advancements. Ramus osteotomies and mandibular setback will be reserved only for patients with true mandibular prognathism.
4. Outpatient surgery becomes a possibility for these patients with severe maxillary hypoplasia, limiting surgery to osteotomies without downgrafting and fixation of the device, minimizing blood loss, and the need for autogenous bone graft.
5. Control of the vector of distraction was simplified by this upgraded version of the RED system, the use of Leipzig plates provided the ability to control the horizontal and vertical distraction of the maxilla and make adjustments at any time without patient discomfort. This
is a major advantage when we compared this device to the original tooth borne device or to intraoral devices.

6. Maxillary distraction using the RED in combination with maxillary expansion addresses vertical, horizontal and transverse deficiencies associated to maxillary hypoplasia.

7. Stability is controlled combining distraction osteogenesis with conventional plate fixation techniques, to decrease relapse and to allow early removal of the extraoral device. Plates secured to the maxilla above the osteomy line were used for rigid fixation after the RED was removed.

8. The response of the facial soft tissues during maxillary distraction using the RED II system has proven to be more favorable than with conventional Le Fort I osteotomy and downfracture. This may be due to the limited dissection of the paranasal soft tissues.

9. No deterioration of the velopharyngeal competency was noted among our patients. This is consistent with previous publications using a similar technique.

Disadvantages

1. The two most important disadvantages are patient acceptance and need for a second procedure for removal of the device. Patients are not willing to tolerate extraoral devices in place for long periods of time. On the other hand, lack of compliance during the consolidation
phase is known to be a source of relapse. We addressed this issue by securing the repositioned maxilla, with internal fixation plates. This second procedure is done in the office, under IV sedation, at the same time of the removal device within 30 days of surgery.

2. The cost of the device is a minor disadvantage, if compared with the combined cost for donor site surgery, longer operation time and hospital stay.

Midfacial Sutural Distraction Osteogenesis

Distraction Osteogenesis using intraoral, extraoral, or transcutaneous devices combined with facial osteotomies has become standard treatment for severe midfacial deficiencies. Sutural expansion osteogenesis has been used as Rapid Palatal Expansion in orthodontic therapy. Hierl et al reported the use of distraction osteogenesis without major bone cuts.

This article presents our experience with midfacial distraction osteogenesis without osteotomies in combination with an extraoral distraction appliance.

The patient is a 16 year-old male with Ellis-van Creveld Syndrome who was diagnosed with midfacial deficiency and severe obstructive sleep apnea. Ellis-van Creveld Syndrome, also known as “chondroectodermal dysplasia” is an autosomal recessive rare genetic disorder characterized by short limb dwarfism, polydactyly, ectodermal dysplasia, malformations of bone of the wrist, congenital heart disease in 50% of the patients, prenatal eruption of the teeth.
This patient's sleep apnea was so severe that his sleep study showed desaturations as low as 30% \( \text{Sa}_2 \) while sleeping in an upright position. For combined correction of his dentofacial deformity and severe sleep apnea we initially considered a Le Fort III osteotomy via bicoronal flap and midface advancement under general anesthesia in the operating room. The patient developed a severe apneic event when he lay down on the stretcher to be transported to the operation room, the anesthesiologists were unable to intubate him but his airway was patent as soon as he was positioned upright and ventilation and oxygenation was maintained through a nasal airway. As a result of this event and the inability to perform an endotracheal intubation or a surgical airway, decision was made to place the RED device under local anesthesia in a sitting position.

This is pre-operative 3DCT and the predicted midfacial advancement using the Le Fort III Osteotomy
No osteotomies were performed and bilateral Leipzig plates were placed bilateral at the lower aspect of the anterior maxillary wall. To achieve clockwise rotation of the midfacial complex two infraorbital miniplates attached to a second cross bar of the RED device. The procedure was otherwise uneventful.

Leipzig and infraorbital miniplates in place. Intraoral view showing the Leipzig plate exiting through the oral mucosa. No signs of infection or mucosal irritation.

Sutural distraction was initiated on the day of surgery and continued at a rate of two 0.5mm turns per day. The patient tolerated the distraction phase well and no headache or pressure pain were reported.

The exophthalmus was corrected and the occlusion improved after 20mm of midfacial lengthening.
3D CT at the end of distraction. See distraction gaps at a Le Fort III level. Up/down elastics were used to improve the occlusal result after removal of the device.

CT reconstruction at the airway window level, please see the antero-posterior increase of the upper airway. His apnea/hypopnea index returned to normal range as confirmed by a sleep study performed six months after surgery.
**Sutural distraction using a transpalatal bone borne device**

Bone borne transpalatal distractors allow the application of heavy forces allows sutural distraction in patients after completion of growth and prevents expansion induced dentoalveolar tipping. Increasing the application of traditional palatal expansion even in patients that would otherwise need a SARPE.

**Palatal expansion to allow maxillary anterior repositioning**

Simultaneous rapid palatal expansion and maxillary advancement without osteotomy using face mask has been reported in growing patients (E. Liou, personal communication).

We present a case of anterior repositioning of the maxilla using Class III elastics immediately after transpalatal distraction in a nongrowing 18-year-old female. We believe that pterygomaxillary suture separation secondary to palatal distraction decreased the need of major osteotomies or heavy forces to allow maxillary advancement.
There is no intraoperative risk of severe bleeding, no damage to tooth germs if the screws are positioned properly, and no problem with patient compliance compared with face-mask therapy, and the correction is achieved in a short period. Furthermore, sutural expansion concerns the whole midface, as shown by the movement of the nasion, and leads to an increase in maxillary dental arch length in a bioplastic transformation that is beneficial in the posteriorly crowded situation often seen in patients with cleft lip and palate.

**Indication**

It’s indication is for a growing children or syndromic patient who has week bone suture, and it is difficult to foresee if this procedure
could also be performed in older patients. However, Brandt et al.2) postulate sutural reactions throughout life, with only a slower adaption in older patients.

References

Unilateral Inferior Repositioning of the Maxilla in Facial Asymmetries with Associated Occlusal Plane Cant

Indication
Patients with maxillomandibular asymmetry and associated canting of the occlusal plane.

Presurgical Orthodontics
Orthodontic preparation before surgery is identical to that for routine maxillary and mandibular orthognathic surgery.
Surgical Technique

After presurgical orthodontic treatment is completed, a prediction of the maxillary and mandibular movement is planned. The transverse plane is evaluated by positioning the dental models in Class I centric occlusion to rule out any transverse discrepancy.

To address the asymmetry, the vectors of distraction are determined using a 3-D CT prediction software if available, otherwise can be predicted with model surgery.

Under general anesthesia, after a Le Fort I osteotomy is completed, the maxilla is repositioned antero-posteriorly. The lateral wall of the maxilla is fixated with a 2.0 titanium miniplate and monocortical screws on the side of shorter vertical repositioning.
In the contralateral side an intraoral Track 1.5 distraction device is adapted and fixated with monocortical screws. The vector of lengthening is confirmed with an intraoperative distraction trial.

This is followed by bilateral Intraoral vertical Ramus Osteotomies (IVRO)

The contralateral aspect of the maxilla is fixated with titanium plate and screws.

After 5 days of latency maxillomandibular distraction is initiated with interarch elastics in place. The distraction of the maxillomandibular complex will continue until correction of the occlusal plane cant and the facial asymmetry is achieved as confirmed by the orthodontist and the patient.
Facial photographs before surgery and during the consolidation phase.

Intraoral photographs showing the final occlusion 2 years after debonding fixed orthodontic appliances.

Discussion

Advantages

1. Unilateral distraction osteogenesis of the maxilla using intraoral miniplate type devices allows for predictable correction of the facial asymmetry and occlusal plane cant. The ability to make postsurgical changes in the vertical position of the maxilla improves the esthetic
outcome of the procedure, since orthodontist evaluation, animation of the soft tissues, and patient’s opinion can be used to determine the final position of the maxillomandibular complex.

2. There is no need for autogenous bone graft. This reduces operating time, prevents donor site morbidity and minimizes the need for hospital stay.

3. The vector of distraction is easy to control and limited to inferiorly repositioning of the maxilla.

4. No need for early removal of the device. This miniature intraoral device has minimal exposure in the oral cavity allowing the patient to be comfortable during consolidation.

5. No vertical relapse. Adequate stability is achieved by at least 6 months of consolidation.

Disadvantages

1. The main disadvantage is the need for a second procedure for removal of the device. It is usually done in the office, under local anesthesia and IV sedation.

2. In cases with a severe occlusal canting, there is a risk of temporomandibular joint luxation caused by early consolidation of the ramus osteotomy at the distraction side followed by the vertical

3-D CT at the end of distraction. See correction of the facial asymmetry using the track 1.5 in the left maxilla and the intraoral mandibular distraction device preventing left condylar sagging.
movement of the maxillomandibular complex. This can be avoided by the application of a distraction device to the mandibular osteotomy site when condylar sag is detected during the distraction trial.

3. The cost of the device is a minor disadvantage. It is still equivalent or less than the combined cost for donor site surgery, longer operation time and hospital stay.

**Conclusion**

Correction of dentofacial deformities has been properly addressed by conventional Orthognathic Surgery in the past. Some of the problems of these traditional techniques have been overcome with bone grafting, combined orthodontic treatment and rigid fixation. Conventional Orthognathic Surgery allows single stage maxillomandibular reconstruction with a high degree of occlusal accuracy and predictability. However, there are limitations associated to the type and degree of the deformity. Distraction osteogenesis is a rapidly evolving field that offers an alternative for the treatment of these severe deformities, and its application in combination with traditional integrated orthodontic and surgical techniques may be the answer to the treatment of these challenging cases.

2. **Mandibular Distraction**

Mandibular retrognathia is the most common etiology for class II dentofacial deformity in Japanese. Mandibular advancement using bilateral sagittal splitting ramus osteotomies (BSSRO) have been the standard treatment for mandibular retrognathia. Postoperative relapse, inferior alveolar nerve injury and postoperative idiopathic condylar resorption have been suggested. On the other hand, distraction osteogenesis applied to the mandible by McCarthy et al. has been gradually established as a treatment option for combined surgical orthodontic treatment. Distraction osteogenesis (DO) is a method that induces partial new bone formation and increases bone volume. However, in the craniofacial skeleton three-dimensional movements of the elongation vector are needed and it is difficult to achieve using
intraoral distraction devices. To overcome this disadvantage, we devised a distractor application method and performed elongation with spontaneous rotation of the bone segment.

Methods

The indication for the use of DO was the need for mandibular advancement of 10 mm or more. All patients underwent clinical evaluation by an orthodontist and a maxillofacial surgeon, and presurgical orthodontics to achieve dental decompensation. Occlusal records, models, and cephalograms were evaluated. In addition, the maxillary and mandibular dental arches were 3-dimensionally evaluated using a craniofacial 3D-CT.

Model surgery was performed and surgical splints were made. The osteotomy line and position of the distractor was determined preoperatively.

Surgery was performed under general anesthesia. When maxillary repositioning was necessary, Le Fort I osteotomy and fixation was completed first. The position of the mandibular canal in the planned osteotomy area in model surgery was confirmed by CT, and the lateral, posterior, and anterior aspects of the mandibular angle were cut using a bone saw. The distractor was temporarily fixed, its plate was bent to adapt to the bone surface, and a drill hole was made. The distractor was removed, and the osteotomy complete with a combination of a saw and osteotome. The osteotomy site was carefully evaluated to avoid any incomplete bone cut. The distractor was applied, and trial elongation was performed. The mandibular distal segment was fixed using a single bicortical screw, which was used as the rotational axis. A surgical splint was applied between the maxillary and mandibular teeth and the patient was put in intermaxillary fixation. When a good positional relationship with the maxilla was not obtained, only the mandible was lengthened, and intermaxillary fixation was performed on some other day.

After intermaxillary fixation, the distraction device was activated, and the wound was closed.
After a latency period of 5-7 days, elongation was performed at a rate of 1 mm/day. Instructions were given to the patients who activated the device twice a day. Pain associated with activation in the elongation area and at the masticatory muscles could be managed by activation of 1 mm divided in four sessions. With this alteration of the protocol we were able to reduce pain, and prevent early bone union. Elongation was continued until the mandibular head is spontaneously seated in the mandibular fossa. When elongation was complete, the intermaxillary fixation was replaced by elastics. Since distraction also induces elongation of the surrounding muscles and skin and mucosa, muscle rehabilitation is important. During the consolidation period, the patients performed masticatory movements and passive range of motion exercises. Masticatory function is known to be beneficial for bone consolidation.

After a consolidation period of more than 6 months, the distractor was removed. Minor occlusal discrepancies were managed by postsurgical orthodontic treatment, Intermaxillary elastics were continuously used after removal of the device. Passive range of motion exercises were continued until the patients recover their presurgical maximum interincisal opening.
Discussion

Advantages
1. Condylar seating was guided by the masticatory muscles and TMJ ligaments. These soft tissue-guided condylar seating allow physiologic positioning of the condylar head in the articular fossa.
2. This method allowed mandibular advancement while keeping optimal occlusion. Patients reported no pain during elongation.

Disadvantage
1. The need for two operations and a prolonged treatment time. 2nd operation is usually done under local anesthesia and IV sedation.
2. Risk of distractor falling. This can be avoided by the application of intermaxillary fixation during activation of the distractor.

Case: Non-Syndromic Class II dentofacial deformity 17y/o F
Superimposition (pre-surg/post-surg)

Facial profile (initial/post-surg)
Predictable Mandibular Ramus Lengthening in Unilateral TMJ Ankylosis

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**Summary:** The purpose of this clinical investigation was to evaluate the predictability of vertical mandibular high gained through distraction osteogenesis when freeing the temporo-mandibular ankylosis in a second stage. Seven active growing patients underwent a two-stage mandibular reconstruction to lengthen the ramus by distraction osteogenesis and gap arthroplasty for the temporo-mandibular joint ankylosis. The Guerrero-Bell distraction protocol was utilized, with 180 to 240 days of consolidation, at this time the second stage was performed, the distractor was removed and the TMJ ankylosis freed by a gap arthroplasty followed by active post-operative physical therapy. A stable average of 12.5mm vertical ramus augmentations and 35 mm interincisal opening was obtained at 24 months post-surgery follow-up.

**Introduction:** Even though distraction osteogenesis is to vertically augment the mandibular ramus has been reported, there are still too many variables involved in the diagnosis and treatment planning to solve all the growth and consequent asymmetry problems using the technique.

All attempts to lengthen the hard tissues will concomitantly lengthen the soft tissues, in the cases of mandibular ramus with an
intact joint, the pterygo-masseteric sling as it is stretched creates a vertical force of the condylar head against the glenoid fossa; compressing the intra-capsular structures with the consequent unpredictable resorption, remodeling and adaptation of the temporomandibular joint; invariably, the cartilages surfaces flattened, the synovial spaces are markedly reduced, the sub-chondral bone follows a reparative phase with vertical condylar loss and damage of the articular tissues. For lengthening the ramus in TMJ ankylosed patients we performed the surgical procedure in two stages; in order to have better control of the two distracted segments, to avoid pressure against the surgically created new joint, and to allow active muscle physiotherapy after releasing the joint. First step was the ramus lengthening, which will allow the clinician a predictable mandibular ramus vertical augmentation, as well as, muscles lengthening, the second surgical step was planned once the consolidation process was completed, and consisted of freeing the temporo-mandibular ankylosis by a gap arthroplasty.

**Material and Method:** Seven active growing patients (5 to 14 y.o. averages 9.5) underwent a two-stage mandibular reconstruction to lengthen the ramus and gap arthroplasty to correct the mandibular vertical deficiency and the temporo-mandibular ankylosis. Under inhalatory sedation with sevoflurane the anesthesiologist assisted the child while a Risdom incision was made to perform a complete horizontal osteotomy of the mandibular ramus; then, the patient was orally intubated or for those patients with limited opening a Laryngeal Mask Airway was used initially to secure the airway and then switched to conventional endotracheal tube; immediately after, the distractor was fixed in place 90 degrees to the inferior border of the mandible. Two superior arms with two screws each above the horizontal osteotomy and another two arms with four screws below. When a 12mm distractor was used an extension key for activation was attached to the appliance and left in place for easy activation. The distractor was activated 2 mm before conventional suture. The flexible key remained in position until distraction was completed. For
the 30mm distractors the activation area was kept through the same Risdon’s incision and protected with a small piece of a sterile nasopharangeal cannula. The distraction protocol consisted on seven-day latency period followed by activation, at a rate of 1mm per day until distraction was accomplished, with 180 to 240 days of consolidation, at this time the distractor was removed and the TMJ ankylosis freed by a gap arthroplasty followed by active post-operative physical therapy. The parents carried out the activation and the patients were seen on a weekly base for three months and then every 30 days until completion of the treatment. Photographs, panoramic, lateral cephalic, and posterior-anterior radiographs were used and evaluated for follow-up and analysis, immediately after surgery, once a month for the first three months and at least a year later, being the longest follow-up 4 years.

**Results:** All radiographs (lateral, P-A and panoramic) were traced and analyzed during distraction, consolidation, 12 months, and 24 months after the gap arthroplasty. No positional changes of the distracted bone segments were observed in any of the different planes, during, after the procedure, or at the end of treatment. The direction of the distraction was paralleled to the planned distraction vector, maintained by the mechanical properties of the device, and the stability of the bone segments by the means of releasing the ankylosis in a second stage. Stable results are demonstrated in this study by vertical ramus augmentation 9 to 15 mm (average: 12, 5 mm) and the interincisal opening of 28 to 40 mm (average 35 mm). The mandibular ramus and concomitant muscles were lengthened in a stable manner, maintaining the range of mandibular motion at the 24 months post-surgery follow up; every patient underwent controlled physiotherapy to ensure adequate interincisal opening after the gap arthroplasty. A concave physiological temporal fossa was formed throughout the active physiotherapy and was clearly observed on the panoramic radiographs in all patients after 2-year follow-up.

**Discussion:** The technique only addresses the vertical increment of facial high of the underdeveloped side by ramus distraction, and
stimulation of the functional matrix by liberating the ankylosis and active physiological mandibular range of motion. Although, the esthetic results were satisfactory, all patients used for this study were on an active growth period during both procedures and lack of normal development was noticed in all of them on the affected side after treatment; the vertical dimension gained after distraction osteogenesis to lengthen the ramus was predictably stable using the ankylosis to prevent undesirable positional changes or relapse by bony resorption. The current thinking of the three theories of mandibular growth is that the condylar cartilage does have some measure of intrinsic, genetic programming, but restricted to a capacity for continued cellular proliferation; meaning that cartilage cells are coded and geared to divide and continue to divide, but extracondylar factors are needed to sustain this activity. In all of the cases the lacking of mandibular condyle and physiological muscle function due to the ankylosis in a growing phase compromised the three-dimensional growth of the affected side. After the functional matrix establishes its new equilibrium and adaptation secondary procedures need to be considered and applied to correct the remaining bony and soft tissue deficiencies. Antero-posterior distraction before the gap arthroplasty could also benefit the patient in terms of growth and development, but the limited anatomy to position a distractor over the mandibular body at early ages could sacrifice the permanent dentition and/or the neurovascular bundle.

**Conclusions:** A two stage approach to initially lengthen the ramus and later performing a gap arthroplasty predictably allows a normal mandibular range of motion and vertical ramus augmentation in hypoplastic mandibles after TMJ ankylosis in growing patients. Somehow the three-dimensional mandibular development was compromised whether or not the condyle has its own intrinsic (genetic) or systemic factors that influence the growth of the mandible or the extrinsic functional-biomechanical environment is part of a complex of those regional factors. This protocol allows stable and ideal vertical facial and occlusal symmetry, but all the patients will
require further antero-posterior advance of the affected side to complete the overall treatment.

References:

Frontal sinus obliteration and craniofacial reconstruction with platelet rich plasma in a patient with fibrous dysplasia

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Platelet rich plasma is a platelet concentrate in a predetermined volume of plasma obtained from the patient’s peripheral venous blood. It represents a new concept in the stimulation and acceleration of bone and soft tissue healing. Regeneration and repair are promoted by the liberation of growth factors contained in the alfa granules of the cells after platelet degranulation: platelet derived growth factor (PDGF), transforming growth factor beta (TGF-b), vascular endothelial growth factor (VEGF), epithelial growth factor (EGF) and others. PDGF are directed to specific membrane receptors on stem cells, fibroblasts, macrophages and endothelial cells resulting in mitogenesis, angiogenesis and macrophage activation.

Materials and methods: 50-60 ml of venous blood are drawn into a syringe with 6 ml of a 10% dilution of sodium citrate and injected into a closed multichamber device. Simultaneously, blood without anticoagulant is left to clot in a special tube (AT-PRO.Kit Harvest Technologies) and both are processed in an automated dual spin unit (SmartPrep, Harvest Technologies, Inc., Plymouth, MA). The system yields the platelet concentrate (PRP) and the
supernatant (PPP platelet poor plasma). 0.5 ml of 10% calcium chloride is then added to the supernatant of the AT-PRO.Kit and mixed with the PRP. The mixture is set to clot with the graft (Human Freeze Dried Demineralized Cortical Bone, Transplant Services Foundation; Mejia-Lequericia Spain). An auto-genous alternative to bank bone is the collection of bone shavings from the surface of the skull. PPP is also clotted in the same way but without a graft and then used as a membrane to cover the surgical site. Suction is avoided while grafting and the remaining fluids, high in growth factors, are injected or sprayed over the site. The end products have to be used immediately.

CT Scan displaying a lesion that invades the left side of the frontal sinus and the left orbital roof (MRI demonstrating the intracranial penetration of the disease)
Surgical technique: A bicoronal flap and an osteoplastic flap developed with an oscillating saw exposed all the dysplastic tissue that was meticulously excised. The healthy bone inside the sinus and the residual walls around the lesion were roughened with a round burr and the area was rinsed with an iodine and antibiotic solution. PRP and PPP were prepared and applied immediately; PPP was transformed into a membrane and used to cover all the continuity defects (dura exposure and orbital roof) and to block the naso-frontal duct. PRP was set to clot with the graft and then placed into the cavity. The orbital roof was reconstructed with extensive bone destruction is visible after removing the pseudotumor; PRP-graft is being placed into the cavity.

Detail of the orbital roof: ear cartilage and calvarism bone is used for reconstruction; perforations in the bone are used for fixing bone fragments and PPP membrane with suture and for enhancing nutrition of the graft.

CT scan eight months after surgery demonstrating abundant osteogenesis.
cartilage from the ear and a cranial bone graft. The graft was then covered with another “membrane” made out of PPP that was sutured to the skull. The bony osteoplastic flap was repositioned and sutured to bone. Evidence of bone formation is present in a CT scan eight months later. Eighteen months after surgery the patient is completely asymptomatic with total relief from diplopia, pain and exophthalmos. Left eye vision has partially recovered.

Discussion

Recent publications describe the use of PRP in fields such as dermatology, cardio-vascular surgery, ophthalmology, plastic surgery, orthopedic surgery and maxillofacial surgery. The aim is the activation of precursor cells, the establishment of a network for the development of the future tissue and the supply of nutrients and immunity to new cellular lines that are developing. Precursor cells, mainly pluripotent stem cells, fibroblasts, macrophages and endothelial cells bear specific membrane receptors for growth factors that initiate the mitogenic cascade. Mitosis does not develop on a linear increase; recent studies demonstrate a low mitogenic activity associated to a normal platelet count and exponential cellular division with four- or five-fold levels. PRP has an evident mitogenic and chemotactic effect on hMSCs initiating the pathway towards osteogenesis, but PRP by itself does not cause osteogenic differentiation of hMSCs.

VEGF is responsible for angiogenesis across the PRP-graft that takes place at day 2 or 3, supplying nutrients, antibodies and immune competent cells and others by chemoattraction. This feature has a significant meaning in graft survival and defense against infection. The low infection rate associated to PRP has also been explained by the secretion of antibacterial agents found in platelets and by the presence of concentrated leucocytes in the clot.3,6

Calvarian blocks can be harvested from the surgical site in a limited quantity but cortical bone regeneration is based on a very slow ingrowth osteoclas-tic substitution process. On the other
hand, disease transmission (Creutzfeldt-Jacob disease) with human bank bone is possible but has never been reported. Alternatively, bone shavings from the skull can be harvested with a special instrument, avoiding second site surgery and morbidity following a strictly autogenous procedure. Twenty cubic centimetres of fine bone shavings can be obtained in less than 5 min with minimal iatrogeny.

Bone shavings for obliteration purposes.

It has been argued that grafts should bear stem cells supplied in the form of cancellous bone; instead, the present technique takes advantage of the environment at the grafting site: the bone is perforated with drills and burrs in order to expose the bone marrow to the grafting material, and superficial bleeding is encouraged by surface roughening with a large round burr facilitating access of BMPs, stem cells, and other cellular lines to the graft. Fibrin strands assemble together to form a three dimensional matrix and represent at least 45% of the clot’s strength. This network is used in nature to construct a complex unit that will not only harbor platelets and red blood cells but will also block the hemorrhage, attract and trap other cellular lines responsible for the healing process, and impede entrance of pathogens.

Our experience in PRP obliteration is limited to seven cases with a satisfactory outcome. The absence of donor site surgery and
morbidity and the shorter surgical time and hospital stay suggest that the technique should be taken into consideration. PRP reconstruction seems to be simple, safe and economic but further clinical experience is still required.

Other Authors: P. Juiz-Lopez, J P. Rubio-Rodriguez

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Predictable 3-D Alveolar Distraction

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Introduction: Severe alveolar defects have been treated by a variety of techniques from bone grafting to soft tissue flaps, obtaining unpredictable results.

Distraction Osteogenesis is an alternative to grafting reconstruction that requires a prosthetic oriented planning, three-dimensional overcorrection and meticulous surgery. This technique is very sensitive to the protocol and planning. Maintaining the surgical vector has been difficult because the palatal mucosa is much stronger than the buccal, forcing the segment posteriorly; an unacceptable situation in prosthodontics. New stronger devices have been developed to be placed buccally to avoid the palatal inclination, but allows food and saliva contamination into the chamber, as a consequence the bone callus contracts and weakness; an unhealthy bone for implant anchorage.

The purpose of this study is to demonstrate that reconstruction of alveolar defects in the anterior maxilla could be predictably performed by distraction osteogenesis using a new distractor concept that allows achieving and maintaining the distraction vector during the whole process.
Material and method: 5 patients (ages 30-65), with alveolar deficiencies were treated by predictable alveolar distraction. Radiographs and dental photographs were taken pre, post-surgery, after distraction, at the time of implant placement and 10 months after final prosthesis was placed. The distractor length was selected based on the prosthetic wax up allowing 25% of over-correction in the vertical and A-P dimensions. The surgery consisted in a small incision deep in the sulcus at the deficient area (maintaining the lingual mucosa intact) preserving the periostium attached to bone as much as possible to optimize the distraction chamber healing. The osteotomy was made under abundant irrigation using a micro-saw; the horizontal osteotomy was gently completed using a fine spatula or a curve osteotome for the anterior maxilla, protecting the palatal mucosa with a finger. The vector control plate was fixed transmucosally over the palate to ensure its maintenance during the activation and stabilization period.

The implants were placed through the mucosa, the transported bone, the distraction chamber and into the basal bone 14-24 weeks after distraction, fixing the distracted bone to the basal bone. Fig 4 If further bone augmentation is needed in the buccal side, the bone collected from the suction-tramp is mixed with alloplastic materials and layered over; using a collagen membrane through a sulcus approach. The chamber final consolidation and the osseointegration occurred simultaneously.

Results: All the alveolar ridges were augmented achieving adequate bony height, width and A-P projection, healthy surrounding tissues for implant placement, as well as proper depth of sulcus to ensure ideal esthetical and functional outcomes. The amount of vertical bone transport was 6 to 15mm (average 9mm.). One patient (1/5) fractured the distraction segment and a micro-plate was used to reduce it, proceeding with the same distraction protocol.
Conclusions: The predictable three-dimensional distraction is a reliable technique for alveolar reconstruction. Distraction osteogenesis should be the first alternative in major alveolar deficiencies for an ideal three-dimensional reconstruction that allows transmucosal implant placement and final prosthetic restoration in a healthy tissue environment obtaining outstanding results.

Reference:
Maxillary distraction by intraoral devices

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**Summary:** Maxillo/malar distraction osteogenesis was applied to 20 patients (12 females and 8 males, average age 18.4 y.o.) with maxillary deficiency using a bone-borne intraoral device. The osteotomy level, design and distractor placement was based on the maxillary deficiency, all the procedures were done intraorally, but the advancement of the infraorbital rim which was approached transconjunctivally, and the nasal bones and septum through a small incision at the sub-glabella site. The surgical movements were predictable, avoiding the use of bone grafts, heavy rigid fixation, and facial scars.

**Introduction:** The development of miniaturized devices for the maxilla offers the possibility to use distraction osteogenesis, through the intraoral route, combining orthodontics, to offer ideal occlusions and elastics control through the post-surgical period.

**Materials and methods:** 20 patients (12 to 35 y.o. average 18.4) with bi or three-dimensional maxillary deficiencies were treated by intraoral distraction osteogenesis to lengthen, widen and/or augment vertically the maxillo-malar complex at different osteotomy levels according to the individual clinical situation. Complete radiographs and photographs were obtained pre, immediately post surgery, 3
months later, at the appliance removal stage and 6 months after braces were removed, and dental models in an articulator were taken before the surgery and after braces removal. All the patients underwent a combined surgical-orthodontics treatment to ideally correct the tri-dimensional problems.

**Results:** The maxilla was advanced 8 to 14mm (average 10.5), augmented vertically 4 to 6 mm (average 4.8) and widen 6 to 10mm (average 8.4) correcting the three or bi-dimensional deficiencies. No major complications were observed; the canines were evaluated by pulp test with positive response at the braces removal stage, no teeth were damaged and no epiphora or infraorbital nerve dysesthesia occurred.

**Conclusions:** Distraction Osteogenesis by intraoral devices allows maxillary bi or three-dimensional corrections avoiding bone grafts, heavy rigid fixation and facial scars. It requires a meticulous surgical-orthodontics planning, adequate surgical timing and individual osteotomy design, sound vector and careful placement of the distractor according to the patient’s individual needs. It is unacceptable to damage teeth, infraorbital nerves and/or lacrimal ducts.

It is a predictable and stable technique that should be considered in major maxillary bi or three-dimensional deficiencies.

**References:**
This case report is presented demonstrating the use of distraction osteogenesis and the ROD 5 device for repair of a severe architectural defect of the maxillary anterior dentoalveolus by distraction of an existing implant along with the surrounding alveolar bone. An adult female in her fourth decade experience loss of tooth # 9. In addition, she had severe bone loss in this area. An endosseous implant was surgically placed to facilitate replace of # 9. A u-shaped defect of the dentoalveolus was not addressed prior to implant placement. This report will describe a small segment alveolar distraction procedure used to correct the bony architectural deficiency and facilitate facial esthetics and physiologic dental form.

This forty-one year old female presented with complaint of problems associated with an endosseous implant placed at tooth # 9 position. Alveolar atrophy in the area was treated using a unique distraction surgical technique and the ROD 5 device.

History of the present illness revealed the loss of tooth # 9. Tooth # 9 suffered a long series of clinical insults. That is, the patient related a childhood event that caused traumatic avulsion of # 9. Endodontic therapy, reimplantation, posting, and fabrication of a full crown
restoration followed this event. Later, # 9 required apical surgery, and finally, a root fracture occurred. The loss of #9 left a U-shaped alveolar defect with vertical and horizontal bone loss. The patient sought treatment for removal of #9 and subsequent replacement. After appropriate discussion of treatment options available, an implant was placed into this defect. However, the bone defect in the affected site was not addressed proximal to the time of implant placement. After osteointegration of the implant, a crown was fabricated. However, the untreated bone defect dominated available prosthetic outcomes, final esthetics were greatly compromised. The implant was relatively short and narrow compared to the clinical dimensions of the prosthetic crown. This narrow implant made normal emergence form impossible. The prosthetic crown had grossly abnormal (width, height, and A-P form) contours. (See figure 2) Esthetic concerns were among the reasons this patient sought our advice regarding a solution.

Note the high smile line, the abnormal width of # 9, the cervical margin of #9, the midline?? to the right.

Note the high position of the cervical gingival margin above #9. The zone of attachment below the mucogingival line has lost vertical dimension. Facial contours of this crown are exaggerated by the excessive dimension of its clinical crown.
Findings
A careful history and physical examination was performed. The patient’s medical history was unremarkable with no contraindications for implant surgery. She is a non-smoker.

Local findings
The cervical gingival margin of # 9 was 5-6 millimeters apical to the adjacent cervical margin of # 8, and # 10. The clinical crown length of # 9 was overtly disproportionate. A relatively high smile line accentuated the esthetic difficulty of restoring this area. Keratinized gingival attachment tissue was lacking on the facial aspect of #9. X-rays revealed the small diameter integrated interpore implant placed in severely resorbed, atrophied, and remodeled alveolar bone.

Treatment Proposal
The consent process: Engaging this patient in a discussion about her treatment expectations was the first clinical goal. The patient was interviewed and encouraged to participate in formulating a treatment plan by articulating her own treatment goals. It was important that this patient understand the significance proposed architectural corrections. She was informed of the importance of returning normal bone and soft tissue dimensions to allow for normal emergence form and vertical sizing of the missing crown. Further, she was instructed that once bone and soft tissue morphology are returned to normal, achieving esthetic goals becomes less difficult. All practical treatment options were considered. A removable prosthesis was described. The standard three unit fixed and the three unit Maryland bridge were also explained. However, in each case the bony defect was thought to be problematic. Further, the possibility of burying the existing implant and making a standard fixed bridge would be compromised if proper dimensions of the alveolus were not recreated. Bone grafting and or distraction osteogenesis was discussed to satisfy bone contour requirements. Among the risk factors discussed regarding bone grafting was the risk of soft tissue dehiscence after
flap distention at closure caused by the required volume of a free bone graft. That is, at the midline of the maxillary alveolus scar tissue, from previous surgery and injury, might result in limited flap development. The team favorably considered the use of DO to develop both hard and soft tissues in the area. Once soft tissue histiogenesis occurred, additional, minor bone grafting or connective tissue grafting would be considered. In fact, if a distraction procedure was successful, the amount of bone required as a graft would be diminished while the amount of soft tissue would be improved. Thus, bone grafting, if necessary could be accomplished under improved conditions.

Two stage small segment osteotomies were contemplated to preserve blood supply to the small segment of bone to be created. A staged osteotomy was planned because of the small segment size. The first surgical stage accomplished bone cuts made from the buccal preserving the entire palatal pedicle. The second stage completed the osteotomy and mobilized the bone segment from the palatal so that distraction osteogenesis could be achieved. Therefore, the possibility of surgical manipulation disconnecting the segment from its periosteal blood supply was limited.

These procedures were performed under IV sedation and local anesthesia.

Several devices are available for this procedure. The surgeon’s choice was the ROD 5 device. The pattern or vector of bone resorption for loss of bone in the anterior maxilla is up and back. Therefore, we chose a device to counter that pattern. The ROD V seemed to fit our goals best. Additional advantages of this device are that minimal disruption of the proximal segment would be necessary for connection and the vector of distraction could be altered during treatment if necessary. Fixation of the bone segment directly to the distractor was not necessary because the crown attached to the implant was available for this connection. Anchorage of the ROD 5 was provided by adjacent dentition.
A copy of the operative report is as follows:

**OPERATIVE REPORT**

**Date:** February 8, 2004  
**Pre-operative Dx:** 1. Alveolar atrophy 2° to trauma  
2. Loss of # 9 tooth  
3. Post endosseous implant placement  
**Post-operative Dx:** Same  
**Operation:** Stage I small alveolar bone segment distraction  
**Surgeon:** Dessner  
**Assistant:** Auliff  
**Anesthesia:** General  

**Procedure:** The patient was placed in the operatory in the supine position. After induction of general anesthesia, she was prepped and draped in the usual fashion. The mouth was opened utilizing a McKesson mouth prop placed on the left between the upper and lower molar teeth. An oropharyneal toilet was performed and a throat pack was placed. The Seldin retractor was placed to elevate the upper lip. Lidocaine 2% with epinepherine was infiltrated at the height of the maxillary vestibule in an area to include the maxillary left and right central incisors, the maxillary left and right lateral incisors, and the maxillary left canine teeth. In addition, a nasopalatine nerve block and palatal infiltrations corresponding to the vestibular infiltrations were performed. Approximately ten cubic centimeters of local solution was administered. Next, a fifteen blade was used to create an incision which began above and remained parallel to the mucogingival line. This incision began at a point one centimeter above the MGJ above the maxillary left canine root. Here it continued in a curvilinear manner across the midline over the lateral incisor apex. The incision was made with a # 15 blade through the mucosa, muscle layer and the periosteum. A full thickness flap was elevated superiorly with the Miller periosteal elevators and the Seldin retractor. The base of the piriform opening, the anterior nasal spine, and the apical portion of the alveolus in the #9 area were thus exposed. No palatal dissection
or elevation was performed. A small diameter endosseous implant was noted. The facial cortical plate in this area was fenestrated and the implant was clearly visible. Next, using a reciprocating saw with a small blade vertical osteotomies were performed on each side of the endosseous implant. Care was taken to avoid the roots of the adjacent teeth. The saw was used to make a complete cut through the bone of the alveolus, but care was taken to leave the palatal mucosa. In fact, the tip of the reciprocating saw was palpated as it cut through the palatal cortex and it was kept in place against the palatal cortex by this digital palpation localization technique. The vertical cut was completed from a point apical to the implant to a point just short of the alveolar crest. These two vertical cuts were joined over the top of the implant using a Hall drill with a 701 burr.

Bone cut made with a # 701 in a straight handpiece

Outline of the osteotomy created from the buccal. Note the vertical discrepancy of cervical margins at # 8 and # 9

Surface of the existing implant fenestrating through bone.

The cut here was through the facial cortical plate. The surgical site was irrigated and the margins of the incision were closed with 4 (o) vicryl sutures. The estimated blood loss was less than 25 ccs. The patient tolerated this procedure well and after emergence from anesthesia was transported to the recovery area in good condition.

The clinical course: The ROD 5 device was attached to adjacent teeth prior to the second stage surgery.
A direct bond, light cured 3M Unitek Transbond™ adhesive was used. The crown of #9 was used to control the bone segment. Two small holes were place to allow passage of a 28 ga. SSW. The wire braided on the facial aspect and passed through the axle of the ROD 5. A five day latency period was observed. Activation of the distraction device began on the fifth day post-op day. The distraction rate progressed at a rate of 1 millimeter per day.
**Description of ROD 5 bi-directional distractor:**

I. Bi-directional Distractor

A. Bucco-Lingual direction with the use of pulleys

B. Clockwise rotation moves the distraction segment lingually and incisally /occlusally

C. Counterclockwise rotation generates new bone buccally and incisally /occlusally

II. Bonding Tips

A. Allen wrench activation by the patient

B. 0.018 Stainless steel surgical wire

III. Rod 5 Protocol

A. Allow a latency period of 3-5 days post-operative, varying per age of patient and health of bone stock

B. Rate of distraction: 1 mm/day = 2 clicks/day until bone level is satisfactory radiologically. Patient is to insert the Allen wrench, push it, rotate 30 degrees (from 12:00 p.m. to 2:00 p.m.), and then remove Allen wrench.

C. Distraction to be removed 2-3 days following the last activation

D. Bone regenerate is stabilized with a 0.036 bonded stainless steel wire for 9-12 weeks following removal of the appliance; If during the orthodontic treatment simply replace the brackets and stabilize with an arch wire.

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In edentulous areas Rod5 attachments can be bonded directly to Mini-Implants

Mini-Implant provides anchorage to distract alveolar segment

Distraction segment
FDA approved, polysulfone, autoclavable, bondable attachments.

Spring loaded detent mechanism

Rod5 attachment bonded directly on to Stainless steel plate

Distraction segment with 2 Mini-Implants

Pulleys for bi-directional distraction

Vector of distraction can be directed to the lingual / occlusal

Vector of distraction can be directed to the buccal / occlusal
During the activation period the crown of # 9 was modified as necessary (See figure 5). As distraction proceeded, the cervical defect descended with the anatomical crown of #9. The crown was shortened and shaped during this process to accommodate the downward and facial movement of the segment.

The distraction process began with a latency period of five days. Once initial healing occurs, callus formation is assumed. Movement of the segment, was accomplished by activating the ROD 5™ appliance. Tension created across the callus caused dimensional growth. The rate of distraction for this case was one millimeter per day. As the tooth crown, implant, and bone complex were moved to the cervical, her crown length and contour were adjusted by her general dentist. An advantage of the ROD5™ distraction device is its orientation to the buccal. With its axle to the buccal, the vector of pull, as the traction wire is rolled on the axle, is to the facial. This facial vector of pull directly counters the “vector of bone resorption.”

Once the bone margins were approximated to a more normal relationship, clinical decisions had to be made regarding the restorative phase of treatment. For example, would the original implant be useable, and would the old implant offer an acceptable esthetic result? The general dentist was a resource for helping us decide these issues. A treatment plan was developed that utilized the original implant. The patient was advised that if the original implant predisposed less than favorable esthetic results it would be removed. However, a temporary, processed acrylic crown was fabricated to demonstrate a favorable esthetic result. A final restoration was then fabricated and placed.

Distraction osteogenesis discussion of rate, rhythm, and immobilization.

Consider the use of the present crown for control of the free bone segment.

Serial reshaping of the crown

ROD 5 appliance

Replace the implant
Bone and soft tissue grafting

Restore

The Rod appliance is mounted on the buccal surfaces of teeth. An advantage of the ROD 5™ is that the vector of distraction can be directed opposite the plane or pattern of alveolar atrophy. This atrophy can be expected after extractions, or when teeth are congenitally missing, as a result of periodontal losses, when failed apicoectomies or root fractures cause labial bone loss. In this case, the orientation of the distractor was a distinct advantage.

Reference:


Developmental Field Reassignment (DFR) in Cleft Surgery: 6 years of Evolution and a New Protocol

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Purpose
Dissection of the prolabium and premaxilla is fundamental to techniques of cleft repair. The developmental anatomy of these tissues is the key to understanding the pathology of the cleft site. The pathology of the labiomaxillary cleft revolves around a missing developmental field: the premaxilla (PMx). Isolated deficiency or absence of the frontal process of the premaxilla (PMxF) explains the piriform fossa deformity characteristic of cleft lip nose in the presence of a normal lip. More proximal extension of the deficiency state into the lateral incisor field creates the primary palate cleft and soft tissue cleft of the lip. The missing premaxillary field alters the spatial relationships of neighboring soft tissues. Developmental field reassignment (DFR) is a new surgical technique designed to address the problem of deficiency-induced field mismatch by (1) using the previously unknown embryology of the prolabium; (2) rearranging soft tissue fields to re-establish the missing premaxilla. The ultimate goals are: restore adequate lining to the cleft nostril for proper breathing, prevent surgically-induced dental arch collapse, and promote normal growth.

Early work with DFR produced aesthetically pleasing restitution of nasolabial anatomy but the original design (using Periosteoplasty alone) did not reliably regenerate bone in the amount desired. The
most recent iteration of DFR uses osteoinduction of missing premaxilla using the commercially available cytokine recombinant human bone morphogenetic protein-2 (rhBMP-2). This IRB-approved retrospective study documents the anatomical basis for DFR and its surgical application in 35 patients followed for 1 year.

Methods

In 5 human fetuses under age 22 weeks presented for necropsy. The specimens were as follows: normal (2), right unilateral cleft lip and primary palate (1), holoprosencephaly with left-sided cleft lip and palate (1), and cebocephaly (1). The common carotid arteries were cannulated while the external carotid, subclavian, and vertebral arteries were ligated. Blue dye (6-10 cc) was injected. Dissection of facial soft tissues was followed by cerebrectomy and subsequent en-bloc resection of all midline structures. Step-wise dissection from lateral-to-medial was done through the nasoethmoid capsule, premaxilla, and palate. The distribution of dye perfusion was documented photographically. Analysis of neurovascular anatomy was correlated with the prosomeric model of neuroembryology. From this date, mapping of the developmental fields of prolabium and premaxilla was carried out.

Subsequent to the above previously reported investigation, DFR technique was modified to separate the prolabium and premaxilla into embryologically distinct components. Prolabial tissue was separated from the philtrum and elevated as a flap in continuity with a chondrocutaneous flap of the medial crus. A lateral columellar incision separated the flap from the columella proper, permitted cephalic advancement of the medial crus into symmetry with the normal side. A McComb dissection was combined with V-Y advancement of the lateral crus. The defect generated reproduced the missing tissue of the frontal process of the premaxilla. The non-philtral prolabial flap was inset into the lateral wall of the nose at the defect created by the V-Y advancement. This, in combination with bilateral subperiosteal dissection and an ipsilateral sliding sulcus
mucoperiosteal flap, permitted soft tissue reconstruction of the primary palate cleft.

The DFR technique evolved over six years with increasing experience and analysis of clinical outcome. The current protocol was followed in 35 patients over 2 years with using preop and postop 3-dimensional CT scans to assess anatomic continuity of the cleft site and an additional 110 patients

Results:

The injection study demonstrated the true prolabium to be perfused via the terminal branches of the internal carotid, the anterior ethmoid arteries (AEA). Anatomic distribution of the AEA's showed prolabial width to be the same as the columella. All remaining prolabial tissue, the non-philtral prolabium (NPP), is supplied by the nasopalatine artery (NPA), the terminus of the external carotid. This tissue can be safely elevated in continuity with a lateral columellar chondrocutaneous flap (LCC). When combined with mucoperiosteal dissection, the primary palate was reconstructed with rhBMP-2. CT scans at 3 months showed complete fill of the alveolar cleft without collapse in all 35 patients. Mechanical dislodgement of the implant occurred in two patients in the early experience. These patients were successfully regrafted intraorally.

Conclusions:

The columella and philtrum are embryologically the same, being supplied by the AEA’s, innervated by V1, and derived from prosencephalic neural crest. The remaining prolabium and the entire premaxilla are supplied by the NPAs, innervated by V2, and derived from mesencephalic neural crest. Subperiosteal dissection of the non-cleft soft tissues allows the philtrum to drop into a normal position without a back-cut. The philtrum and columella should not be separated. Sufficient tissues are present in both primary and secondary clefts to reconstruct a stable premaxilla using rhBMP-2. At one year, arch collapse is prevented and normal dental eruption takes place.
Syndromic craniofacial anomalies-management protocol: infancy to adulthood

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The pathway for the skeletal correction of patients with syndromic craniosynostosis varies between Units but generally there is agreement that in infancy a fronto-orbital advancement or monobloc is performed to minimise the deformity, alleviate raised intracranial pressure and to take advantage of rapid bone formation in the first 24 months of life. Following this initial procedure, mid-facial advancement has been undertaken to correct the mid-facial deficiency by a Le Fort III advancement with immediate repositioning or distraction techniques.

When these patients reach puberty, orthodontic treatment is desirable to prepare the dental arches for subsequent procedures to continue the correction of the progressively worsening mid-facial hypoplasia. The number and nature of procedures required to produce the best outcome is variable and there is a paucity of discussion in the literature regarding adolescent skeletal correction.

Protocols are difficult to develop for craniofacial anomalies but following the initial procedures, post-pubertal treatment planning should initially concentrate on improving orbital contour in order to prepare for definitive skeletal occlusal correction post-growth. Further surgery to address temporal hollowing and aesthetic rhinoplasty can subsequently be included. Several cases illustrating these pathways are presented.
The degree of complexity of 3d models can sometimes be so high that our brain cannot either imagine the reactions or process it. Different methods were introduced to science to deal with these kinds of problems. Sometimes the process of solving is so time consuming that we prefer to do it by a computer. In 1960s a numerical method was introduced in science to solve problems in aerospace field. Finite Element Method (FEM) showed its efficiencies soon and developed. Living tissues are among the structures that can be considered as complex in geometry and thinking about biomechanical rules will be almost impossible while not being able to get a complete knowledge of its response to external and internal loads.

The topics that will be covered:
1. What is FEM?
2. How does it work?
3. 3D modeling past and present
4. How can it help our researches?
5. What kind of researches can be conducted by FEM?
6. A few examples of clinical questions solved by FEM that could not be solved by any other laboratory methods.
When are MRIs necessary for an optimal Orthognathic Surgery and Distraction Osteogenesis?

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**Keywords:** Magnetic Resonance Imaging (MRI), Temporomandibular Disorder (TMD), Orthognathic Surgery

**Aim:** A constant problem in Orthognathic Surgery and Distraction Osteogenesis has always been with undesirable TMJ discomfort and pain after surgery. In the last five years we have taken thorough MRIs on all our surgery cases presurgically. The purpose of this paper is to describe the percentage and distribution of the pre-existing TMJ pathology. Also suggestions will be made on how to prevent these undesirable reactions by condylar repositioning during surgery. The ultimate goal is not only to give the patients their facial harmony, but also functional harmony with the TMJ so the joint will not be uncomfortable. This research showed that a thorough presurgery MRI should be taken to help reposition the condyles during surgery. The TMJ functions without symptoms can then be improved at the same time as the facial harmony. Suggestions to do this will be given.

**Materials and Methods:** MRIs were taken which included all 3 dimensions plus the true-time video and/or an animation video to have a triple control method to make sure there were no false positives or negatives. The TMJ-MRIs of 200 random surgery candidates were studied as to the position and the degree of degeneration of the
condyles and of the discs. The percentage and the types of condylar and discal condition were then made into graphic tables, the general condition of the TMJ analysed and interpreted in order to see to what extent TMJ problems occurred and where they originated. Then a thorough analysis of how surgery could be altered to improve the TMJ condition could be undertaken.

Results: The results from the graphic tables showed that all joints suffered from at least moderate and usually to severe TMJ degeneration. This should alert all surgeons and orthodontists treating orthognathic surgical patients to take accurate MRIs to see which type of pathology exists. One should be aware of this problem and to modify the surgical procedures so as to improve the situation as much as possible.

Conclusions: From the study above, it appears that all potential surgery patients should have MRIs to yield optimum surgical results and treatment modifications must be made to do this. In the last years, we have been re-evaluating the use of condylar repositioning splints in which the condyles are repositioned with a fixed mini-splint before surgery. Primarily the chosen position is calculated from the MRI results, but also from a Manual Functional Analysis (MFA) of the TMJ. Before surgery is started, the condyles are fixed in the orthognathically optimal position with the joint splint, so that after the surgery is done, the condyles are in this newly elected position (with slight overcorrection).

Summary: The above study addressed the phenomenon of patients having or developing TMJ complaints after maxillofacial surgery. In 200 potential surgery patients, MRIs were taken and analysed specifically to detect and qualify TMJ problems. The condyles and the discs were looked at as to where they were positioned and what degree of degeneration was apparent. The idea to involve - much more as it has been done up to now - TMJ-considerations into orthognathic surgery to prevent or decrease TMJ-problems, is the aim of this study.

This study shows that all orthognathic surgery patients should have a thorough MRI taken prior to surgery.
Objective: In cranio-maxillofacial surgery, the principle of distraction osteogenesis (DO) can be used for the reconstruction of the deformed skull, midface complex, mandible and alveolar ridge. Optimal results can only be obtained with accurate planning of the osteotomies and accurate positioning of the distraction device. In addition, the surgical planning must be transferred very precisely to the patient in the operating theater. The clinical accuracy and utility of stereolithographic models and computer aided simulations in cranio-maxillofacial distraction osteogenesis of the midface, mandible and alveolar ridge will be demonstrated.

Materials and Methods: Thirteen patients were treated by DO in the cranio-maxillofacial skeleton. Five patients suffered from midface retrusion and were treated by a LeFort III advancement. One patient suffered from an aseptic necrosis of the condylar process of the mandible and had a reconstruction of the condylar process by DO. Seven patients underwent an osteotomy of the alveolar ridge of the mandible with subsequent placement of distraction screws and implants because of advanced atrophy of the mandible. Following preoperative acquisition and conversion of the CT-scan data, a model
was fabricated by stereolithography (SLA). Simulation of the osteotomies and placement of distraction devices was performed on these models and in a virtual three-dimensional environment (Simplant CMF, Materialise), then surgical guides were used to transfer the surgical planning to the patient in the operating theater. Pre- and postoperative facial photographs and X-rays were compared to evaluate the accuracy of the transfer procedure.

**Results:** In all cases, matching of pre- and postoperative facial photographs and X-rays showed reconstruction of the bony structures to be as accurate as planned on the SLA models. Transfer of the surgical plan by means of custom-made surgical guides was optimal in all cases. Pre-operative computer aided simulation of the procedure was very helpfull in the surgical planning and try-out.

**Conclusion:** Preoperative planning of distraction osteogenesis of the cranio-maxillofacial skeleton and transfer to the operating theater by custom-made surgical guides remains the standard procedure for the planning of complex distraction cases. However, improvements in surgical simulation software and accurate virtual-reality surgery will probably make the use of these models redundant in the future.
“Treatment planning with reformatted CT scans and Cone Beam scans using Three Dimensional Printing”

Jerry L. Soderstrom

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CT scans and Cone Beam scans may be electronically reformatted and software programs such as Mimics and Simplant Master may be used to capture occlusal relationships. Three-dimensional models can rapidly and relatively inexpensively be rapid prototyped using a three dimensional printer. Distraction osteogenesis may be treatment planned from both the reformatted scans and from the articulated models. Distraction osteogenesis appliances may be fitted on the models and trial surgery and distraction completed. Bone augmentation blocks from autogenous, heterogenous, and alloplastic sources can be fitted on these models when covered with sterile foil. Dental implant treatment planning may be completed and transferred to the clinical situation with precision drill guides using this technology. Dr. Soderstrom has worked with CT scan generated rapid prototype models and custom implant devices since 1986. Distraction osteogenesis is an exciting new application.
Clinical application of a public domain based computer aided surgery system in craniofacial skeleton

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Abstract: (I) The outcome of complex craniofacial surgical procedures is critically dependent on careful and accurate preoperative planning. Computer-assisted virtual 3D surgery simulation assists the necessary visual understanding of complex pathological situations and has so far been dependent on expensive hard- and software.

(II) We describe a clinical application of a public domain based computer-aided surgery system in craniofacial surgery. Use and limitations are demonstrated by the example of a hypertelorism surgery. The osteotomy lines and the amount of resection for outward positioning of the orbitae were determined by the surgeon on a workstation using CT data. Possible movement patterns of the osteotomy fragments were rotations, sagittal and transversal movements or combinations of these. The program then allows the calculation of anatomical distances on the screen in a 1:1 relation. Normative values according to age and pathological anatomy determine the degree of displacement. The program calculates the new position of the osteotomy fragments and transfers the data of the segment movement to the original CT data.
(III) Three-dimensional visualization of bone and soft tissue contours have been produced with an acceptable quality on a workstation for the demonstration and visual understanding of the surgical plan. The operative outcome was compared to the planning in order to determine the feasibility and accuracy of the operative realization.

(IV) The use of three-dimensional simulation programs allows a better understanding of the pathological anatomy in all dimensions and in many cases enables limitations to be recognized in advance. Public domain applications enormously contribute to the quality of planning orthognathic and craniofacial surgery by cost-free usability, and supports continuous development and exchange of experience.

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Simplant use in TMJ ankylosis

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Abstract: Trauma or infection in early childhood may cause ankylosis of the temporomandibular joints with severe deficiencies of bony AND soft tissues. The functional disorders for mastication, communication and regular breathing together with the aesthetic aspects require a reconstruction of jaws, temporomandibular joints and soft tissues. With sophisticated software (Simplant) we succeeded in virtual planning of the surgical steps, in producing templets for the accurate osteotomy- lines and to place the bidirecional distractors with minimal approach in several cases.

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The Fourth Dimension: Fusion Imaging

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The principle aim of diagnostic imaging is to evaluate the true extent of disease to best determine surgical and therapeutic options. Ideally, the definitive diagnosis of disease should be obtainable using non-traumatic as well as non-invasive methodology. The development in radiology during the current century to include nuclear medicine, computed tomography (C.T.), ultrasound, digital radiography, and nuclear magnetic resonance have provided diagnostic methods that are approaching ideal.

At the forefront of new technologies transforming medicine is multimodality or fusion imaging, a sophisticated technique that combines two or more different types of images. The fusion imaging technique combines the anatomic detail provided by computed tomography with metabolic information provided Positron Emission Tomography (P.E.T) to provide additional clinical relevant information.

Fusion imaging can be a modality of choice as it eliminates false positives and false negatives of P.E.T. findings, hence more accurate identification of tumor margins and metastasis is possible. However, detection of large tumors in clinically inaccessible areas, spotting
recurrent tumors obscured by scar tissue at the site of incipient radiation or post-operative necrosis, locating the primary lesion in unknown primary tumors are also important indications of this technique. Fused images are superior in staging, biopsy site selection, radiotherapy guiding, evaluation of prognosis and treatment planning. The scope of this modality is also discussed in terms of inflammatory and endocrinal lesions wherein the assessment of bone metabolism plays a pivotal role.

This presentation is a journey, one which will enable you to gain a revelation of computed tomography and positron emission tomography (PET-CT) – A vision, a sight or perhaps an insight into intriguing case reports.
Surgical assisted palatinal expansion of the maxilla with Piezosurgery

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The aim of this report was to examine results and experiences using an ultrasonic bone-cutting device for surgical assisted palatinal expansion of the maxilla with attention of protecting the mucosa of sinus maxillaris.

From June to December 2006, 30 patients (eighteen female and twelve male; aged 15-54 years) were treated by surgical assisted palatinal expansion of the maxilla with a combined orthognatic and surgical treatment. Patients were divided randomly in two groups. Group one was treated with an oscillated bone-saw and group two was operated by using an ultrasonic bone-cutting device. For the examination we just selected patients with skeletal transversal narrow upper jaw, and who were indicated to get a surgical assisted palatinal expansion of the maxilla.

For examination results we controled blood (Hb, HKT, MCH, MCV, MCHC and erythrozyts) prae-, direkt post and six hours post operation, X-ray control of sinus maxillaris prae and post operation to realise bleeding in sinus maxillaris. We colected results of operation time in minutes, use of pain killers, antibiotics and other drugs, blood presure, temperature and admission time at ward.

Results:

a. All 30 patients were treated with a surgical assisted palatinal expansion of the maxilla without any complications.
b. No heavy arterial bleeding was found. Group one shows an average lose of blood 0.87 (Hb in g/dl) and group two 0.96 (Hb in g/dl). There was no need to give blood transfusion.
c. The average operation time of group one was 31, 20 minutes and group two 40.34 minutes.
d. Admission time on ward on average 3.8 days by group one and 3.46 days by group two.
e. Group one, four patients were treated with painkillers and group two nine patients got painkillers.
f. There were no big differences in temperature and blood pressure.
g. There was no bigger soft-tissue swelling in both groups. Swelling goes down by Hilotherm therapy.
X-ray control showed bleeding by all patients of group one and by four patients of group two.
Conclusion was, that 11 patients of group two got no damage of mucosa sinus maxillaris.

Resumeé: It is possible to do a surgical assisted palatinal expansion of the maxilla by using an ultrasonic bone-cutting device (Mectron Medical Technology) by protecting mucosa sinus maxillaris.

Our used method of piezoelectrical bone cutting, by operating a surgical assisted palatinal expansion of the maxilla is a very good method for surgeons to protect soft tissue. It is not a device for fast surgeons, like you can see at the average operating time of plus 10 minutes by group two, but this method shows a lot of advantages like bloodfree operating field, micrometric cutting and selective protecting of soft tissue. This technique is brilliant for surgeons in training, who can operate with this easy method in critical areas.

Tight interdisziplinare work between orthodontist and maxillo-facial surgeons in diagnose and indication of a surgical assisted palatinal expansion of the maxilla is very necessary.

This method of piezoelectric surgery with it’s great advantages is going to replace many conventional operating methods in oral and maxillo-facial surgery.

Other Authors: W.Kater, R.Sader
The zygomatic “sandwich” osteotomy - a review of 42 consecutive cases

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**Purpose:** Achievement of adequate upper mid-facial projection is an important goal when correcting disproportion of the craniofacial complex. Differential movement between the upper mid-face and the main fragment is often desirable for the best aesthetics. The technique of the ‘sandwich’ zygomatic osteotomy is described and a series of cases retrospectively reviewed.

**Methodology:** The records of 42 consecutive patients who had mid-facial deficiency and underwent zygomatic osteotomies in conjunction with maxillary advancements were retrospectively evaluated. There were 31 males and 11 females ranging in age from 16 to 45 years. Pre-operative and postoperative photographic images were assessed with a minimum follow-up of 1 year and postoperative complications were recorded.

**Results:** In all cases, there was a notable aesthetic improvement in mid-facial contour that enhanced the associated skeletal change. Four patients were noted to have a minor degree of malar asymmetry but only one required correction. Three patients complained of uneven infraorbital contour. One patient developed a localized infection associated with a fixation plate and bone graft and two patients had persisting, mild infraorbital paraesthesia unilaterally.
Conclusions: The zygomatic osteotomy is recommended to the maxillofacial surgeon as a predictable and useful adjunctive procedure that complements associated mid-facial advancements.

Others Authors: Shand JM
Distraction Osteogenesis in Orthognathic Surgery; how to choose or to combine

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Introduction
Since years, osteotomies of the upper and the lower jaws are being the standard corrective procedures for treatment of dentofacial deformities and malocclusion. Rigid internal fixation rendered the intermaxillary immobilisation largely unnecessary neither in monomaxillary nor in bimaxillary surgery. When accompanied with appropriate pre- and post-operative orthodontic treatment, stability becomes a highly predictable issue. The advent of distraction provided new treatment options worthy to explore.

Problems
Besides the usual simultaneous corrections of the position of maxilla and mandible in sagittal direction, tilting and segmental procedures, two other movements are to be observed in the transversal and the vertical directions. If the simulation of the planned operation shows more than 7mm of skeletal movement in one straight direction, the combined three dimensional corrections can no more be achieved in only one operation, but in two procedures; with the final operation scheduled 12 months after the initial one. In most cases, transversal
widening of the maxilla by distraction is done before bimaxillary surgery. Tooth borne, bone borne, fan-like or individual devices can be used. A combination with transversal widening of mandible is possible in indicated cases. Also, shortened mandibular rami are lengthened by distraction before the final surgery. The other way around is the secondary correction of skeletal relapse after final surgery as in the cases of clefts and post-traumatic deformities. State of the art is maxillary distraction particularly in cleft cases, and distraction of lower jaw to manage relapse after mandibular advancement.

Results
Severe dysgnathias cannot be corrected in one operation. Step by step treatment including different distraction procedures is necessary for stable long term results. Particularly, the transversal widening of upper jaw and the vertical elongation of mandibular ascending ramus are considered the main indications for distraction in orthognathic surgery. Undoubtedly, this step by step approach increases the stability of the definitive osteotomies.

Conclusion
Distraction can be easily integrated in the total management of dentofacial deformities along with the conventional orthognathic procedures. Every day experience proves that this approach would overcome the limitations of conventional osteotomies, optimize a synergistic outcome and minimize the rate of relapse.
Long term stability of distraction osteogenesis in the constricted maxilla

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I thought I would start my lecture by reviewing what I had learnt a number of years ago at a conference that was organized by the American Association of Orthodontists. The course that I attended had listed a number of conclusions about distraction osteogenesis. The first was that there should be a latency period of about 7 days after the initial surgical cut, and then the rate of turning (from a number of evidence-based research reports) should be 1mm a day with a rhythm of 0.25 mm. So, in other words, 4 turns x 0.25 mm. They felt that 20mm of distraction could be achieved and they had suggested a consolidation period of about 7 weeks. A number of researchers who presented at this conference felt that if those criteria were followed, it was certainly possible to move teeth into the new bone; which is great for me as an orthodontist; but also, the bone was of sufficient quality that it was possible to place implants in the newly formed bone. This would be very interesting for our referring general dentists, implantologists, periodontists, etc.

One of the controversies that is often raised, is “when would be the best time to perform distraction osteogenesis for our patients?” and the answer very much depends on what effect it may or may not
have on the growing craniofacial skeleton. The second controversy is stability, and long-term studies associated with that. We need to ask ourselves the question whether long-term stability of bone (that has been lengthened by osteo-distraction) is the same quality as bone from a conventional surgical procedure. Then we need to look at the limits of soft tissue stretching during distraction osteogenesis (DO). One of the reasons many surgeons are now looking at DO versus a conventional osteotomy is based on the ability for soft tissue to adapt. Many people feel that it is easier for the soft tissue to adapt during a prolonged DO than during a 4 hour operation for a normal osteotomy procedure. As an orthodontist, I have been looking at the effect of DO on the eruption of teeth; if we are performing DO in a mixed dentition, where tooth buds are still present, and where eventually teeth will have to erupt in the new bone that has been formed by the DO procedure. Also, in situations where we have new bone formed as a result of DO, is that bone of sufficient quality for us to move teeth into via normal orthodontic tooth movement. A number of papers have been presented on the effect of the periodontal ligament and the associated oral soft tissues following DO. Researchers have also reviewed the undesirable tooth movements when using an intra-oral tooth borne, or a hybrid device, versus a bone-bone (direct skeletal fixation) device.

Many of the people I have spoken to, who I have spent time with at Baylor College in Texas, (which is one of the leading centres of distraction in the world) still debate as to whether an appliance should be used which is totally tooth borne or whether a hybrid type appliance should be used, i.e. one that is partly fixed to teeth and partly fixed to bone. Other proponents state we should have a direct bone-bone type distraction appliance.

The main reason I became interested in distraction osteogenesis, is that I felt that one of the main limitations of conventional orthognathic surgery, is the inability of facial muscles to be acutely stretched without the inherent risk of relapse. In orthodontics that involves a combination of orthognathic surgery there is a war between
tooth, bone and muscle; and in considering long term stability, muscle will always win the war. So, if we can perform our surgeries with a procedure that would allow facial muscles to re-adapt then maybe we can reduce some of the relapse that we have seen in previous osteotomy procedures. The other point to remember is that many of the congenital deformities require large musculoskeletal movements that soft tissues cannot accommodate. This could lead to a compromise in function and aesthetics, unless we have additional soft tissue procedures performed at a later stage. One of the questions I raise with my surgeon, at our joint-surgical meetings, deals with patients who have a severe mid-face deficiency, but are only 11 years old. Do we have to wait until that patient is at the recommended age for an osteotomy (18 or 19 for a female, slightly older for a male)? By waiting this long, some patients go through a miserable social existence, as far as facial deformity, especially during the adolescent time frame.

The whole concept of DO is that the traction generates tension within the callus and this stimulates new bone formation, which is parallel to the vector of distraction. The team at the University of Southern California has been using a combination of distraction with micro-implants. They use the micro-implants after the distraction (sometimes during) to change the vector (direction) of bone movement. The early work on DO, revealed that although new bone was formed, it was very hard for the oral surgeon and the orthodontist to control the vector of force, and many times we ended up with a distorted facial balance. I particularly remember a case where we tried DO in a short ramal height, long-faced individual; and although the ramal height increased, so did the direction (forward position) of the mandible. Distraction forces applied to bone, also create tension in the surrounding soft tissues. Some people use the term ‘distraction histogenesis’ saying that by using distraction osteogenesis vs. conventional osteotomies, we may have an improvement in the surrounding soft tissues and not just in the bone. Under the influence of these tensional stresses, which are produced by gradual distraction,
active histogenesis occurs in different tissues. This includes the skin, fascia, blood vessels, nerves, muscle, ligament, cartilage, and the periosteum. These adaptive changes in the soft tissue may allow larger skeletal movements while minimizing the potential relapse seen in acute skeletal corrections.

“The Long-Term Stability of Distraction Osteogenesis in the Constricted Maxilla”

In the pursuit of optimum function and facial harmony, one of the biggest problems is the failure of general dentists to be educated on what can be achieved with conventional surgery, let alone DO. I still feel that the majority of general dentists talk their patients out of a combined orthodontic/orthognathic treatment plan as they feel that there is an inherently high risk; they find it is unstable; or many times they have heard that the desired results will not be achieved through surgery (perhaps due to their previous knowledge of out-dated surgical techniques). We all need to educate general dentists to recognise which underlying skeletal disproportions can be corrected with orthognathic surgery, rather than orthodontics alone.

The indications that a patient requires a combined approach, is the patient whose orthodontic problems are so severe that neither growth modification nor camouflage offers a viable solution. For example, a patient who has a border-line Skeletal III problem and the orthodontist suggests the removal of upper and lower premolars to compensate and get the dentition into a Class I relationship. Although this may achieve a reasonable dental result, it may (on many occasions) worsen the facial balance. The same could be said for a Class II individual that has a retrognathic position of the mandible. Rather than extracting upper first premolars and retracting the upper incisors, to camouflage the underlying Skeletal II base, it may prove more successful to bring the mandible forward to balance the face. In cases such as the one described above, before you bring the mandible forward, you need to check the width of the maxilla. Many times, a patient who has a retrognathic mandible will also have a constricted
maxilla. Hence, my surgeon and I will normally perform two surgeries, approximately 12 months apart. The first surgery will involve a lateral corticotomy (Surgically Assisted Expansion of the Maxilla); I will then place braces for 12 months to level and align the dentition and to de-compensate the arches in preparation for the second stage surgery which would normally be a one or two jaw procedure with or without a genioplasty.

Distraction osteogenesis relies on prolonged, progressive and gradual distraction which does not disrupt the vascular supply. Some of the initial work done on this surgery was with the ‘Ilsasarov technique’, i.e. the ability not to perform a through and through cut of the bone, making a big difference in the callus formation. It is my understanding that there are two main cellular processes at action. The first is the formation of the callus, and subsequent to this, the generation of new bone via distraction. The latter is histologically similar to that seen in orthodontic tooth movement. Traditional orthodontics (often involving extractions) may achieve a satisfactory functional occlusion at the expense of facial aesthetics. This is now considered by most clinicians to be an unacceptable compromise and treatment should not be undertaken unless the patient is fully informed of the advantages and disadvantages of the surgical and non-surgical options. This discussion is limited to the non-growing individual. If you have a young child with a mid-face deficiency I would still develop the arch, and maybe use a reverse-pull facemask. If there is a young child with a retrognathic mandibular position, I would still try a functional appliance. However, in the non-growing individual, the above procedures are prone to relapse due to lack of facial growth. This is where the concept of the ‘osteotomy’ procedure is relevant.

Most clinicians realise that in a severe skeletal discrepancy, dental camouflage is an unacceptable compromise. I offer my patients three possibilities; the first is not to do anything; the second is to dentally camouflage; and the third is to prepare the arches for surgery. I would personally prefer not to do anything rather than compromise the patient’s facial aesthetics for the sake of merely aligning teeth. Many
times if a patient does not want to undertake orthognathic surgery I will accept the skeletal discrepancy and align the front anterior teeth (the ‘social six’) without worsening the profile.

If we evaluate the advantages and disadvantages of surgery, with the patient, and he/she understand the limitations of surgery and what the possibilities are, the majority of people are quite happy to proceed. It also helps if the general dentist has already informed the patient that their problem is more severe than orthodontics alone can treat. That way, if the patient is aware of the possibility of joint orthodontics/orthognathics, they are not as reluctant to proceed. A patient who is dissatisfied with their facial proportions, patients with severe occlusal attrition (aggravated by skeletal discrepancies) and those with marked skeletal malocclusions experiencing severe TMD symptoms are suitable candidates for surgery. The same could be said for patients with sleep apnoea. My surgeon and I have had a number of successful cases where we have performed DO expansion in the upper and lower jaw as the first stage surgery, followed by a maxillary and mandibular advancement to improve the airway. The changes are quite astounding when reviewing the before and after sleep studies.

We must then question, what is possible when it comes to changes in the width of the maxilla. We can certainly widen the maxilla and make it narrow, but narrowing is more difficult because bone must be removed. The amount of expansion that can be achieved is limited, with the major constraint being the soft tissue pull.

In our clinic, prior to surgery, we place a maxillary expander, and we show the patient how to turn that expander. Following the osteotomy cuts, the patient turns the expander on a daily basis and we leave the appliance in for 2-3 months to allow bone stabilization. During that 3 month period I commence my orthodontics, so that by the time I have removed the expander, there is a wire left in the mouth that is rigid enough to maintain the expansion. Using this technique, we have had much better stability of the expansion than in the past.
The relapse after orthodontic expansion is very similar to surgical expansion, therefore I recommend in younger patients the use of maxillary orthopaedics (expansion) which is effective until late teens, followed by a long term retainer. Using this method, I achieve good stability, and I believe that this may be due to the growth of the individual and the fact that the mid-palatal suture is not totally fused. In a non-growing individual, however, we certainly need surgically assisted expansion. The surgically assisted expansion will rely on an osteotomy in the lateral buttress of the maxilla, in conjunction with expansion devices.

In the mandible it is possible to narrow anteriorly, and to widen. However to significantly widen, we need to perform a distraction procedure. My surgeon and I have tried a number of different distraction procedures. One procedure, with a purely tooth borne appliance, involves me moving the mandibular central incisors apart so that he can do the surgical cut; another procedure is where he has done the surgical cut and fitted an expansion appliance directly to the bone.

The problem with traditional orthodontic diagnosis is that most orthodontists are very familiar with the lateral cephalometric radiograph, but do not concentrate enough on the frontal PA skull radiograph. In our surgical work-ups we use a lateral cephalometric radiograph, and a frontal PA skull view. New and improved technology has also given us the opportunity to work with long-cone CT Xrays, where in 30 seconds we can have 230 sections of the upper and lower arches. We also use Spiral CT technology to perform a three-dimensional reconstruction. This has helped greatly when planning the treatment options of the transverse and AP discrepancies.

I warn the patients, prior to surgery, that they can expect a large diastema between their teeth because many of them are not prepared for this. The main problem that I encounter with patients, is that they try to convince me that the orthodontic treatment needs to be started straight away in order to close the diastema. When I attempted to try
this early, many years ago, I found that I was moving the front teeth into ‘thin air’. This increases the chance of the incisors becoming non-vital. We now advise the patient that we will not commence orthodontics for at least 3-4 weeks after they have ceased their last expansion. Once orthodontics is commenced we use ultra-light forces. We employ the principles of the Damon system, which is a passive self-ligating bracket that drastically reduces the amount of force we place on the teeth. I have found that with this method, I am not seeing the same degree of root resorption and non-vitalities that I used to see 10 years ago when we did not use passive self-ligation.

In terms of overexpansion, the first thing you will notice if a patient is expanding too quickly, is tipping teeth. Teeth will tip when you have reached the patient’s genetic potential for expansion. To avoid this, it is best to stay within the Schwartz Korkhaus measurements. The Schwartz Korkhaus measurements are calculated from the width of the four upper incisors.

In terms of forward movement of the maxilla, my surgeon and I have not yet offered distraction osteogenesis, but this is something that hopefully we may recommend in the future. I find that a maxilla can be moved forward, up to 10-15 mm, with good stability. The major limitation to the forward movement is the resistance of soft tissue, particularly the upper lip, and the stretch of the palatine artery. You must also be aware of the effects that the advancement can have on speech and the velopharyngeal closure.

The expansion appliance is fitted on the patient, however it is not cemented so that the surgeon can remove it to make the midline palatal cut. The surgeon will then cement the expander after the midline cut. The lateral wall surgical cuts are then made.

The benefit of working as a team is that we can perform plaster model surgery. We take a face-bow transfer, and mount the models on a semi-adjustable articulator, so we can look at the amount of movement that is required and where the surgical cuts need to be placed. We then construct a wafer-thin surgical splint, from these
working models, which we use as a guide during surgery and also to maintain stability of the upper and lower jaw post-surgery.

**Why so many patients would benefit from Surgically Assisted Expansion of the Maxilla.**

The ‘perfect smile’ is indicative of what most patients would like to achieve; that is white teeth, and a wide smile. I can achieve straight teeth regardless of whether I choose to extract or not; however the question is whether I can achieve that wide smile without some form of maxillary expansion.

Research published in the American Journal of Orthodontics, 2005, (Moore et al) attempted to determine the influence of the dark buccal corridors when it came to the attractiveness of the smile.

The ‘perfect smile’ can be defined using the following characteristics:

1) The amount of incisal display showing all upper teeth, minimal lower teeth, and showing no gingiva;
2) The upper teeth follow the line of the lower lip (smile arc);
3) The absence of dark buccal corridors.

When it comes to expansion of the maxilla, we need to ask ourselves a number of questions. Firstly, does it work; secondly, is it stable; thirdly, when should we commence expansion; fourthly, once we start the expansion at what rate should we activate our device; lastly, which appliance is best to achieve the expansion.

The orthodontic literature, and practical information provided by clinicians at meetings and in courses, regarding maxillary buccal segment expansion is variable and confusing. Therefore I will attempt to answer the above questions myself. In answer to the first question, in a growing individual (for a boy up to 14/15 years old and for a girl up to 12/13 years old) good expansion can be achieved, slowly, without the need for surgery. However, for the non-growing individual, I recommend a surgically assisted expansion to achieve stability, and the distraction approach to achieve stability from the soft tissue pull. In terms of rapid expansion versus slower techniques,
in the non-growing individual, the best rate of expansion is about 1mm per week; whereas in a surgical case I would increase that to 2-3mm per week. Can we minimize the number of pre-molar extractions if we expand? Before we answer that question, we need to assess the patient’s smile line. If the patient already has a very broad smile and we remove teeth, but bring the back teeth forward in the same corridor width, you will find that the smile is not affected. Nevertheless, what sometimes happens in traditional orthodontics, teeth are removed and there is no pre-extraction arch development so the crowding is resolved by retraction of the incisors. This may narrow the archform and flatten the smile. So, although I wouldn’t say that all extraction cases end up with a narrow smile, certainly those patients who need arch development (surgically or not) should have that completed before a decision is made on the relief of crowding and the need to remove teeth. Regarding the elimination of buccal corridors, and achieving a fuller smile, a full smile can be achieved (with and without extractions) provided the archform is maintained, and provided that the extraction space is closed by bringing the back teeth forward rather than total retraction of the incisors.

In young children where the maxillary sutures are active, we can influence full growth of the mid-face based on the arch development. It is a far reaching effect from what we see dentally. I find that ‘A’ point comes forward in a growing individual when you expand, and many times in the borderline Class III patients, with a narrow arch, after the first stage expansion procedure we find that we don’t need to do the second stage maxillary advancement because the expansion opens up the palate like a ‘V’ and as a result the pre-maxilla tends to push forward. For young children the timing of treatment can be determined by the cervical vertebrae. This is based on the research by Franchi, Baccetti, Cameron and McNamara. They feel that between stage 3 and 4 of vertebral maturation is a good time for mandibular movement, i.e. where use of a functional appliance would be appropriate. For a maxillary expansion, however, compared
to the control, the skeletal growth philosophy or period to commence expansion would be even earlier, i.e. between the stage of C2 and C3.

WHICH APPLIANCE IS USED AND WHEN?

Initially we used an expansion screw or jack screw that needed a key for the parent or patient to place in the hole in order to activate the device. This was a difficult procedure for parents, and many experienced problems with it. Also, we never put bands on the 1st bicuspids in the premolar region, instead we would use a heavy-bodied wire which resulted in tipping of the teeth. Now we always use bands on the 1st bicuspids and the first molars. For accuracy I fit the bands myself and I take an alginate over the bands. This way, when I send the case to my laboratory I know that it will fit. In the past, an alginate was taken and sent to the laboratory. They poured up the model and cut the teeth to fit the bands; this of course, would ensure that the bands fitted on the model, however it did not necessarily fit chair side.

Dr. Lewis Klapper, Orthodontist, developed a ‘super screw’ expander design. The benefits of this design is that it is a rigid expander so there is less tipping of the teeth; secondly it has a screw that is easy for the parent or patient to turn; lastly it has a gauge built into the appliance, so as the patient is turning it you can measure the amount of expansion.

The ‘super screw’ is the style of expander that I am now using in my surgical cases, where bands are fitted on the fours and sixes. We extend a heavy bodied wire from the cuspids to the second molar so that when the expansion is activated, we have movement of the entire arch. Otherwise, in the past, we would have expansion of the buccal segment but narrowing of the anterior segment.

CONCLUSION

Distraction Osteogenesis is a scientifically proven technique to expand the arches in non growing individuals. The clinician must pay close attention to what appliance they would use, when they
should start turning, how many times the appliance should be turned per week, and how long they should retain the expansion to enhance stability.

A patient should at least be offered the possibility of arch development as opposed to extraction based, dental compensation, before a final treatment plan is made. This is particularly relevant to relieve crowding in a constricted archform, for a non-growing individual.
An Objective System to Measure Facial Attractiveness

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**Background:** Research over the past twenty years has shown that judgments of facial attractiveness are universal, people from all cultures and backgrounds rank and rate faces for attractiveness the same. As such a model for objectively rating facial attractiveness is theoretically plausible, and if designed would have many uses including outcomes analysis in plastic surgery of the face. We test a schematic facial composite/prototype mathematical model (the phi mask created by Dr. Stephen Marquardt) as a method to measure facial attractiveness in an objective manner.

**Methods:** 37 male and 35 female faces of 18-30 year old whites of European extraction were rated as well as 31 composite faces of each sex using both Internet and direct survey judges. The faces were tested against the phi mask model analyzing deviations of facial anthropometric points from corresponding phi mask nodal points using equivalent weightings and weightings arrived at by way of multiple linear regression.

**Results:** the deviation from the phi mask significantly correlates with attractiveness, explaining from 25 to 75% of the variance in attractiveness judgments, depending on the methodology used.
**Conclusions:** the phi mask model supports averageness or prototypicality of the face as being the major component of the facial attractiveness gestalt and is a first step in producing an objective system for measuring facial attractiveness.

**Background**

Surgeons have as their mission to restore function and health to the patient, while minimizing morbidity and mortality, and maintaining or improving the final aesthetic outcome. In the last twenty years the emphasis on aesthetic outcome has moved into the forefront, not just in plastic surgery but in all fields of surgery. As facial plastic surgeons the most important thing to all our patients is the aesthetic outcome of the operation. This holds true when performing reconstructive and functional facial plastic surgery and not just when performing pure cosmetic surgery. Patients are very concerned about their facial appearance and as surgeons (in the last few decades especially) we too have made aesthetic outcome a primary concern.

Coinciding with this new emphasis on aesthetic outcome, dramatic drives in cost containment and quality assurance have also been implemented in the health field. Administrators and managers utilizing as their major tools various objective outcome measurement systems have helped bring these changes about. In tandem with them, physicians have found these same tools to be an excellent means of self monitoring, allowing discrepancies and problems to be quickly picked up and permitting objective surveillance of outcomes as changes in practice and technique are implemented.

Mostly as a result of the fact that cosmetic surgery is an elective procedure not paid for by third party payers it has managed to largely escape the outcomes knife and its associated good and bad spin-offs. Surgical aesthetic outcome is currently evaluated by completely subjective methods,(Ching, Thoma et al. 2003) and little has been done to quantify these qualitative results in an objective manner.(Alsarraf 2000; Alsarraf and Larrabee 2001; Alsarraf,
Larrabee et al. 2001) Patient and surgeon subjectively decide if the aesthetic outcome is acceptable or not. The subjective nature of this evaluation makes statistical analysis of surgical outcomes impossible. Surgeons and patients and likely health administration and health payers would all benefit from an objective outcome measurement system.

Recently some investigators have begun to talk about the need for outcomes analysis in the aesthetic surgery field. (Ching, Thoma et al. 2003) The approach they use is to create outcomes scales, and preliminary data indicates that they may have some utility. (Alsarraf 2000; Alsarraf and Larrabee 2001; Alsarraf, Larrabee et al. 2001) However, the scales are still based on patient subjective evaluation, and while we agree that this is a very relevant measure, a purely objective outcome scale would be extremely desirable.

In a recent review by Ching et. al. (Ching, Thoma et al. 2003) of outcomes measurements for aesthetic surgery (facial and otherwise) 53 identifiable instruments were found in the literature extending back to 1961. These instruments were divided into four subtypes, satisfaction assessments (6 found), objective assessments (5 found), psychological assessments (34 found) and quality of life assessments (8 found). For satisfaction assessment the most commonly used method of all 53 identified instruments is comparison of preoperative and postoperative photographs usually by a surgeon or an independent observer. Ching et. al. (Ching, Thoma et al. 2003) feel that this method is limited “because there are no validated and reliable means to quantify results to make meaningful comparisons.” For another identified satisfaction assessment instrument, facial halves comparison by Hamra, (Hamra 1996) where two halves of a face one preoperative and one postoperative are combined together in a photograph, Ching et. al state that its “evaluation is subjective, without a numerical assessment.”

In their review of objective assessments only five methods were found, which we ourselves have looked at in detail. These included Tapia et. al. (Tapia, Etxeberria et al. 1999) who looked at their results
of 685 rhytidectomies (face-lifts) by analyzing 4110 preoperative and postoperative digitized photos. They create a scoring system on twelve aspects of facial aging, 3 surgeons visually and subjectively score the preop photos (average score 9.75) and postop photos (average score 2.84) using this scoring system, and note an average improvement of 6.91 points. Tapia et. al. also look at two objective measurements, the cervicomental angle (which improve an average of 20 degrees) and lifting of the eyebrows (the medial eyebrow average lift is 0.1275 cm, the central eyebrow average lift is 0.2259 cm, and the lateral eyebrow average lift is 0.2877 cm). Amazingly enough no correlation between the subjective score and objective measurements is attempted, furthermore no mention is made of how the change in cervicomental angle relates to the improvement in patient result and for the eyebrow measurements all that is said is “we noticed a clear relation of greater lifting of the eyebrow corresponding to more satisfactory overall final results.” No data statistical or otherwise was provided.

The second objective assessment identified by Ching et. al.(Ching, Thoma et al. 2003) was in Pitanguy et. al.(Pitanguy, Pamplona et al. 1998). In fact Pitanguy and his Brazilian colleagues designed an elegant objective system to model soft tissue changes with aging, not an objective system for assessing aesthetic outcomes, or capable of measuring facial attractiveness. The study was conducted using 40 women who had photographs of their face at least 5 years apart in time. These photographs were marked with 26 characteristic points (of interest to us is that 24 of these points were identical by chance to the 24 of the 37 points we used in our study). These points were used to calculate various linear distances on the face in each photograph and the change in the distance was normalized by dividing by the interpupillary distance for that subject (again this is of interest to us, because while we did not normalize the faces using the interpupillary distance we did place and resize the phi mask using the interpupillary distance). These normalized changes in anthropometric distances over time were fit by least squares using the second order polynomial that produced the smallest error. Essentially their method allows,
after measuring and normalizing a photograph of a woman, prediction with a known amount of error, the appearance of that woman at a different age. In fact their method has been used to create a warping (aging/de-aging) program for facial photographs.

The third objective assessment identified was in Yousif et. al. (Yousif, Gosain et al. 1994) Yousif et. al. again did not directly create an objective system for assessing aesthetic outcomes, or capable of measuring facial attractiveness. They looked at a very specific facial feature the nasolabial fold using photogrammetry (anthropometric measurements from photographs) noting that with “aging there is anterior, lateral, and inferior displacement of the cheek mass with a resultant deepening of the nasolabial fold, while relationships between the upper lip and the fold itself remain constant.” (Yousif, Gosain et al. 1994) This evidence was used to support the theory that the nasolabial fold is created by loss of support of the cheek mass complex by gravitation and aging.

The fourth objective assessment identified was in Mishima et. al. (Mishima, Sugahara et al. 1996) This paper essentially announces that the authors have created two software systems that allow them to: (i) use a 3-D digitizer to automatically identify (AI) facial landmarks from a wire frame model of a plaster cast (only the area around the nose is described) and capture their 3-D coordinates and (ii) allow automatic superimposition (AS) of a postoperative wire frame model and calculate the displacement of the 3-D coordinates. Again this paper does not directly describe an objective system for assessing aesthetic outcomes, or capable of measuring facial attractiveness. It is of interest in that it looks at displacement of anthropometric model we describe in this dissertation as a 3-D wire model to evaluate the face pre-and postoperatively looking at the change in fit for an objective measure of improvement.

The fifth and final objective assessment identified was in Bhatia et. al. (Bhatia, Vannier et al. 1994) This paper is similar to that by Mishima et. al. (Mishima, Sugahara et al. 1996) in that it announces another 3-D facial scanning and measurement system capable of
measuring volume changes in the face with a facial operation. Again
the paper does not directly describe an objective system for assessing
aesthetic outcomes, or capable of measuring facial attractiveness.
Furthermore the procedure was not tested on a real facial surgery
patent just on a volunteer who had their face injected with known
amounts of saline solution subcutaneously.

In order to have an objective system, facial attractiveness must
be able to be objectively measured. Is it possible to measure facial
attractiveness objectively? Research findings from the psychology
field show that not only do judges strongly agree about facial
attractiveness but they also indicate that a universal standard of facial
attractiveness does in fact likely exist.(Langlois, Kalakanis et al. 2000)

Cognitive visual psychology research in the field of facial
attractiveness has made numerous profound discoveries in the last
twenty years. A common view held by many contemporary scientists
involved in the area, however, is that the field would greatly benefit
from an objective measurement system for facial attractiveness.(Patzer
1985)

Two recent mathematical modeling systems have been developed
for human facial attractiveness. One model we will not discuss directly
here is the FacePrints model created by Victor S. Johnston.(Johnston
1994; Johnston, Solomon et al. 2003) The second model is a facial
overlay system or mask variously called the phi, archetypal, golden,
or golden ratio mask. This mask has been claimed as being adaptable
to the creation of an objective system for measuring facial
attractiveness.(Marquardt 1997; Marquardt 1999; Marquardt 2001)

The phi mask is based on the golden ratio phi (the ratio obtained
when a line ABC is cut such that AB/AC = BC/AB) first derived by
the ancient Greeks but certainly in use since even more ancient times
(in Egyptian art and architecture) and possessing many fascinating
mathematical properties not least of which are the Fibonacci sequence
and the logarithmic spiral.(Wolfram Research 2005) This ratio
appears almost ubiquitously in nature including in the basic geometric
shapes of the pentagon, decagon, and dodecagon, in the phyllotaxis
or leaf arrangement of a vast number of plants and flowers in the spiral of seashells such as the nautilus, in the human mandible and its growth rate, in the human figure and face, and even in the spiral of DNA. (Cook 1978; Thompson 1992) The growth rate of an organism has been found to be proportional to the size of the organism and follows the pattern of the logarithmic spiral — this growth pattern can even be observed in the unfolding of the human embryo as it gestates. The phi ratio has been found in the faces and figures of statues dating from the Ancient Egyptian and Greek periods and was first introduced into the modern medical literature by Ghyka (Ghyka 1977), Seghers et al. (Seghers, Longacre et al. 1964) and popularized by Ricketts (Ricketts 1968; Ricketts 1981; Ricketts 1981; Ricketts 1982; Ricketts 1982). Marquardt builds upon the findings of these researchers by theorizing that an archetypal or prototypical face can be built entirely by using the ratio phi, an idea he supports by the ubiquitous presence of the ratio in nature particularly in DNA and gestational growth (perfect unperturbed growth = prototypical = perfect adherence to the golden ratio). The mask is based on the use of multiple variously sized pentagram complexes as Marquardt terms them. These pentagon complexes are in fact variously sized golden or regular decagons, which can be created by superimposing two same sized golden or regular pentagons pointing in opposite directions.

Marquardt uses the primary pentagonal complex to form the basic framework of the mask, using specific lines, line segments, and points to construct the component lines and points of the mask. Various sized secondary decagons or pentagonal complexes related mathematically to the primary complex (the size of the subsidiary pentagon complexes is derived using the formula

\[
P_{\text{subject}} = P_{\text{reference}} \times \left( \frac{1}{\phi} \right)^n \times Z
\]

where \(n\) and \(Z\) are variables used) are used to derive the remaining component lines and points of the mask. [n=6; Z=1] – is used twice for the two iris complexes; [n=5;
Z=1\] – is used 3 times, for the nasal tip complex, the internal lip complex, and the internal nares complex; \([n=5; Z=\frac{\phi}{2}]\) – is used once as the inner nasal tip halo complex; \([n=5; Z=\frac{2}{\phi}]\) – is used once as the outer nasal tip halo complex; \([n=4, Z=1]\) – is used four times, for the nasal pentagon complex, the chin button pentagon complex, and the two eye pentagon complexes; \([n=3, Z=1]\) – is used fourteen times, for the nose/mouth complex, the mouth/chin complex, chin inferior border complex, chin complex, right and left sided chin complexes, right and left eye/cheek complexes, right and left eyebrow complexes; right and left cheek complexes, and right and left nose/mouth complexes; \([n=3, Z=\frac{1}{\phi}]\) – is used twice for the right and left eyebrow/cheek complexes; \([n=2, Z=1]\) – is used once for the frontal repose smile complex; and \([n=1, Z=1]\) – is used once for the internal facial pentagon system.

It is of note that Marquardt derived the placement of the particular component lines and points of the mask by applying the pentagon complexes to the faces of females (specifically to cut out magazine pictures of various female models). Further details of the phi masks mathematical derivation and properties may be found in its patent documents.(Marquardt 1997; Marquardt 1999)

This mathematical model in addition to two US patents(Marquardt 1997; Marquardt 1999) has received tremendous publicity and media attention(Marquardt 2001), and has become implanted in the mind of the general public, but to our knowledge it has never been scientifically tested. Are the claims made of it by its creator in the media in fact true? If they are then this is a potentially powerful tool worthy of scientific attention. If the claims are false, we feel that given the amount of public exposure that the model has already had, a note in the public record indicating the claims are false is important. Finally, if the claims have some validity but are exaggerated, than an exact understanding of the model’s capabilities
as well as its limitations would be useful to allow researchers to build on, and hopefully improve or create a new model which does meet the original claims if at all possible. Furthermore, as has been the experience of many researchers the simple act of testing a model often create new avenues of research by itself. Thus the central hypothesis of this paper is that the phi mask can be used to create an objective measurement system for facial attractiveness.

If that is indeed the case, then an objective quantitative system should be devisable that would have at least the same correlation with measures by various panels of judges (at least an $r > 0.80$ and preferably an $r > 0.90$ ). (Langlois, Kalakanis et al. 2000) To date the details of such a system or even of its scale have not been published as far as we are aware.

The specific definition of facial attractiveness we use is:

The visual properties of a face that are pleasing to the visual sense of an observer.

This is as opposed to beauty which we define as:

The assemblage of graces or properties pleasing to the eye, the ear, any or all of the senses, the intellect, the aesthetic faculty, and/or the moral sense.

In fact, what is measured in this and many other studies is a more scientifically precise component of the ‘beauty’ gestalt – full frontal repose static two dimensional photographic facial attractiveness.

This can be precisely defined as:

The time-static visual properties of a face in a photographic two dimensional frontal repose image that are pleasing to the visual sense of an observer.

**Method**

37 males and 35 females ages 18 to 30 years old (mean age male = 22.8 years / SD = 3.27 and mean age female = 21.2 years / SD = 2.92) were recruited from the student body at University of Toronto. All subjects were of white European extraction. The subjects were
financially compensated for their time and the research was approved by the Ethics Board of the University of Toronto.

The subjects were digitally photographed using a Kodak DCS-560 Camera (a digital Canon EOS-1N SLR camera which produces very high resolution uncompressed 18 MB pictures). Subjects were without make-up or adornments (e.g., earrings), and males were clean shaven. All individuals wore hair off the forehead, head position was standardized to that prescribed by Dr. Marquardt (Marquardt 1997; Marquardt 1999; Marquardt 2000; Marquardt 2001) and subjects were told to adopt a neutral facial expression with closed mouth while sitting for the photographs. Photographs were taken using a standardized photogrammetry technique (Farkas, Bryson et al. 1980; Farkas 1994) with standardized lighting conditions against a common background using the same distances for the faces from the focal plane of the 100 mm lens (chosen to produce the least lens distortion in face photography). (Farkas 1994) All face images were kept at their respective relative sizes and not normalized. All images were finally cropped to reduce visibility of hair, ears and neck as only the face itself was of relevance in this experiment. (Brown and Perrett 1993; Perrett, May et al. 1994; O’Doherty, Winston et al. 2003)

For analysis purposes and to allow comparison to previous studies a series of sixteen 2 face composites (Av2), eight 4 face composites (Av4), four 8 face composites (Av8), two 16 face composites (Av16), and one 32 face composite (Av32) were also created from 32 of the original face pictures for each sex using the same technique previously described by other researchers (Langlois and Roggman 1990; Alley and Cunningham 1991; Langlois, Roggman et al. 1991; Langlois, Roggman et al. 1994; Perrett, May et al. 1994; Perrett, Lee et al. 1998). In total there were 68 male faces, and 66 female faces which were evaluated by raters in the next stage (31 for each sex being the above described composites).

In creating the composites the shape of the major facial features of each face was defined by manually marking 224 predefined feature points (e.g., left corner of the mouth) for each digital face image. (Benson
Points were allocated to capture the distinctive shape of individual facial features while maintaining an equivalent spacing on the left and right sides of the face.

All the faces (including composites) were rated using a program custom designed for multiple face rating written using Visual Basic Script in Microsoft Access. The program is capable of being used either directly on a desktop or notebook system or via the internet while being based on a server.

The faces were rated both directly by students at the University of Toronto and by patients at Lasik MD in Montreal in one arm of the rating process (henceforward called the Survey arm) and by random internet users in the other arm of the rating process (henceforward called the Internet arm).

In the Survey arm mean age = 25.8 years old (S.D. = 10.8) with an age range of 10-52 years old and 25 male and 25 female judges. In the Internet arm mean age = 21.6 years old (S.D. = 9.8) with an age range of 10-52 years old and also 25 male and 25 female judges. Combining the 2 arms of the study we get a Combined mean age = 23.7 years old (S.D. = 10.3).

The rating scale used ranged from 1-10 and was classified as 10-extremely attractive, 9-very attractive, 8-attractive, 7-mildly attractive, 6-neutral plus, 5-neutral minus, 4-mildly unattractive, 3-unattractive, 2-very unattractive, 1-extremely unattractive. The means of the ratings for each face were calculated for each of the Internet and Survey arms as well as for the combination of the two arms and was termed an Attractiveness Quotient or AQ, thus giving us three measures: Survey AQ, Internet AQ, and Combined AQ.

Using this phi mask model as a template for ‘attractiveness’ we create a quantitative system by measuring the numerical divergence of the real anthropometric landmarks from their equivalent mask nodal points. Two different methods of weighting the landmarks/nodal points as more or less important for ‘attractiveness’ are modeled:
· Equivalent weightings
· Weightings arrived at by way of multiple linear regression

Each of the faces had the phi mask applied to it using Adobe Photoshop 8.0 (considered the gold standard for photo-manipulation) and in consensus with the general body of the facial attractiveness literature (Burson, Carling et al. 1986; Langlois and Roggman 1990; Langlois, Roggman et al. 1991; Benson and Perrett 1993; Brown and Perrett 1993; Grammer and Thornhill 1994; Langlois, Roggman et al. 1994; Rhodes and Tremewan 1996; Rhodes, Sumich et al. 1999; Little and Hancock 2002) the mask was sized and placed using only the interpupillary distance (IPD) as the reference line. Because of the standardized photogrammetry technique used in taking the photographs we were able to have all the faces imaged as their real size on the computer monitor and were able to measure distances in metric units either by hand or using computer software. We elected to use Image Pro Plus 4.5 (considered the gold standard for scientific image analysis) to objectively and reproducibly measure the deviation of the mask focal points from their equivalent points on the image of the face. Thirty seven nodal points were selected that were both present on the mask and that we were able to accurately and reproducibly identify on the image of the face as anthropometric landmarks. The deviation of mask to face nodal points was measured in centimeters and a total deviation termed the Mask Deviation Score or MDS was used as a measure of how far a face deviated from the phi mask. Our working hypothesis was that we expected to find a significant negative correlation between this MDS score and the AQ found by judges.

This direct correlation of MDS vs. AQ is the most basic system of analysis and it essentially assigns equal weightings to deviations from each of the anthropometric landmarks. Multiple linear regression for 35 nodal point deviations (excluding the two pupil nodal points since they are the fixation points for the mask and have zero deviation) was also undertaken as a statistical method of weighting the nodal points.
Results

Reliability of the attractiveness ratings was assessed for the male and female sets of faces using Cronbach’s coefficient alpha and was 0.97 for male faces, 0.96 for female faces and 0.98 when both sexes were combined for the Survey arm of the judges. The reliability of the male and female raters was equal at 0.96 for the Survey arm. For the Internet arm Cronbach’s coefficient alpha and was 0.91 for male faces, 0.96 for female faces and 0.95 when both sexes were combined. The reliability of the male and female raters was equal at 0.90 and 0.95 respectively for the Internet arm.

AQ Internet vs Survey

Mean AQ (and S.D.) for both sex faces in Internet and Survey Arms were 4.05 (1.08) and 4.76 (1.27), for female faces were 4.30 (1.22) and 4.80 (1.36) and for male faces were 3.80 (0.86) and 4.73 (1.20). T-test for the AQ means obtained by Internet and Survey Arms showed t = 15.39 (p<0.0001) for both sexes. For male sex t = 9.59 and for female t = 13.79 (p<0.0001 for both). However, linear regression showed r = 0.91 (F = 626.56, P<0.0001) for both sexes and r = 0.95 (F = 631, P<0.0001) for female and r = 0.91 (F = 302, P<0.0001) for male faces.

Individual vs. Composite Faces

The means for the faces were submitted to separate analyses of variance (ANOVA), with composite level as a repeated measures factor. The ANOVA comparing images of individual male faces with Av2, Av4, Av8, Av16, and Av32 composite images revealed a significant effect of the number of faces F(5,67) = 17.78, 25.28, and 24.61 p<0.0001 for the Internet, Survey and Combined Arms respectively. Planned comparisons by two sample t-test with separate variance estimates showed that the Av32, Av16, Av8, Av4 and Av2 composites were all rated significantly more attractive than their corresponding individual male faces at p<0.0001. (Bonferroni corrected significance level for multiple comparisons is .006).
The ANOVA comparing images of individual female faces with Av2, Av4, Av8, Av16, and Av32 composite images revealed a significant effect of the number of faces F(5,65) = 15.20, 19.41 and 18.03, p<0.0001 for the Internet, Survey and Combined Arms respectively. Planned comparisons by two sample t-test with separate variance estimates showed that the Av32, Av16, Av8, Av4 and Av2 composites were all rated significantly more attractive than their corresponding individual female faces at p<0.0001. (Bonferroni corrected significance level for multiple comparisons is .007).

The ANOVA comparing images of both sexes faces with Av2, Av4, Av8, Av16, and Av32 composite images revealed a significant effect of the number of faces F(5,133) = 16.34, 45.36 and 21.63, p<0.0001 for the Internet, Survey and Combined Arms respectively. Planned comparisons by two sample t-test with separate variance estimates showed that the Av32, Av16, Av8, Av4 and Av2 composites were all rated significantly more attractive than their corresponding individual faces at p<0.0001. (Bonferroni corrected significance level for multiple comparisons is .007).

Mask Deviation Score (MDS) vs. Attractiveness Quotient (AQ)

ANOVA analysis of MDS with sex and level of composites as factors showed a significant effect for both the number of faces in the composite F = 7.98, p<0.0001, and for sex F = 13.84, p<0.001. (Bonferroni corrected significance level for multiple comparisons is .006).

For male faces MDS had a mean = 18.39, SD = 4.17 (range 11.47 to 28.46) and for female faces MDS had a mean = 15.96, SD = 4.15 (range 9.46 to 28.81). T-test for the means showed a significant difference between male MDS scores and female MDS scores with t = 3.38, p < 0.001.

For faces of both sexes (combined) Pearson’s correlations between MDS and Survey AQ, Internet AQ, and Combined AQ were -0.49, -0.48 and -0.50, all p<0.0001 respectively. For male faces alone Pearson’s correlations between MDS and Survey AQ, Internet AQ,
and Combined AQ were: -0.53, -0.46 and -0.51, all p<0.0001 respectively. For female faces Pearson’s correlations between MDS Survey AQ, Internet AQ, and Combined AQ were -0.51, -0.47 and -0.49, all p<0.0001 respectively.

**Multiple Linear Regression of Nodal Point Deviations vs. AQ**

Giving higher weightings to the more significant nodal point deviations, and lower to the less significant nodal point deviations could produce a phi mask model with better fit. In an effort to demonstrate this a multiple linear regression analysis of the nodal point deviations (as independent variables) against the average facial attractiveness score obtained for each face was conducted for all arms of the survey (Internet, Survey and combined AQ are the dependant variables).

For phi mask placed on faces of both sexes for Internet AQ R = 0.74, R² = 0.55, adjusted R² = 0.39, F = 2.44 (p<0.0001); for Survey AQ R = 0.73, R² = 0.53, adjusted R² = 0.36 F = 3.28 (p<0.0001); and for Combined AQ R = 0.74, R² = 0.55, adjusted R² = 0.38, F = 2.76 (p<0.0001); when placed on female faces alone for Internet AQ R = 0.93, R² = 0.87, adjusted R² = 0.71, F = 5.59 (p<0.0001); for Survey AQ R = 0.93, R² = 0.87, adjusted R² = 0.72 F = 5.75 (p<0.0001); and for Combined AQ R = 0.94, R² = 0.88, adjusted R² = 0.74, F = 6.35 (p<0.0001); and when placed on male faces alone for Internet AQ R = 0.78, R² = 0.60, adjusted R² = 0.16, F = 1.38 (p = 0.1825); for Survey AQ R = 0.79, R² = 0.63, adjusted R² = 0.22 F = 1.54 (p = 1.087); and for Combined AQ R = 0.79, R² = 0.62, adjusted R² = 0.21, F = 1.50 (p = 0.1265).

**Discussion**

This study is the first to compare direct survey rating of facial attractiveness and internet based rating of facial attractiveness, the only other published Internet research into attractiveness only looked at female body attractiveness from line drawings(Krantz, Ballard et al. 1997). While the agreement (r =0.91) between the two rating arms is as high or higher than that found between most facial attractiveness...
studies (which range from $r = 0.80 – 0.95$)(Langlois, Kalakanis et al. 2000) allowing us to combine both arms some interesting points do arise. They are that: Internet judges rate male faces much more harshly than female faces and that they judge all faces more harshly than their counterparts in the direct survey arm. This is probably as a result of the combination that Internet judges feel more anonymous(Hewson, Laurent et al. 1996), that they do not feel as directly involved in the process or responsible for its outcome as do judges directly asked by the investigators for their participation,(Hewson, Laurent et al. 1996; Buchanan and Smith 1999; O'Neil and Penrod 2001) and that they are more bothered by the cut off aspect of the face when they were probably expecting normal full faces as are commonly seen in online attractiveness Internet sites such as www.hotornot.com. The results of the Internet are still reliable ($r = 0.91$), and this is an important finding which will allow researchers in the future to increase their efficiency by harnessing the power of the internet.(Buchanan 2000; Reips 2001) Our findings that attractiveness increases with the number of component faces in a composite are not new and have been published previously.(Langlois and Roggman 1990; Langlois, Roggman et al. 1994; Rhodes and Tremewan 1996; Rhodes, Sumich et al. 1999; Rhodes and Zebrowitz 2001) Our results are perhaps even stronger than those published previously since all the composites including the 2-face composites (Av2) were more attractive than almost any of their component faces. Previous studies have shown that the attractiveness of these composites is not due solely to their morphed textures (which give smoother complexions and soft-focus appearance)(Langlois, Roggman et al. 1994; Rhodes, Harwood et al. 2001) nor to their increased symmetry or conveyed youthfulness.(Langlois, Roggman et al. 1994) Studies have also found that these composite faces as they increase in number of component faces become less variable in judged attractiveness ratings and look more and more alike by visual observation (these findings are mirrored in our study). Thus the mathematical averaging procedure of morphing faces results in more
typical and less unusual faces. It is hypothesized that these “averaged” or typical faces are preferred in attractiveness by both adults and infants alike because they are perceived as prototypes of the face—they are more facelike. Both evolutionary psychology theory and cognitive psychology theory support the notion that prototypical faces should be viewed as more attractive. Evolutionary theory states that the preference is innate due to evolutionary sexual and natural selection pressure; and cognitive theory states that the preference is acquired very early in infancy through learned exposure to category exemplars in this case faces. (Langlois, Roggman et al. 1994) These findings are robust and have been supported in multiple cross-cultural studies showing strong agreement which is the hallmark of biologically based preferences.

Direct correlation of MDS to AQ assigning equal weightings to deviations from each of the anthropometric landmarks shows that the phi mask does indeed work to give an objective measure of facial attractiveness at the most rudimentary level of weighting and explains more than 25% of the variance in attractiveness.

Studies have shown that certain features are more important in influencing attractiveness ratings than others. (Cunningham 1986) As such we expect that deviations from more important featural anthropometric points should have more of an influence on attractiveness than deviations from other less important points.

Multiple linear regression (MLR) is in essence a statistical method of weighting the nodal points. From our results our contention that weighting the nodal points would allow us to achieve a closer correlation to judged attractiveness appears to be true. As expected the correlation to female faces is much higher than to male faces, in fact it is in the same range as correlations obtained between judges. Of note are the adjusted R² values for the MLRs, an inherent problem with MLR is as you add variables you increase the correlation, often artificially, the adjusted R² gives a sense of a more accurate correlation when this is taken into account. However, even the adjusted R² for female faces is still 0.74. Interestingly looking at effect tests which
show the variables that have the most significance on the MLR, the variables that were most consistently found significant were SPR (the position of the upper lid) and EBARCHS (the position of the eyebrow arch superiorly), followed by GN (essentially the width of the jaw), and AP (essentially the width of the nose). This is consistent with other studies showing the eyes, jaw, and nose to be the most significant features in attractiveness. (Brown and Perrett 1993)

The much stronger correlation of the mask to female faces over male faces suggests that Dr. Marquardt is mistaken in his belief that the phi mask as designed is ideal for both male and female faces. (Marquardt 1997; Marquardt 1999) Marquardt’s phi mask was essentially derived from studying and averaging together multiple images of very attractive female models mostly from the covers of fashion magazines. (Marquardt 2000) The use of the golden ratio as a method to give mathematical integrity to the pursuit of a system for objectifying facial attractiveness had been first suggested this century by Seghers in 1964 (Seghers, Longacre et al. 1964) and gained popularity due to Ricketts work afterwards. (Ricketts 1968; Ricketts 1981; Ricketts 1981; Ricketts 1982; Ricketts 1982) The phi mask we feel is essentially a schematic of a high component number composite consisting of highly attractive female faces that has been given mathematical credence by fitting the golden ratio to it. Is the mathematical association of the golden ratio necessary for the schematic mask to correlate to attractive ratings for faces? Most likely it is not and we believe any schematic derived from a high component composite would work just as well but it would not have the precise reproducibility that only a mathematically derived model can have.

Conclusions

Our observational and experimental research has led us to several conclusions regarding being able to measure facial attractiveness objectively. The general conclusion is that indeed it seems possible that at some point in time researchers will be able to devise a highly accurate method to measure facial attractiveness objectively. The phi mask used in the most rudimentary way (with equal weightings
being given to deviations from anthropometric landmarks) yields a statistically significant correlation to measures of facial attractiveness obtained from the current gold standard measure ‘truth by consensus.’ While the basic analysis using equivalent weightings shows a significant statistical correlation it is not very high at most explaining only 25% of the variance in facial attractiveness.

This result in itself brings us to some other conclusions, the first being that the phi mask method relies on the ‘attractiveness is averageness’ or the ‘attractiveness is protoypicality’ hypothesis. The facial attractiveness literature shows us that while the averageness hypothesis is extremely strongly supported by many studies averageness is most likely not the only cue that humans use to determine facial attractiveness. Different studies have shown that other cues including symmetry, youthfulness or neoteny, and sexual dimorphism have an impact on human judgment of facial attractiveness.

The phi mask model in its current state partially factors in symmetry because the model is itself perfectly symmetrical but as tested it does not directly take into account featural fluctuating asymmetry. This could be possibly achieved by adding a weighting factor to instances of featural fluctuating asymmetry. For instance if it is determined that asymmetry in the eyes is especially important (let us say twice as important as any other featural asymmetry measure) then we could multiply the nodal displacement measures for the eyes by the fluctuating asymmetry measure for that feature and finally by the importance weighting (two in our example for eyes).

The phi mask model does not take into account the age of the face in any way except for the fact that the prototypical model was created using faces in the young adult range (18 to 30 years old) and we could hypothesize that some of the deviation away from the mask of a particular face could be related to age changes, but we could not know if that were the case for any individual face. Even though this has no bearing on the results of our own research since the faces we used for testing are all within the same age range of the faces that
went into creating the model, we still feel for a model to achieve its purpose it must in some way factor in age of the face. This can be accomplished either by creating prototypical models for various age ranges (30-40, 40-50, 50-60, 60-70 etc.) and/or multiplying the result by an age factor (e.g. 0.8 for 30-40, 0.7 for 40-50, 0.5 for 50-60, 0.4 for 60-70 etc.) There is strong evidence as well that the age cue affects males and female faces differently with female ageing beyond age 25 resulting in a far more precipitous drop in attractiveness than for similarly aged males. This sex difference may also be considered as partially belonging to the below section.

Sexual dimorphism has been shown to have a major impact on judgment of facial attractiveness. With hyper-feminine features and hyper-masculine features both yielding increased facial attractiveness scores in their respective sex faces (the masculinity effect has also been shown to be correlated to the day of the menstrual cycle of female judges). This sexual cue is also not taken into account by the mask in its present form. Again as for the ageing face separate prototypical models for each sex could be created. In fact, Dr. Marquardt has since created a male variant of the phi mask. Dr. Marquardt notes that the differences in the male variant mask in the repose frontal view are: “[1] prominent supra-orbital (brow) ridges (frontal bossing) resulting in deep set appearing eyes; 2] flatter and narrower eyebrows; 3] slightly narrower eyes; 4] eyes less “wide open” (eye lids slightly closed); 5] slightly longer and/or wider nose; 6] slightly thinner lips (especially upper lip); 7] square/angled and or larger jaws.”(Marquardt 2001) Clearly, Dr. Marquardt has departed from the original claim that he made in his patents that the phi mask in its original state could be used to measure facial attractiveness in both sexes.

Other cues, have also been shown to have an effect on facial attractiveness as well; for example skin quality and Body Mass Index(Hume 2001) and it is theoretically possible to provide weightings for these in constructing a facial attractiveness measurement model.
For example an equation such as the below may be constructed to arrive at a final number for objective attractiveness:

\[
AQ = \text{weighted deviation from sex prototypical age face} \times \text{sex featural fluctuating asymmetry weightings} \times \text{sex specific age factor} \times \text{sex skin quality factor} \times \text{sex BMI factor}
\]

The multiple linear regressions for the 35 nodal points allowed the phi mask to explain 70% of the variance in male facial attractiveness and almost 90% of the value in female facial attractiveness.

These values are in the same ballpark as correlations obtained between judges therefore our contention that weighting the nodal points would allow us to achieve a closer correlation to judged attractiveness appears not only to be true, but we have seem to have devised an objective quantitative system that has “at least the same correlation with measures by various panels of judges (at least an r > 0.80 and preferably an r > 0.90).” (Langlois, Kalakanis et al. 2000)

So we can add to our list of general conclusions that: the phi mask fits female faces more closely than male faces; that weighting the deviation of nodal points improves the performance of the phi mask model; and that the phi mask model can potentially explain perhaps as much as 80-90% of the variance in facial attractiveness when tweaked appropriately in the future. Finally, the phi mask model supports averageness or prototypicality of the face as being the major component of the facial attractiveness gestalt and is a first step in producing an objective system for measuring facial attractiveness.

References:


Individual Model Fabrication for Distraction Simulation

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Oral and maxillofacial surgery has long needed a methodology for accurate definition of the third dimension. The introduction of computer-aided tomography in the 1970s provided surgeons with multiple 2-D maps which they themselves had to conceptualize into a third dimension. The later advent of computerized summation of these data made it possible to provide the basic information that is needed for the fabrication of an individual model. Laser-hardened acrylic resins have been shown to be useful for simulation of operative procedures using distraction devices. Alternatively “model operations” can nowadays be performed on the monitor using animation software. Pros and Contras of both planning procedures are discussed.

KEYWORDS:
Individual models, 3-D reconstruction, rapid prototyping

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Midfacial Distraction Osteosynthesis – Long Term Results

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Introduction
Craniofacial distraction osteogenesis was introduced into orthognathic surgery in the mid-nineties of the last century. After the first good results in adolescents and children the method was adapted for the use in marked midfacial retrusion and/or soft tissue deficiency in adults, too.

Methods
At the craniofacial center of the University of Leipzig, Germany 51 patients aged 6 to 65 years suffering from severe midfacial hypoplasia were treated by way of distraction osteogenesis with a RED (= rigid external distractor (Fa. MARTIN, Tuttlingen, Germany)) from May 1998 to January 2006. There were 44 cleft lip and palate cases (6 of those bilateral, 29 with velopharyngoplasty) and 5 with midfacial hypoplasia. In 2 M. Crouzon cases Le Fort III osteotomies were performed with a subsequent total midfacial distraction (17 and 25 mm). 11 patients were almost or totally edentulous. Preoperative diagnostics were comprised of a lateral cephalogram, an orthopantomogram, a logopedic and a nasal breathing assessment. The
actual treatment planning was done using CT-scans as a basis for 3D computer models. During the course of distraction the vector could be changed not even in the vertical plane but also individually for the right and left maxillary halves in the horizontal plane if indicated. Different distances could also be achieved, if the lesser segment in a cleft case had to be moved further forward in the sagittal plane.

**Results**

Extensive movements of the maxilla and the whole midface could be performed even in multiple pre-operated cleft and syndromic cases. No patient of our series received a distraction below 10 mm. The largest distance was 31 mm. Aesthetics and nasal respiration could also be improved in all cases. There was a nasal flow increase of 155%.

An analysis of pre and postoperative lateral cephalograms showed a relapse of 15 to 20% in the first 6 months with hardly any more changes later (up to 20 months).

The logopedic analysis of all patients showed a worsening of velopharyngeal insufficiencies in 21% of the cases but also an improvement in 8% of all patients. In the end, only 4 velopharyngoplasties had to be performed after DOG.

No major complications were seen.

**Conclusion**

At the end of an eight year experience with 51 cases of midfacial distraction osteogenesis it may be stated that this is a safe and reliable method. Thus it may be the only alternative to conventional orthognathic surgery in certain selected cases.

Other well-known procedures will keep their importance, however, because they may be less time consuming and/or do not require the same amount of patient compliance.

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Monobloc craniomaxillofacial distraction osteogenesis in a newborn with severe craniofacial synostosis: a preliminary report J Craniofac Surg 5, 1995
Midface Advancement for Syndromic Craniosynostosis

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In severe syndromic craniosynostosis cases, mid-face retrusion and exophthalmus are both functional and cosmetic problems. Mid-face advancement has been done to deal with these problems. But there was a limitation in advancement length. Relapse due to soft tissue tension occurred often. Introduction of distraction technique to this area helped surgeons to solve some of the problems.

Fronto-facial monobloc advancement is one of the most rewarding procedures for upper and mid-face reconstruction in patients with craniosynostosis. Though, it has challenging aspects. Epidural abscess and frontal bone necrosis following retro frontal dead space are ones of the major complications, which led many experienced surgeons not to continue with the procedure. Bone distraction can play a great role in preventing these problems. Rigid External Distraction (RED-II) system is a external distraction device using cranium as an anchorage point. Fronto-facial monobloc advancement with the system was performed. Controllability of the monobloc segment increased significantly. Operative time and blood loss were saved.

In LeFort III advancement with conventional one-staged operation, mid-face segment was advanced forward and downward
to maximize orbital volume with limited advancement length. Long mid-face and limited opening of the mouth were inevitable as a trade-off. Distraction expanded the limitation. Advancement vector can be set more horizontal.

Distraction certainly does have drawbacks. Selection of the technique has to be done case by case.
Intraoral versus extraoral distractors for the correction of maxillary hypoplasia in cleft patients

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**Abstract:** Introduction: The distraction osteogenesis of the maxilla has become an important procedure to treat cleft lip and palate patients with midfacial hypoplasia successfully. The conventional orthognathic surgery with maxillary advancement in cleft patients is frequently limited and bears a high risk of relapse. The aim of this study was to evaluate the indication for the intraoral vs. the extraoral distraction.

Material and Methods: The sample comprised 11 patients who had undergone a distraction osteogenesis using either an extraoral (5 patients; 17-27 years old) or an intraoral (6 patients; 11-48 years old) distraction device. Clinical and cephalometric measures were taken of all patients. The intraoral distractor (modell Zuerich) was left until the distraction zone was consolidated, i.e. it was only removed between three to six months after accomplishing distraction. The extraoral distractor (Red II) was removed three weeks after the distraction phase and the fixation was following carried out by means of miniplates.

**Results:** All patients exhibited improvement of the maxillofacial deformities after distraction. The tracing of the preoperative and postoperative cephalograms showed a significant advancement of the maxilla. In all patients treated by an extraoral distraction system
the planned occlusion could be realised in the sagittal as well as in the vertical dimension in a stable manner. Two patients who underwent an intraoral distraction, the distractor had been deformed before the aimed maxillary advancement was accomplished. In one of these cases the planned overjet could be only achieved by an additional mandibular osteotomy.

**Discussion:** Advantages of the intraoral distractors are the higher acceptance by the patients and the surgical integration with rare complication. We recommend that extraoral distractors are used in all cases where great forces are anticipated during distraction. That will be constantly found in adult patients. Therefore intraoral distraction systems should be particularly applied in younger cleft patients. If a controllable vertical shifting is necessary beyond the maxillary advancement an extraoral system is indicated. The removal of the extroral distraction system at an early stage and the fixation by a conventional plate osteosynthesis reduces the morbidity and increases the acceptance by the patient.

**Others Authors:** Lauer, G., Tausche, E., Eckelt, U.
Clinical report on the distraction osteogenesis of the zygomatico-maxillary complex with the RED

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Purpose: In this report, the unilateral augmentation of the zygoma with modified application of distraction osteogenesis using rigid external device is presented in two patients who had radiation therapy during growth period.

Patients and Methods: Two patients (one male and one female) with severely atrophied zygomatic complex were treated with rigid external distraction device (Red II system, KLS Martin, Germany). The patients had severe depression of right zygomatic complex resulting from growth disturbance by radiation therapy at childhood. One patient underwent two jaw surgery for correction of facial asymmetry before distraction osteogenesis. The distraction device was eccentrically positioned to distract zygomatic segment to anterolateroinferior direction. The distraction rhythm and rate were 0.5 mm activation twice a day in one patient and once in the other. The distraction was continued until obtaining a little overcorrection and symmetrical prominence of the zygoma. The follow-up period was more than 1 year in both patients.

Results: No surgical complications occurred during the follow up period. The distracted zygomatic bone segment showed stability.
when the external device was removed. However, rigid fixation with titanium miniplates was performed for the purpose of preventing relapse.

**Conclusion:** To our knowledge, this is the first clinical report on the distraction osteogenesis of the zygomaticomaxillary complex with a rigid external device in the three-dimensional direction. One patient showed clinically satisfactory results and the other patient suffered moderate relapse. These results suggest that more clinical experience may be needed.

**Others Authors:** Seung-Ho Jeon, Jong-Ho Lee, Jin-Young Choi, Myung-Jin Kim
The use of the Stryker MID system for distraction of patients with syndromic craniosynostosis

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Abstract: The selective use of distraction for cases of syndromic craniosynostosis has become incorporated into the treatment protocols of the Australian Craniofacial Unit. The indications are those skeletally immature children who require midface movements to improve airway management and those who are skeletally mature but who have previously undergone mid-face surgery.

For the previous three years we have only used the Stryker MID system. We report our technical modifications to the recommended techniques both for the placement and the removal of these distractors, which have evolved managing fourteen cases between 2004 and 2005. This includes our simultaneous use of the system in the upper third when different vectors for the midface and upper third may be used to advantage.
Distraction Osteogenesis for Bilateral Alveolar Cleft Reconstruction

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Purpose: Secondary autogenous cancellous bone grafting is a widely used method for the treatment of alveolar clefts and oronasal fistulae. However, Failure of iliac bone grafting sometimes occurs due to inadequate covering with surrounding soft tissue and marked scar formation, inappropriate patient age, or large clefts. For alveolar clefts, we developed a distraction osteogenesis method and presented at the 2nd Asia Pacific Congress on Craniofacial Distraction Osteogenesis. The present study was our performed bilateral clefts cases.

Materials and Methods: In patients with bilateral clefts, one side was narrowed by dental arch correction, and bone grafting was performed. The intraoral bone was used as a donor. Premaxilla transport was initiated after 3-4 weeks before adequate consolidation of the bone graft. The subsequent procedure was similar to that in patients with unilateral cleft. Transport distraction osteogenesis along the curve of the dental arch is ideal. Alveolar bone is transported in the planned direction using a ready-made bone-borne distractor in combination with an orthodontic arch wire for transport guidance. In patients without premaxilla, both sides of alveolar bone were transported.
**Results:** This method allows simultaneous correction of nasal septal deviation and also correction of maxillary arch deformities and malocclusion since, the dental arch is expanded without donor sacrifice. Since 1997, we have performed this method in 7 bilateral clefts patients and obtained good results.

**Conclusion:** This method can be regarded as tissue engineering to expand bone tissue. This method can be safely performed not only in patients undergoing initial treatment for alveolar clefts but also in patients in whom bone grafting has failed.

**Others Authors:** Masaharu Mitsugi, R.E. Alcalde, Noriko Uemura, Aki Takada & Yuiro Hata
The best timing of distraction of maxilla in the maxillary hypoplasia cases

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Abstract: Orthodontic treatment goal is achieved in the permanent dentition including second molars. The eruptions of second maxillary molars tend to delay in maxillary hypoplasia cases such as cleft lip and/or palate or craniosynostosis syndromes. The purpose of this study is to investigate when maxillary distraction should be performed in order to accelerate eruption of maxillary second molars. The subjects were 15 maxillary hypoplasia cases between 10 to 35 years old. They were performed maxillary distraction using halo-type devise (8 cases) or internal devise (7 cases) by plastic surgeon. The relation between the state of second molar eruptions and amount of distraction, posterior space increase, and mandibular growth were estimated by X-rays taken at pre-operation, removal of distraction device and after about 1 year. In the cases that obtain space behind first molar more than 11 mm by distraction of maxillae, postoperative second molar went to good state. Immature root of the second molar obstruct their eruption. It was few relation with age. We conclude the best timing of distraction of maxillae in the maxillary hypoplasia cases to be the late period of root maturity of maxillary second molars. In addition to that maxillary distraction should bring space behind first molars more than 11 mm.

Others Authors:

Acknowledgement : Dr.Nobuyuki Mitsukawa
Distraction Osteogenesis Vs Orthognathic surgery in CLP Patients

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Abstract: Objectives: To compare the long term stability of distraction osteogenesis (DO) and conventional orthognathic surgery (CO) in cleft lip and palate patients.

Methods: 30 CLP patients with moderate maxillary hypoplasia requiring a Le Fort I advancement of 4-10mm were randomized to two equal groups either for distraction or immediate fragment transposition. The conventional Le Fort I osteotomy was fully mobilized to the pre-planned position and fixed using titanium mini-plates. The Le Fort I distraction was only mobilized to a limited extent without achieving the final surgical position. Fixation was achieved on the zygoma and the molar alveolus with an intra-oral bone-borne maxillary distractor on each side. All 30 patients had more than 2 years follow-up. Serial lateral cephalographs were taken for the assessment of stability at different post-operative intervals of 2 to 8 weeks (T1), 8-12 weeks (T2), 3-6 months (T3), 6-12 months (T4), and 12-24 months (T5).

Results: The mean maxillary advancement for the distraction group and the osteotomy group was 6.83mm and 6.72mm, respectively. There is no statistical difference between the two
movements (p>0.05). The vertical relapse of statistical significance in the CO group at A-point was 18% at T1, 10% at T2 and 4% at the T5. In contrast, the DO group had further downward movement of 25%, 12% and 11% respectively during the same period. In the horizontal movement of statistical significance in the CO group at A-point, backward movement of 15% was noted equally during T1 and T2, and 13% during T3. In contrast, a further forward movement of 31%, 13% and a backward movement of 5% was recorded in the distraction group at the same periods respectively.

Conclusions: Distraction osteogenesis of the cleft maxilla can achieve better long term skeletal stability in maintaining its advanced and downgrafted position than conventional orthognathic surgery.

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Maxillary anterior segmental advancement using DO to preserve velopharyngeal morphology

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**Purpose:** Midfacial retrusion and velopharyngeal incompetence (VPI) are the two major challenges in treating cleft palate patients. Distraction Osteogenesis (DO) combined with total maxillary osteotomy may result in deterioration of speech in the cleft palate patients, though the rate of its incidence is quite lower than that resulting from simultaneous maxillary osteotomy. The purpose of this study was to show the surgical technique of maxillary anterior segmental distraction osteogenesis (MASDO), which does not affect nasopharyngeal morphology.

**Methods:** For 11 patients with a cleft, MASDO was performed by the use of internal distraction device of the Dynaform System (Stryker Leibinger, Micro Implants, USA), as a palatal distraction device. All patients had a possibility of speech deterioration after DO in combination with a total maxillary osteotomy for correction of their maxillary retrusion. The osteotomy line was made at anterior portion of maxillary bone and the distraction device was positioned on the palatal surface and was secured with bone screws transmucosaly.
Result: In all patients, an excellent improvement was achieved in the anterior relationship between the maxilla and the mandible with sufficient bone generation in the distraction gap. Additionally, the posterior part of the oropharynx did not show any morphological change.

Others Authors: Emiko Isomura 1), Takakazu Yagi, DDS, PhD 2), Seiji Haraguchi, DDS 3), Taku Yamamoto, DDS 3), Tomonao Aikawa DDS, PhD 1), Kenji Takada DDS,PhD 3), Mikihiko Kogo, DDS, PhD 1)

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Morphological changes of nasopharyngeal structures after maxillary distraction

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**Purpose:** The purpose of this study was to describe the morphological changes of nasopharyngeal structures after maxillary distraction and clarify how they relate to velopharyngeal function.

**Methods:** Six male and 3 female patients with repaired cleft palate in the mixed dentition ranging from 9 to 11 years of age underwent maxillary distraction of 2.4-6.9 mm using a face mask and elastics following a high Le Fort I osteotomy. Six patients had a unilateral cleft lip and palate; three patients had a bilateral cleft lip and palate. In all patients, before and after distraction, velopharyngeal function was evaluated using a nasopharyngeal fiberscope, speech evaluation was made by perceptual judgments, and measurements on the nasopharyngeal area such as pharyngeal depth, velar length, and the rotation of the palatal plane were derived from lateral X-ray cephalograms.

**Results:** a. Seven of 9 patients had complete velopharyngeal closure and normal articulation before distraction and they were unchanged after distraction. b. Two patients were evaluated as borderline velopharyngeal incompetence before treatment. One of these two showed no change in velopharyngeal function, but the other
experienced deterioration from borderline velopharyngeal incompetence to velopharyngeal incompetence after distraction despite a small maxillary advancement of 2.4 mm. c. There was no significant change in velar length between before and after distraction. d. The adequate ratio (the velar length to pharyngeal depth ratio) decreased in all patients. e. The point of posterior pharyngeal wall at the intersection with the palatal plane situated on the hypertrophied adenoid before treatment migrated to immediately below the adenoid after treatment in two patients. This finding was caused by the rotation of palatal plane. In the patient who showed deterioration in velopharyngeal function, the migration of that point caused an increase in pharyngeal depth to such an extent that the contact between the posterior pharyngeal wall and the velum was lost.

**Conclusion:** One of the most important characteristics of the nasopharyngeal structures in patients with repaired cleft palate in the mixed dentition is a hypertrophied adenoid. Increase in pharyngeal depth is not always proportional to the amount of maxillary advancement. A hypertrophied adenoid appears to be a potential risk factor that may cause unexpected widening of the pharyngeal depth. When velopharyngeal closure is found to occur by velar contact against the hypertrophied adenoid, candidates for maxillary distraction should be counseled about risks for subsequent deterioration in their speech before surgery.
The benefits and risks of LeFort I, III and segmental maxillary advancement using Distraction

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Abstract: The classical treatment for the maxillary hypoplasia of the cleft patients usually consists of Le Fort I osteotomy and advancement of the maxilla, block bone grafts and rigid internal fixation. These procedures have been used successfully and the long term result was quite stable and satisfactory. For example, the data from my own 24 cases showed mean 7.5mm maxillary advancement was ended up with 1.4mm relapse (18.7%) without any significant clinical problems. However, since the new concept of distraction osteogenesis (DO) was observed and developed by Dr. Ilizarov in 1950’s and its introduction to the western society in about 20 years, the technique and devices for DO have been refined remarkably and the clinical application has been tried in many indications. Not to mention of the long bones including the mandible, the osteodistraction has been applied to the maxilla and cranial bones in recent years and hypoplastic cleft maxilla of the young individuals is an especially good indication for the osteodistraction.

Gradual distraction after LeFort I osteotomy using external force system is a relatively simple procedure with minimal morbidity and complications. Combined approach of both surgical and orthodontic therapy is almost always recommended. In this presentation, the author will show 14 experiences using LeFort I, III and segmental maxillary osteotomies, and discuss the benefits and risks and some questions such as relapse and overcorrection, soft tissue response, velopharyngeal changes and additional treatments.
Mid Maxillary distraction osteogenesis of cleft patients using new technique and new device

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Distraction osteogenesis is a method of producing unlimited quantities of living bones directly from a special osteotomy by controlled mechanical distraction of the bone segments.

The concept of bone lengthening by distraction was 1st described by Codivilla in 1905.

Further developed and refined by Ilizarov a Russian surgeon in 1951. The use of distraction on craniofacial skeleton was introduced by McCarthy in 1992.

It creates bone as well as soft tissue. Therefore distraction histiogenesis is more appropriate. Some times distraction can be used as an alternative to bone grafting and to osteotomies. But patient’s cooperation and compliance is very important.

We are practicing this new technique for the last 3 years with lot of success to improve hypoplastic maxillary bones especially on cleft patients.

In our technique preoperatively surgical access space created at pre molar/molar region of mid maxilla by orthodontic colleagues. Impression of the upper dental arch is taken and plaster model was casted. Then the special distraction device is prepared using Rapid
Maxillary Expansion screw (Hyrax screw) and molar bands. This special distraction device was planned and constructed by the help of our orthodontist in the cleft team.

![Midpalatal distractor](image1.png) ![Intra oral view with distractor](image2.png)

Mid maxillary osteotomy was performed. Osteotomy cuts were made distal to premolar or 1st molar teeth, depending on the availability of the space. The vertical cuts were directed posteriorly and superiorly to get maximum amount of maxillary bone anterior to the bony cuts. If the nose is not prominent enough vertical cuts can be extended up to the infra orbital rim and superior cuts can be placed to include part of the nasal bones.

![Diagram of surgical cut](image3.png)
Thereafter fixation of mid palatal distraction device was done by orthodontic colleagues on 2nd post operative day. Distraction starts on 4th or 5th day, 1mm per day till desired results achieved. Then the distraction device left in place for average of 3 months for post operative bone stability.
The advantages of this special mid palatal distraction are:-

- less expensive,
- less invasive,
- less cumbersome to patient,
- device is not visible to outside (patient can take part in usual activities)
- can avoid damaging adjacent teeth due to insertion of standard intra-oral distraction device,
- less surgical time,
- better vector control,
- results more predictable
- unlimited distraction is possible (if the 1st appliance is not adequate the 2nd appliance can be fitted and activate)
- may improve the VPI and therefore the speech

The disadvantages are:-

- may damage adjacent dental roots
- the space created at the dental arch may need advance restorative procedures like implants or bridge work

To overcome the excess space at dental arch, we have changed the treatment protocol of orthodontic treatment. That is dental extractions to relieve crowding was postponed till completion of distraction.
The advantages to orthodontist are less time for pre-surgical orthodontic treatment (creation of space for surgical incisions only). Unlike other osteotomies and standard maxillary distraction osteogenesis procedures this method creates space within the dental arch and this created space can effectively be utilized to correct dental malocclusion. And also if necessary minor orthodontic treatments can be done during distraction period.

Acknowledgement: Dr W M Senadeera Cons. Orthodontist THK Galle Sri Lanka
The Role of Orthodontics in Maxillary Distraction of Cleft Patients

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The AIM is to present our experience of orthodontics in Cleft-Lip and Palate patients undergoing maxillary advancement with distraction osteogenesis.

MATERIALS and METHOD: 30 patients have undergone an integrated treatment concept of orthodontics and distraction osteogenesis using internal maxillary distractors treated by a designated multi-disciplinary team.

RESULTS: All patients had the alveolar cleft grafted prior to the pre-distraction orthodontics. The pre-distraction orthodontic treatment aimed to place the teeth in good position in the alveolar process, well aligned and in contact with each other. Post-distraction size coordination of the maxillary and mandibular dental arches was in general prepared by co-ordination of the labial arch wires during the pre-distraction orthodontic phase. The treatment also aimed to correct the dental midlines with the facial midline. Any space after congenitally missing or extracted teeth was in general closed by orthodontic tooth movements, and rarely prosthetic replacements become indicated. Post-distraction orthodontics commenced 2-3 months after distraction surgery. Usually the orthodontic treatment
aimed to improve the interdigitation of the occlusion with minor tooth movements and to close any posterior open bite.

**Conclusion:** Orthodontic treatment before and after maxillary distraction osteogenesis of Cleft patients has a defined and essential role in order to optimize final occlusion

**Others Authors:** Hannah D Chua, Lim K Cheung
Maxillary Retrognathism - What are the Clinical Options?

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This report will evaluate the clinical options available for the patients with maxillary retrognathism:
1. No treatment-growth changes,
2. Growth modification,
3. Camouflage treatment and
4. Surgical options including distraction osteogenesis.

The presentation will be based on our own investigations and the current literature.
Surgically aided palatal extension and the concominant orthodontic treatment in the correction of openbite

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Abstract: The skeletal open bite is a dysgnathia being difficult to treat, both with orthodontics and with oral and maxillofacial surgery. A satisfactory therapy result is not guaranteed and there is a high recurrence rate. The skeletal open bite very often involves a narrow apical base, a resulting narrow jar as well as crowding and lateral position of teeth. Despite the treatment with tight-fitting orthodontic appliances, split osteotomies in the Le Fort I level or segmental osteotomies are necessary. The risk of teeth injuries, gingival recessions and diminished perfusion of particular fragments is very high. In order to minimise these risks and to assure a successful therapy without any complications, the following treatment for an open bite with a narrow apical base is proposed: After the integration of the tight-fitting appliance and a short levelling phase, a surgically-aided palatal extension with a bone-supported device is carried out. So, the bone of the narrow apical base will effectively be extended and the crowded teeth or teeth being in lateral position will be arranged during the moulding process. The open bite will already be reduced during this treatment. In some cases, the open bite can already be closed with the surgically-aided palatal extension and the concomitant orthodontic
treatment. Depending on the sagittal situation, the remaining vertically open dimension and the smile line, a graduated scheme comes into operation. This scheme varies from the sole mandibular osteotomy to the bimaxillary osteotomy with forward and backward displacement as well as asymmetric maxillary cranialisation/caudalisation. In order to close the remaining open bite, in most of the cases a mandibular osteotomy with moderate rotation is sufficient. Additional teeth extractions in order to gain more space can regularly be avoided. The treatment period will be reduced by the simultaneous beginning of tight-fitting orthodontic treatment and surgically-aided palatal extension. In our opinion, the recurrence risk will be reduced by the lasting osseous changes of the apical base. Maxillary split osteotomies as well as segmental osteotomies will only be necessary for extreme cases.

**Other Authors**: Tauche, E., Harzer, W., Eckelt, U.
Clinical Applications of Recombinant Human Bone Morphogenetic Protein in Craniofacial Surgery

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Purpose:
Reconstruction of the craniofacial skeleton in cases of traumatic loss or congenital absence remains a challenge, particularly when the defect is substantial. Because bone grafts must take by a process of osteoconduction, blood supply considerations limit the ultimate size of the graft; in large defects, vascularized grafts become necessary. Additional OR time, donor site morbidity, and cost of hospitalization figure into the equation.

Recombinant human bone morphogenetic protein-2 (rhBMP-2) is commercially available as an implant; it forms bone via osteoinduction. Stem cells from the environment of the implantation site migrate into the implant where they multiply and differentiate into osteoblasts. Rapid formation of site-specific bone ensues until the implant is completely replaced. Craniofacial mesenchymal cells, particularly those of neural crest origin, are exquisitely responsive to rhBMP-2. Neural crest cell membranes contain receptors for BMP. With the exception of the cranial base and the parietal bone, the mesenchyme of the craniofacial skeleton is of neural crest derivation. Skeletal reconstruction using cytokine-based induction of stem cells
is called *in situ osteogenesis* (ISO). When combined with distraction technology, it is known as *distraction assisted in situ osteogenesis* (DISO). The future direction of this technology will greatly affect the care of craniofacial patients as expanded experience with ISO and DISO is reported.

Technical aspects of preparation and application of rhBMP-2 are discussed in detail. This series described applications of ISO and DISO in over 190 patients. The pathologies include primary and secondary alveolar cleft grafting, calvarial reconstruction, the BMP “switch” procedure, total synthesis of hemandible, craniofacial trauma, and augmentation osteoplasty for Treacher-Collins. Lessons from the learning curve are frankly discussed.

**Material and Methods:**

Patient population varied from 6 months to 52 years. The pathology was as follows: Alveolar clefts (105 unilateral, 40 bilateral) totaling 185 sites
- Calvarial defects (22)
- Facial trauma (9)
- Mandibular defects (1 hemimandible, 5 immediate neonatal distraction)
- Augmentation osteoplasty (5)
- LeFort I osteotomy (3)

All patients received rhBMP-2 at a dosage of 1.5 mg/cc. Three kit sizes (2.6 cc, 5.4 cc, and 8.4 cc) were used. In selected cases, an inert bulking agent containing 85% tricalcium phosphate and 15% hydroxyapatite was used to maintain pocket shape. Three-dimensional CT scans were obtained pre-op and post-op at 3 months (early series) and 6 months (late series). In clefts, ability to unite the arch (transverse fill) was distinguished from volumetric stabilization of teeth.

**Results:**

Graft fill was achieved primarily in 187/190 patients (98%).
Mechanical dislodgement of graft occurred in the early experience (3 patients); these were re-grafted successfully. In alveolar clefts transverse fill (spanning) was 100%. Vertical fill was 50% in the early series. This improved with use of bulking agent to 75-100% in the late series. Two infections in trans-oral augmentations were treated with antibiotics. All patients had prolonged edema at the implant site, resolving without sequelae in 5-7 days.

Conclusions
Osteoinduction of stem cells with rhBMP-2 reliably produces membranous craniofacial bone that is embryologically equivalent to the recipient site. Limitations of traditional grafts due to availability, blood supply at the recipient site, and donor site morbidity are avoided. In Situ Osteogenesis (ISO) is a reasonable alternative reconstructive method for craniofacial defects where harvest of autogenous bone graft is undesirable.

Main Objectives of Presentation
1. Attendees should be able appreciate the biologic rationales of ISO and DISO.
2. Proper technique will be presented.
3. This presentation is intended to be provocative and generate new ideas.
Effect of Recombinant Human Bone Morphogenetic Protein-2 on Mandibular Distraction Osteogenesis

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Introduction

Distraction osteogenesis is a method of producing new bone directly from the osteotomy site by gradual traction of the divided bone fragments. Since the first clinical report on the use of distraction osteogenesis to lengthen the human mandible in 1992, it has become a widely-accepted approach in the treatment of severe craniofacial deformities. However, one of the major disadvantages of this technique is the lengthy course of treatment required for distraction and consolidation, which may result in pin tract soft tissue infection, bone infection and psychological problems. Consequently, both surgeons and patients would welcome any technical improvement that can speed up the treatment process.

The rate of distraction is the amount of the bone fragments to be stretched apart per day. The ideal rate for lengthening is widely accepted to be around 1.0 mm per day. Slow distraction tends to result in premature union, whereas rapid distraction may delay bone union or even give rise to fibrous union. In rabbit mandibular distraction models, different distraction protocols have been used: 1.0 mm once daily, 0.5 mm twice daily, 0.18 mm twice daily,
and 0.9 mm once daily, all these protocols are capable of leading to complete bone healing. At rapid distraction rates, such as 1.5 mm twice daily, 1.0 mm twice daily and 2.0 mm once daily, unreliable bone ossification has been confirmed.

BMPs are one of the most potent factors in bone development and healing, and have demonstrated the same important role in regulating bone and cartilage formation during distraction osteogenesis in long bone and in mandible. The application of rhBMPs to promote bone induction and ossification process in distraction osteogenesis has been reported only in a few publications so far. rhBMP-2 and rhBMP-4 have been shown to be able to enhance bone formation at the early stage of long bone and mandible distraction. On the other hand, rhBMP-7 has produced conflicting results in distraction osteogenesis. No study has compared the effect of rhBMPs on distraction regenerates under routine and rapid rates of distraction.

This study aims to evaluate the effect of rhBMP-2 on mandibular distraction at routine and rapid distraction rates, and to determine the feasibility of compensating for the increased distraction rate by the addition of rhBMP-2 while maintaining the quality of the distraction regenerate.

Materials and Methods

Animal care: The animal experiment protocol was approved by the Committee on the Use of Live Animals for Teaching and Research, the University of Hong Kong. Eighteen adult New Zealand white rabbits (3.0-3.8 kg) were used. The rabbits were kept in a dedicated animal holding facility under veterinary supervision in the Laboratory Animal Unit of the Faculty of Medicine, the University of Hong Kong.

Surgical procedure and post-operative care

A standardized surgical procedure used in our previous study was performed on all the rabbits. Briefly, after the administration of pre-operative antibiotic and analgesic (30 mg/kg long acting
oxytetracycline and 0.03 mg/kg buprenorphine), each rabbit was anesthetized by intramuscular injections of ketamine (35 mg/kg), xylazine (5 mg/kg) and acepromazine (1 mg/kg). The skin was incised along the inferior border of both sides of the mandibular body with the rabbit’s head hyper-extended. The platysma was dissected and the periosteum was reflected laterally. Bilaterally straight body osteotomy cuts were performed with a small bur immediately anterior to the first premolar root. The custom-designed bone borne distractors were adapted on both sides of the mandible along a plane perpendicular to the osteotomy cut and fixed by 2-mm diameter titanium screws. The periosteum, muscle and skin were repositioned and closed using 3-0 silk sutures.

After the operation, an antibiotic (long acting oxytetracycline 30 mg/kg) was administered intramuscularly twice per week for 2 weeks. For pain relief, buprenorphine (0.03 mg/kg) was administered subcutaneously twice daily for 10 days. Each animal remained under close observation by a veterinary technician until it regained consciousness. The clinical condition, weight and food consumption of the animals were monitored.

**Distraction procedure**

Eighteen rabbits were randomly assigned to two experimental groups, each with nine rabbits. After a 5-day latency period, bilateral distraction was activated at 0.9 mm once daily for 12 days in the routine rate group, and at 2.7 mm once daily for 4 days in the rapid rate group. 1.08 mg rhBMP-2 in phosphate buffer was injected into one side of the distraction regenerate at the end of the active distraction period, whereas the contralateral side was used as a control. Three rabbits in each group were sacrificed at 1 week, 2 weeks and 4 weeks of the consolidation period respectively.

**Assessment methods**

*Plain Radiography*: Each mandibular specimen was placed on an occlusal film with the lingual side touching the film. Plain
radiography was performed by an Orthoralix 9200 X-ray machine (Gendex, Des Plaines, USA) under a standard condition of 50 KV, 16 mAs.

Micro-computerized tomography: After plain radiographic examination, the distracted tissue regenerate and a 2-5 mm section of the neighboring normal bone in the distracted mandible were harvested. The specimens were subjected to morphological and quantitative examination by a µCT20 scan machine (Scano Medical AG, Bassersdorf, Switzerland). Each harvested specimen was placed into a 17-mm diameter sample holder with the sagittal plane vertical to the X-ray tube. Between 120 and 140 cross sectional scans with a slice increment of 100-ìm were made for each specimen.

A standardized method of quantitative assessment used in our previous study was performed. Briefly, the serial scanned images for each specimen were inspected on the computer. On each scanning image, the total area of the distraction regenerate was outlined as the region of interest (ROI). The bone volume fraction (the ratio between bone volume and total volume, BV/TV) within the ROI on each section was calculated individually and a mean value of BV/TV for the total regenerate was obtained by pooling from all the scanned sections within the distraction gap. To determine the threshold all ROIs of one specimen were subjected to an adaptive procedure in which the bone fraction was determined for a range of thresholds. The optimal threshold (120) was defined at the minimum change of bone fraction.

Histology: After the micro-CT examination, the samples were decalcified in a solution of 14.5% ethylenediaminetetraacetic acid (EDTA) buffered (pH 7.2) at room temperature. The decalcified specimens were processed and embedded in paraffin wax. Sections 5 µm in thickness were cut longitudinally in the axial plane with a microtome and stained with haematoxylin and eosin for light microscopy.

Statistical test: The intra-individual controls were compared by paired t-test, and groups at different distraction rates were compared by two sample t-test with SPSS for Windows (SPSS Inc., Chicago, USA). A statistical result of 0.05 was considered as significant.
Results

Clinical examination

All eighteen rabbits completed the experimental process uneventfully. None of the animals experienced postoperative complications, and distractors maintained stable till the day of sacrifice. Both sides of the mandible were lengthened symmetrically, and obvious crossbite and overgrowth of the lower incisor developed in all the rabbits.

Plain radiographic examination

At 1 week of consolidation, two of the three cases of the control side of the routine distraction group still demonstrated incomplete union at the central area of the distraction regenerate, but confluent radio-opacity was seen across the distraction gap in all three cases of the BMP injection side. In the rapid distraction group, radio-opaque streaks were observed in both the BMP injection and control sides, but partial union only was noted in two of the three cases of the BMP injection side.

At 2 weeks, the osteotomy site demonstrated bony continuity in both the BMP injection and control sides of the routine distraction group, and the radio-density of BMP injection side seemed to be higher. In the rapid distraction group, complete bone union was observed in two of the three cases of the BMP injection side, but the control side still demonstrated obvious nonunion in the central area.

At 4 weeks, the radiographic images of the BMP injection sides of both the routine and rapid distraction group were similar to each other. When compared with the control sides, the radio-density in the distraction gap was higher and clear corticalization was only observed in the BMP injection side. In the control side, bone union was complete in all the cases, but corticalization was not clearly seen.

Micro-computerized tomography

Distraction regenerate in the serial CT images demonstrated continuous ossification with gradually increased mineralization from
the center to the edges of the distraction regenerate. Bone formation and remodeling of the distraction regenerate in the BMP injection sides in both the routine and rapid distraction groups were more obvious than in the control sides at all observation time points.

At week 1 of consolidation, obvious new bone formation was seen in all mandibular samples of the experimental animals. More bone formation was noted in the BMP injection side of both the normal and rapid distraction groups than in the control side.

At week 2 of the consolidation period, new bone formation was more obvious in all the mandibular samples. The BMP injection side of both the normal and rapid distraction groups displayed more newly-formed bone than the control side. Early corticalization was only observed in the BMP injection side of the normal distraction group. The peripheral bone became denser and the marrow cavity appeared, although it was not very clearly defined yet.

At 4 weeks of the consolidation period, the CT images of the BMP injection side of the normal and rapid distraction groups were quite similar to each other, advanced remodeling was noted, and obvious corticalization and marrow cavity formation were clearly seen. In the control side, multifocal bony defects were still obvious.

Quantitative analysis of the distraction regenerate showed that bone volume of the BMP injection sides had higher values than the control sides in both the routine and rapid distraction groups, the difference between the groups became statistically-significant at 2 weeks and 4 weeks of consolidation. When the bone volume of the BMP injection sides was assessed, the routine distraction group tended to have higher values than the rapid distraction group, but the differences were not statistically-significant.

Histology

Corresponding to the findings demonstrated by the micro-CT study, histological examination showed that bone formation and remodeling in the BMP injection sides was more advanced than the control sides.
At 1 week of consolidation, the distraction regenerate of both the experimental and control sides in the routine distraction group was composed of primary trabeculae and loose fibrovascular stroma, fibrous tissue was still obvious in the central area. The control group also demonstrated a few small cartilage islands at the central area close to the periosteum. In the rapid distraction group, most of the distraction gap was bridged by fibrous tissue, the new bone was generated at the edges of the distracted gap, and also at the medial surface of the distraction regenerate by periosteal reaction.

At week 2, bone formation and remodeling was more advanced in BMP injection sides of both the routine and rapid distraction groups. Complete bony union was observed at the central area of the distraction regenerate. In the control sides, focal fibrous tissue was obviously observed in the routine distraction group, and more frequently seen in the rapid distraction group.

At week 4, in the BMP injection sides of both groups, bone remodeling was evident, the new cortex increased its thickness and bone marrow cavity formation was clearly seen. In the control sides, the distraction gap was completely united, corticalization and marrow cavity formation were not evident yet in the routine distraction. In the rapid distraction group, fibrous tissue remained to be obvious.

**Discussion**

Varying the rate of distraction influences significantly on the outcome of distraction osteogenesis. A higher rate of distraction may lead to poor bone quality and high incidence of soft tissue complications. Li and colleagues investigated the angiogenic response to different distraction rates and demonstrated that the vascularization process in the central fibrous zone was maximally stimulated at 0.7 and 1.3mm/day. A slow rate of distraction at 0.3mm/day does not maximally stimulate angiogenesis in the distraction regenerate, and a high rate of 2.7mm/day appeared to impair this response. A study in our department demonstrated that change in the mechanical environment resulting from different rates
of distraction leads to different expression of the BMP-2 and -4. The biological environment created by distraction at a routine rate (0.9 mm per day) is superior to the rapid distraction rate (2.7 mm per day) at the early stage of consolidation.

From the clinical perspective, most surgeons in maxillofacial and orthopaedic surgery would wish to be able to reduce the treatment course of distraction osteogenesis. A reduction in the consolidation period or an increase in the distraction rate are possible options for reducing the treatment course. The present study attempts to accelerate the distraction rate with the injection of rhBMP-2, and compare the bone ossification process at routine and rapid distraction rates.

rhBMP-2 is among the most potent of the BMP family. It has been shown to be capable of promoting bone regeneration and remodeling during the bone repair process in a variety of animal models. The development of the recombinant DNA technique enables recombinant human BMPs to be produced reliably in substantially larger quantities, and offers promise for hard tissue engineering.

A baseline study for this article conducted in our department demonstrated that the osteogenic activity of rhBMP-2 in mandibular distraction osteogenesis is dosage dependent, and a single injection of rhBMP-2 at a sufficient dosage of 1.08 mg is just as effective as multiple injections. In the current study, a single injection of 1.08 mg rhBMP-2 was used at the end of the active distraction period. Exogenous BMPs are normally delivered to the site of regeneration by a carrier matrix in reconstructive surgery. The matrix is supposed to be capable of retaining the BMP at the site of implantation and of controlling its release to the tissues. Although a matrix is often used together with BMP, there is no biological indication for its use. If enough BMP is applied, bone is formed in the absence of a matrix. Bony reconstruction of a surgical defect is different from the distraction regenerate because the latter provides a richer source of osteoprogenitor cells that are essential for bony regeneration. We
delivered rhBMP-2 directly to the distracted area by percutaneous injection without a matrix in the present study.

1 week after the completion of active distraction, obvious signs of new bone formation were seen in all mandibular samples. In both the routine and rapid distraction groups, the images obtained from all assessment methods suggested that the bone ossification in the BMP injection sides were superior to that in the control sides, but were not yet statistically-significant. The histological study showed a few small islands of cartilage in the control sides of the normal distraction group, but bone formation during distraction osteogenesis was primarily through intramembranous ossification. At 2 weeks, bone formation in the BMP injection sides was significantly enhanced in both the routine and rapid distraction groups. Bone volume of the experimental sides was significantly higher than that of the control side. At 4 weeks, the BMP treated samples at both routine and rapid distraction rates were similar to each other. Bone union was complete in the central area, and the cortex and marrow cavity architecture could be distinguished. Although the ossification process at the routine distraction rate seemed to be much superior to that at rapid distraction, no statistically-significant difference could be observed during treatment with rhBMP-2.

In conclusion, the study indicates that rhBMP-2 can enhance bone formation at both routine and rapid distraction rates. The addition of rhBMP-2 seems to be able to compensate for the rapid distraction rate in mandibular distraction osteogenesis.

Reference


Development of New DO Technique
Compression force

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This presentation will be contained sequential studies to identify the effectiveness of new distraction osteogenesis method with compression force which has been first suggested by the author in 2002 and to explore the efficient applicable condition for new DO technique throughout several basic researches till in 2006. The presentation will be given the results of 5 projects as follows:

1. Bone regeneration in mandibular distraction osteogenesis with compression stimulation (JOMS 64:1498-1505, 2006)
2. Optimal distraction-compression ratio and appropriate latency period for compression force application following distraction
3. Biomechanical analysis on bone regenerate to the forces,
4. Expression of TGF-ß1, Osteonectin, BMP-4 on bone regenerate after DO with compression stimulation.
5. TMJ response to DO with compression force.
Obstructive sleep apnea (OSA) in pediatric populations is often associated with congenital craniofacial malformations, as Pierre Robin Syndrome, Hemifacial microsomia, Treacher Collins syndrome and others resulting in decreased pharyngeal airway, which, in severe cases, leads to tracheostomy-dependence. A part of patients had tracheostomies placed and another part of patients were considered tracheostomy candidates. The patients that were without tracheostomy were respiratory distressed and had various complaints of OSA, as noisy breathing during sleep, waking episodes, pauses in respiration, daytime somnolence and are considered tracheostomy candidates. All patients had polysomnography before and after the treatment.

OSA due to congenital malformations, was treated by mandibular distraction osteogenesis bilaterally in the mandibular body using two extraoral distraction devices. After a latency period of four days, a gradual distraction in a rate of 1mm/day was performed followed by consolidation period of eight weeks. The expansion of mandibular framework was analyzed using bony cephalometric landmarks and 3D CT. The size of the pharyngeal airway preoperatively and post-
treatment was evaluated by measurements of lateral (sagittal) and axial width and by 3D CT. The results demonstrate average mandibular elongation of 30mm on each side, and an increase in mandibular volume and pharyngeal airway. The group of patients with tracheostomies were decannulated and in the other respiratory distressed patients there was improved airway with improvement of signs and symptoms of OSA and elimination of oxygen requirement. Then, continuous treatment of the palate and the velopharyngeal sphincter was possible without impairing the airway.

**Conclusions:** Bilateral mandibular distraction is a useful method in younger children with OSA expanding the mandible and concomitantly advancing the base of tongue and hyoid bone increasing the pharyngeal airway.
Long term results of Mandibular Distraction Osteogenesis by Intraoral tooth-borne distraction device

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Abstract
Distraction osteogenesis (DO) has been applied successfully in the oral and maxillofacial region; however most of the appliances used are usually bone-borne appliances that necessitate a second surgical intervention to remove these appliances. Previous reports questioned the stability of craniofacial distraction osteogenesis. This was attributed in part to the circum-oral musculatures, immature bone formation at the time of devices removal and to differential growth pattern when unilateral distraction was performed in growing patients. Also, tooth–borne distraction devices were questioned regarding the slight movement of the anchor teeth bearing these devices. There is paucity of information regarding the long term outcomes of using tooth-borne distraction devices after mandibular distraction osteogenesis. Ten adult patients who had distraction osteogenesis of their mandibular bodies to correct severe mandibular retrognathism were followed up for 8 years after distraction. Pre-treatment, immediately after distraction, post-orthodontic treatment and 8 years after retention clinical records were taken and evaluated. These records included photographs, study models, cephalomteric
and panoramic radiographs. Study model and cephalometric analyses showed that the achieved skeletal and dental outcomes post-orthodontic treatments are stable (p< 0.05). The results of this study suggest that the use of tooth-borne distraction devices for mandibular lengthening might be a clinically acceptable substitute for bone-borne mandibular distraction devices when the patients presented with healthy anchorage teeth.

Introduction

Skeletal Class II jaw relationship is usually due to mandibular deficiency more than being due to maxillary excess.\textsuperscript{1,2} For many adult patients with mandibular deficiency, optimal treatment results are obtained utilizing surgical-orthodontic approach.\textsuperscript{3} DO successfully
increased bone and soft tissue mass in a variety of craniofacial deformities including patients with Class II mandibular deficiency.\textsuperscript{4-7} Razdolsky introduced an intraoral tooth-borne distraction device to facilitate complex multiplanar distraction.\textsuperscript{8-14} The advantages of this device can be summarized as followings: 1) intra-oral application eliminates extra-oral scarring; 2) device orientation parallel to the vector of distraction;\textsuperscript{15} 3) pre-surgical cementation of the device saves operating time; 4) Removable expansion screws maximize surgical access; 5) Precision attachments enable reassembly of bone segments to their original position and it has small size with adequate rigidity.\textsuperscript{8}

There is paucity of information in the literature regarding the skeletal and dental effects as well as long term stability of the results of tooth-borne mandibular distraction devices. The purpose of this study was to evaluate the long term skeletal and dental changes after mandibular osteodistraction using ROD1 device in adult orthodontic patients.

**Materials and Methods**

Ten adult patients with skeletal Class II relationship due to mandibular retrognathia and Class II dental malocclusion who sought correction of their malocclusions and improvement of their profiles were included in this study. These patients were advised for two options of treatment, either the regular orthognathic surgery to advance their mandibles via bilateral sagittal split osteotomy or by distraction osteogenesis using ROD1 devices. All of these patients agreed on choosing the distraction osteogenesis using ROD1 devices. Table 1 shows the sample distribution and their ages. Each patient had bilateral mandibular osteotomies performed between the mandibular second premolar and the first permanent molar. Distraction was performed using ROD1 devices. A full description of ROD1 devices and components has been previously published.\textsuperscript{8-14}

Prior to surgery anchor teeth were fitted with pre-formed stainless steel crowns from Unitek\textsuperscript{TM} (3M Unitek, Ca, USA). Impressions of the lower dental arch with fitted stainless steel crowns in place were taken. Finally, the fitted crowns were placed within the impression
and a model was generated using heat resistant stone. The model with stainless steel crowns accurately transferred was positioned on a special ROD™ Laboratory Tool to determine the relationship of the distraction screws to the occlusal plane and the position of occlusal stops (struts) and lingual stabilizing bars to enhance dental anchorage. The appliances were cemented using Fuji light curing cement (GC America Inc., USA). The surgical procedure was described in detail elsewhere. Each surgery was performed in an outpatient setting under local anesthesia and intravenous sedation. The distraction protocol was as follows: 1) 5-7 days latency period depending on the age of the patient; 2) distraction rate was performed at 0.75 mm/day; 3) distraction rhythm of three turns per day (0.25 mm per turn) until proper length was attained. The distraction appliance was left in place for 10-12 weeks after the last activation to allow for complete bone formation that was confirmed by panoramic radiographs. The

A) Clinical Extraoral photographs for a patient before B) immediately after finishing distraction (C) after finishing orthodontic treatment and (D) 8 years in retention.
Clinical Intraoral photographs for a patient before A) immediately after finishing distraction
B) after finishing orthodontic treatment C) and (D) 8 years in retention.

Lateral Cephalometric and Panoramic X-rays for the same patient before (A), immediately
after finishing distraction (B) after finishing orthodontic treatment (C) and (D) 8 years in
retention.
distraction devices were then removed, fixed appliances were placed, and the cases were finished. The clinical records obtained were lateral cephalometric radiographs and dental study casts. The lateral cephalometric radiographs were taken before, after distraction, at the completion of the orthodontic treatment and at 8 years on average after finishing the orthodontic treatment representing T1, T2 and T3, T4 respectively. Overall superimposition between T1, T2 and T3 was carried out using the best fit of anterior cranial base structures as described by Bjork (1969). By superimposing on the anterior cranial base, the FH plane (Orbitale-Porion) at T1 (before distraction) film (FH) was transferred to T2 (after distraction) film and to T3 (after the finishing orthodontic phase). Mandibular rotation and change in dimensions were assessed on the lateral cephalometric radiographs, according to the method described by Bjork (1969) and by Bjork and Skieller (1972). Mandibular cephalometric superimposition was carried out twice as follows: 1) By superimposing on the following landmarks: the tip of the chin (Pogonion), the inner cortical plate and trabecular patterns of the symphysis; and 2) By superimposition on the inferior alveolar canal, and best fit of the inferior border of the mandible and posterior border of the ramus. Superimposition on the inner surface of the symphysis gives information about changes in lower incisor position both vertically and horizontally. Further, this

Mandibular superimposition using the best fit of the inferior alveolar canal, and best fit of the inferior border of the mandible and posterior border of the ramus.
Mandibular superimposition using the best fit of the inferior alveolar canal, and best fit of the inferior border of the mandible and posterior border of the ramus.

Superimposition of the occlusal outlines of the lower teeth guided by the mandibular superimposition on the lateral cephalograms at T1 and T2 when registered on the symphysis.
Symphyseal superimposition defines vertical and horizontal changes of the lower first molar. Superimposition on the inferior alveolar canal, mandibular angle, inferior border of the mandible and posterior border of the ramus determined information about changes in the vertical and horizontal planes at pogonion. Angular changes Frankfurt mandibular plane angle (MPA) and in the Y-axis were used to evaluate the mandibular rotation. The amount of mandibular distraction was assessed by comparing body corpus length (Xi-Pm) according to Ricketts (1961), and total mandibular length (Articulare-Gnathion) at T1, T2, T3 and T4. The antero-posterior expression of mandibular distraction was evaluated by measuring horizontal movement of the pogonion. For this measurement, nasion vertical line at T1 (NV₁) that is perpendicular to the FH plane was used. This line was transferred from T1 to T2, T3 and T4 on the overall superimposition described above, and the distance from pogonion to NV₁ was measured parallel to FH₁. In addition, the antero-posterior expression of mandibular distraction was further evaluated by measuring the facial angle as measured by the angle between the facial plane (Nasion-Pogonion) and FH plane. Apical base relationship (ANB angle) were evaluated to assess the antero-posterior outcome of mandibular distraction. All cephalometric radiographs were traced on acetate tracing papers and measured following identification of landmarks. Bilateral structures were bisected.

Each study model was photocopied and the occlusal outlines of all the teeth were traced. Magnification distortion due to photocopying was corrected for each linear measurement. Landmarks were registered on the tip of the canines and the tips of the mesiobuccal cusps of the lower first molars. Inter-canine and inter-molar distances were measured on the tracings of the study models. Arch length was measured for each study model by tracing from the distal surface of the right first molar to the distal surface of the left first molar. Superimposition of the occlusal outline tracings of the lower dentition was performed by registering on the occlusal outlines of the lower
first molars and the changes in the position of the lower incisors before (T1) and after (T2) distraction were calculated.\textsuperscript{22}

**Results**

Five sets of pretreatment and post-distraction lateral cephalometric radiographs were double traced and measured. Also, five sets of pre- and post-distraction study model were traced and measured. Two trials for each analysis were separated by a period of two weeks. Mean pre- and post-treatment differences for the first and second trials were compared using paired t-test in order to determine the reliability of the superimposition and model measurement techniques used. There were no significant differences between the studied variables using a significance level of 0.05 indicating that the all of the measuring techniques were reproducible.

Skeletal, linear, and angular dental and soft tissue changes after each time point are presented in Tables III- V. Table VI shows the lower dental arch changes after distraction. Lower arch length showed significant increase $7.75 \pm 2.48$ mm $P=0.0001$. Inter-canine width showed slight but statistically significant increase $0.9 \pm 0.73$ mm. Also, inter-molar width showed slight but statistically significant increase after distraction $1.6 \pm 0.84$ mm, $P=0.0002$.

The degree of association between the variables change during treatment was evaluated by the statistical correlation test, using the SPSS 10, computer program (SPSS, Chicago, IL, USA) (Table VII). Correlation was considered little or no correlation if $r = 0$ to 0.25 (or -0.25), weak if $r= 0.25$ to .50 (or -0.25 to -0.50), moderate if $r= 0.50$ to 0.75 (or -0.50 to -0.75), and strong for $r= > 0.75$ (or >-0.75).

**Discussion**

The sample size of this study was to some extent small that could be considered as a pilot study. However, it was based on the patient availability and the number of patients who consented to participate in this study. The patients treated in this study were all skeletally matured so the treatment may not be affected by growth. The clinical photographs and X-rays for these patients were taken before,
immediately after finishing the distraction and at the end of the orthodontic treatment. However, the dental study models were taken before and after consolidation of the newly formed callus and at the end of the orthodontic treatment so not to over manipulate the soft callus by the impression and disturb the newly formed bone regenerate.

Lateral cephalometric radiographs were taken before and immediately after distraction and at the end of the orthodontic treatment, so that changes due to distraction alone and at the end of the orthodontic treatment could be traced and evaluated. Overall superimposition was carried out using the best fit of anterior cranial base structures as described by Bjork (1969). Transferring the FH plane at T1 film (FH1) to T2 and to T3 was done to minimize the possible error in point identification and in variables measurements. Regional superimposition of the mandible was performed using the method described by Bjork (1969); by Bjork and Skieller (1972), and was modified because from previous study (Dessner et al., 1999) it was noticed that in many patients there was bending of the callus and the anterior part of the mandible with the distraction. Hence utilization of all fixed structure in one superimposition was impossible. By superimposing on the tip of the chin (around pogonion), the inner cortical plate and trabecular patterns of the symphysis, changes in the vertical and horizontal incisor position to mandibular symphysis can be evaluated. By superimposition on the inferior alveolar canal, and best fit of the inferior border of the mandible and posterior border of the ramus, vertical and horizontal changes of the symphysis, Pogonion and lower first molar positions can be evaluated.

Vertical and horizontal movement of the lower incisors and lower first molars were not recorded after T2, due to the presence of the stainless steel crowns on the lower first molars that did not allow us to trace the anatomical landmarks of the lower first molars and these stainless steel crowns opened the bite anteriorely, which was difficult to trace the accurate position of the lower incisors.

Model analysis was performed after photocopying the occlusal outlines of the lower dental arch, traced on a tracing paper and
corrected for magnification distortion by the photocopy machine. This technique was recommended to perform superimposition of successive dental casts for the same patient to show the dental arch changes after distraction using the tooth-borne distraction devices. The superimposition was based on the information about lower incisor positional changes obtained from the mandibular regional superimposition as described above. This technique was developed because the occlusal outlines of the lower dental arch were changed, even if it is not clinically significant for Intercanine distance for example. The nonsignificant changes of the cephalometric variables at T3, T4 suggested that the results obtained by tooth-borne distraction devices are stable, both skeletally and dentally. It is to be noted that the slight significant changes of the lower anterior facial height could be attributed to the slight increase in the total facial height N-Me that could be attributed to late upper face changes. This upper face height increase could be attributed to late growth activity at the sphenoccipital syndchondrosis. It is well known that this syndchondrosis is active until 25 years of age, and its activity leads to increase in the upper facial height. Also, the significant stability of the achieved results could be attributed to the fact that some of these patients, especially who had some initial tooth mobility, had some bone anchorage to stabilize the appliance as well as to support the teeth bearing the appliance.

Inferior alveolar nerve sensation was evaluated using the two-point discrimination test which is considered to be simple and valid method. It is evident that no significant change in the patients’ sensation was developed after distraction. It was decided not to perform the sensation test right after the surgery or distraction, because some of the patients were still suffering from postoperative edema, some could not be able to respond to the sensation test in the same way due to the presence of the distraction device intraoral.

The presence of mild to moderate skeletal Class II after distraction and the slight increase in the Facial angle could be explained by the downward and backward rotation of the anterior segment of the
mandible as evidenced by the increase in total face height, in lower anterior face height, in mandibular plane angle and in Y-axis. This is in agreement of previous reports by Dessner et al.\textsuperscript{10-12} On the other hand mandibular body length, mandibular corpus length and total mandibular length were also increased. Occlusal plane inclination to Frankfort plane was increased same as the lower incisor inclination to mandibular plane and its inclination to N-B line. This may be due to bending and posterior rotation of the anterior segment after distraction. On the other hand, when mandibular superimposition was performed by registering on the lingual outlines of the symphysis, lower incisor slightly moved horizontally forward and vertically. This may be because all the anterior teeth were bonded to the lingual bar extended between the crowns on the first premolars on each side of the anterior segment of the mandible. The wide range in the horizontal movement of the first molars may be explained by the fact that in some patients it was decided to protract the molars to achieve Class I molar relationship, and in the other patients the molars did not move forward as much as the anterior teeth were retracted. Also, the wide range in the vertical movement of the first molars may be explained by the fact that in the cases where the patients wore the chin cup as instructed, the upward anterior force resulted in intrusive forces on the molars to minimize downward rotation of the anterior segment of the mandible. On the other hand, in cases where the patients did not wear the vertical chin cup as instructed, the downward and backward rotation of the mandible could in part be contributed to the extrusive force on the molars.

The main skeletal change from T2-T3 was the upward vertical movement of the pogonion. This may be due to the continuous vertical elastic and vertical chin cup wear by the patient during the post-distraction orthodontic phase. It seems that the continuous vertical elastic wear and the relatively soft new bone contributes to this post distraction modification. It can also be explained by the slight decrease in mandibular plane inclination to Frankfort horizontal plane between T2 and T3. On the other hand, mandibular body length was
decreased, which may be due to the change of Gnathion position as the anterior part of the mandible moved upward.

The main dental changes from T2 to T3 are the upward rotation of the occlusal plane in relation to Frankfort plane, which may be due to the upward rotation of the anterior segment of the mandible by the vertical elastic use. Also, lower incisor inclination, to both the mandibular and N-B planes was decreased. This could possibly be due to the retraction of the lower incisors and the anterior teeth into the space generated by the distraction, and also due to the slight upward rotation of the anterior part of the mandible caused by vertical forces from Chin cup and vertical elastics. Also, this can be confirmed by the decrease in the horizontal position of the lower incisor when measured on the mandibular superimposition.

Lower lip position in relation to the E-line was decreased between T2 to T3, which may be due to retraction of lower incisors and to upward and slight forward movements of the Pogonion.

Overall skeletal changes showed significant increase in mandibular apical base anterio-posterior position in relation to cranial base, as confirmed by the significant decrease in the ANB angle. There were significant increase in total face height, lower anterior face height, posterior face height and backward mandibular plane inclination in relation to Frankfort plane. This is confirmed by the increase in Y-axis. These changes might be due to the backward rotation of the anterior part of the mandible, which may be due to the pull of the suprahyyoid muscles on the newly formed bone in the distraction site. Also, this could possibly be due to the fact that the distraction forces at the tooth level were applied above the center of mass of the anterior part of the mandible after osteotomy. This could lead to a clockwise moment that contributes in part to the backward rotation of the anterior part of the mandible. There were significant increase in total mandibular length, mandibular corpus length, but less significant increase in mandibular body length. This again may be due to the positional change of Gnathion after distraction.
Overall occlusal plane inclination to Frankfort plane showed increase in backward rotation. This may be due to the backward rotation of the anterior part of the mandible. Lower incisor inclination in relation to mandibular plane was decreased (decompensated) as was planned for these patients with Class II skeletal malocclusion. However, lower incisor inclination in relation to N-B line didn’t significantly change. This might be due to the forward change of B point after distraction. In the same sense, lower anterior dental height was significantly increased. Also, posterior dental height was significantly increased. These changes might be compensatory mechanisms to the increase in face height and the backward rotation of the mandible. Also, it might be due to the fact that the distraction forces were applied above the center of mass of the teeth, which in turn create moments with resultant extrusive forces on both the incisors and molars.

Overall lower lip position in relation to E-line showed improvement, which may be mainly due to the forward movement of mandibular apical base and chin.

The strong correlation between the increase in face height and the increase in mandibular body length ($r=0.91$); mandibular corpus length ($r=0.89$) and total mandibular length increase ($r=0.87$) indicates that there were skeletal changes in the mandible. These changes contribute in part to the increase of the face height. Also, the strong correlation between the changes in mandibular and in mandibular corpus length ($r=0.91$) confirms the skeletal changes in the body of the mandible. The moderate negative correlation ($r=-0.603$) between the changes in facial angle and Y-axis confirms the backward rotation of the mandible. The strong correlation ($r=0.77$) between the changes in Y-axis and mandibular plane angle confirms the backward rotation of the mandible. The moderate correlation between the changes in SNB and facial angle ($r=0.74$) may indicate that the changes in facial angle were affected by other factors rather than ANB, and may indicate the effects of backward rotation of the mandible. The strong correlation between total face height and LADH ($r=0.83$),
LPDH (r=0.85) indicates that the changes in total anterior face height might influence the vertical changes in the anterior and posterior teeth, or vice versa. The moderate correlation between lower lip position in relation to E-line and the inclination of the lower incisor to mandibular plane may indicate that the position of the lower incisor to mandibular plane contributes in part to the anteroposterior position of the lower lip. However, this also may indicate that other factors like the anteroposterior changes in pogonion might affect lower lip position.

Conclusions
The present study leads to the following conclusions:

1. Distraction osteogenesis of the mandible using the tooth-borne devices provides anteroposterior improvements in the facial profile. Also, there was increased in facial height and backward rotation of the mandible. These results together lead to a reduction of facial convexity and maxillary-mandibular apical base discrepancy. These treatment effects were shown to be stable following treatment.

2. The amount of bone gain by distraction was somewhat camouflaged by the rotation of the mandible. Also, the facial profile improvement after distraction was due to skeletal and dentoalveolar changes as indicated by the forward movement of the lower incisors.

3. Orthodontic treatment after distraction influenced mandibular position, dentoalveolar and lower lip changes. The amount of mandibular rotation was correlated with the amount distraction.

4. Horizontal displacement of pogonion was negatively correlated to mandibular rotation.

5. There was a moderate relationship between the changes in the total mandibular length and the amount of distraction as evaluated at the device.

6. Vertical chin cup during distraction and during consolidation period seems to be important for better skeletal and dental outcome.
7. The use of tooth-borne distraction devices for mandibular osteodistraction may be particularly beneficial in cases with short facial height.
8. The incorporation of bone plates to tooth-borne distractors minimizes the amount of dental movement and mandibular rotation.
9. The results achieved by the use of tooth borne distraction device are stable over the follow up period. Longer term evaluation can be carried out after extended period of time.

Other Authors: Yan Razdolsky, Stuart Dessner

Acknowledgement

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References

<table>
<thead>
<tr>
<th>Male</th>
<th>Female</th>
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<td>N</td>
<td>Average</td>
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<td>25.42</td>
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</table>

*Age in years

### TABLE II

A comparison of cephalometric measurements by t-test between the Before distraction (T1) and after distraction (T2)

<table>
<thead>
<tr>
<th>Variable</th>
<th>T1 Mean</th>
<th>SD</th>
<th>T2 Mean</th>
<th>SD</th>
<th>Change (T2-T1) Mean</th>
<th>SD</th>
<th>P</th>
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<td>1.0</td>
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<td>3.97</td>
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<td>24.8</td>
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<td>26.1</td>
<td>4.1</td>
<td>2.57</td>
<td>2.17</td>
<td>0.006</td>
</tr>
<tr>
<td>L1/L2 (degrees)</td>
<td>113.1</td>
<td>7.3</td>
<td>119.4</td>
<td>7.54</td>
<td>6.3</td>
<td>2.22</td>
<td>0.006</td>
</tr>
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<td>TAF (mm)</td>
<td>67.73</td>
<td>5.06</td>
<td>69.1</td>
<td>5.1</td>
<td>1.4</td>
<td>2.47</td>
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<td>0.008</td>
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<tr>
<td>LPBH (mm)</td>
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### TABLE III
A comparison of cephalometric measurements by t-test between the after distraction (T2) and after orthodontic treatment (T3)

<table>
<thead>
<tr>
<th>Variable</th>
<th>T2 Mean</th>
<th>T2 SD</th>
<th>T3 Mean</th>
<th>T3 SD</th>
<th>Change (T3-T2) Mean</th>
<th>Change (T3-T2) SD</th>
<th>P</th>
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</thead>
<tbody>
<tr>
<td>SNA (degrees)</td>
<td>80.6</td>
<td>4.7</td>
<td>80.5</td>
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<td>0.4</td>
<td>1.07</td>
<td>0.26</td>
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<tr>
<td>SNR (degrees)</td>
<td>78.8</td>
<td>4.7</td>
<td>77.1</td>
<td>4.7</td>
<td>0.3</td>
<td>0.82</td>
<td>0.77</td>
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<tr>
<td>ANB (degrees)</td>
<td>3.3</td>
<td>1.3</td>
<td>3.7</td>
<td>1.33</td>
<td>0.4</td>
<td>1.19</td>
<td>0.78</td>
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<td>MPA (degrees)</td>
<td>25.2</td>
<td>5</td>
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<td>5.35</td>
<td>-0.6</td>
<td>3.2</td>
<td>0.56</td>
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<tr>
<td>Y-axis (degrees)</td>
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<td>60.2</td>
<td>4.86</td>
<td>0.4</td>
<td>1.89</td>
<td>0.52</td>
</tr>
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<td>GPO (degrees)</td>
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<td>7.3</td>
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<td>-3.5</td>
<td>3.43</td>
<td>0.01</td>
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<td>8.9</td>
<td>94.4</td>
<td>10.75</td>
<td>-12.4</td>
<td>8.18</td>
<td>0.0008</td>
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<td>7.59</td>
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<td>9</td>
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<td>5.08</td>
<td>0.0006</td>
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<td>TAFH (mm)</td>
<td>115.4</td>
<td>7.54</td>
<td>120.6</td>
<td>8.2</td>
<td>5.2</td>
<td>7.10</td>
<td>0.59</td>
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<tr>
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<td>6.3</td>
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<td>PFH (mm)</td>
<td>78.44</td>
<td>6.76</td>
<td>79.07</td>
<td>7.1</td>
<td>0.63</td>
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<td>0.44</td>
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<td>5.57</td>
<td>59.22</td>
<td>4.85</td>
<td>-1.64</td>
<td>3.28</td>
<td>0.44</td>
</tr>
<tr>
<td>MPF (%)</td>
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<td>5.57</td>
<td>69.22</td>
<td>4.85</td>
<td>-3.64</td>
<td>3.33</td>
<td>0.67</td>
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<tr>
<td>Go-Gn (mm)</td>
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<td>0.43</td>
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### TABLE IV
A comparison of cephalometric analysis by t-test between the before distraction (T1) and after orthodontic treatment (T3)

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<tr>
<th>Variable</th>
<th>T1 Mean</th>
<th>T1 SD</th>
<th>T3 Mean</th>
<th>T3 SD</th>
<th>Change (T3-T1) Mean</th>
<th>Change (T3-T1) SD</th>
<th>P</th>
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<tbody>
<tr>
<td>SNA (degrees)</td>
<td>80.6</td>
<td>4.7</td>
<td>80.5</td>
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<td>1.37</td>
<td>0.82</td>
</tr>
<tr>
<td>SNR (degrees)</td>
<td>78.8</td>
<td>4.7</td>
<td>77.1</td>
<td>4.7</td>
<td>0.3</td>
<td>0.82</td>
<td>0.77</td>
</tr>
<tr>
<td>ANB (degrees)</td>
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<td>3.7</td>
<td>1.33</td>
<td>0.4</td>
<td>1.19</td>
<td>0.78</td>
</tr>
<tr>
<td>MPA (degrees)</td>
<td>25.2</td>
<td>5</td>
<td>24.6</td>
<td>5.35</td>
<td>-0.6</td>
<td>3.2</td>
<td>0.56</td>
</tr>
<tr>
<td>Y-axis (degrees)</td>
<td>50.8</td>
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<td>60.2</td>
<td>4.86</td>
<td>0.4</td>
<td>1.89</td>
<td>0.52</td>
</tr>
<tr>
<td>GPO (degrees)</td>
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<td>7.3</td>
<td>3.4</td>
<td>-3.5</td>
<td>3.43</td>
<td>0.01</td>
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<td>94.4</td>
<td>10.75</td>
<td>-12.4</td>
<td>8.18</td>
<td>0.0008</td>
</tr>
<tr>
<td>L1/N-E (degrees)</td>
<td>38.4</td>
<td>7.59</td>
<td>25.3</td>
<td>9</td>
<td>-13.1</td>
<td>5.08</td>
<td>0.0006</td>
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<tr>
<td>TAFH (mm)</td>
<td>115.4</td>
<td>7.54</td>
<td>120.6</td>
<td>8.2</td>
<td>5.2</td>
<td>7.10</td>
<td>0.59</td>
</tr>
<tr>
<td>LAFH (mm)</td>
<td>69.1</td>
<td>6.3</td>
<td>69.57</td>
<td>5.6</td>
<td>0.5</td>
<td>0.98</td>
<td>0.79</td>
</tr>
<tr>
<td>PFH (mm)</td>
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<td>6.76</td>
<td>79.07</td>
<td>7.1</td>
<td>0.63</td>
<td>2.17</td>
<td>0.44</td>
</tr>
<tr>
<td>LAFH (%)</td>
<td>57.57</td>
<td>5.57</td>
<td>59.22</td>
<td>4.85</td>
<td>-1.64</td>
<td>3.28</td>
<td>0.44</td>
</tr>
<tr>
<td>MPF (%)</td>
<td>65.56</td>
<td>5.57</td>
<td>69.22</td>
<td>4.85</td>
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<td>0.67</td>
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<td>73.60</td>
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<td>-1.74</td>
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<td>A1-Gn (mm)</td>
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<td>7.06</td>
<td>110.78</td>
<td>7.5</td>
<td>-0.9</td>
<td>3.12</td>
<td>0.43</td>
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<tr>
<td>LADH (mm)</td>
<td>42.1</td>
<td>3.52</td>
<td>43.01</td>
<td>3.52</td>
<td>0.91</td>
<td>3.4</td>
<td>0.42</td>
</tr>
<tr>
<td>LAFH (mm)</td>
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<td>2.64</td>
<td>37.47</td>
<td>2.96</td>
<td>-15.6</td>
<td>1.92</td>
<td>0.32</td>
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<tr>
<td>LL-E (mm)</td>
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<td>-1.73</td>
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<td>-2.13</td>
<td>2.72</td>
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### TABLE V

A comparison of cephalometric analysis by t-test between after orthodontic treatment (T3) and 8 years in retention (T4).

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<th>T3 Mean</th>
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<th>T4 Mean</th>
<th>SD</th>
<th>Change (T3-T4) Mean</th>
<th>SD</th>
<th>P</th>
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<tr>
<td>SNA (degrees)</td>
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<td>8.1</td>
<td>73.4</td>
<td>4.7</td>
<td>6.97</td>
<td>1.2</td>
<td>0.3</td>
</tr>
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<td>SNB (degrees)</td>
<td>77.1</td>
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<td>73.2</td>
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<td>0.51</td>
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<td>5.35</td>
<td>27.2</td>
<td>7.3</td>
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<td>0.07</td>
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<td>Y axis (degrees)</td>
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<td>69.6</td>
<td>4.02</td>
<td>1.41</td>
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<td>0.34</td>
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<td>GPx (degrees)</td>
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<td>3.4</td>
<td>8.03</td>
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<td>0.71</td>
<td>4.6</td>
<td>0.7</td>
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<td>L1/Mp (degrees)</td>
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<td>9</td>
<td>23.3</td>
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<td>1.6</td>
<td>0.26</td>
</tr>
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<td>TAH (mm)</td>
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<td>0.24</td>
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<td>TAH+H (mm)</td>
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<td>Ph-H (mm)</td>
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<td>39.9</td>
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<td>0.8</td>
</tr>
<tr>
<td>LAFH (mm)</td>
<td>57.5</td>
<td>2.06</td>
<td>54.3</td>
<td>2.3</td>
<td>3.2</td>
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<td>0.07</td>
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<td>PPH (%)</td>
<td>69.22</td>
<td>4.86</td>
<td>65.1</td>
<td>6.2</td>
<td>4.1</td>
<td>7.4</td>
<td>0.19</td>
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<tr>
<td>Gn-Gn (mm)</td>
<td>73.58</td>
<td>2.8</td>
<td>71.2</td>
<td>4.2</td>
<td>2.3</td>
<td>1.2</td>
<td>0.37</td>
</tr>
<tr>
<td>A-Gn (mm)</td>
<td>110.76</td>
<td>7.5</td>
<td>108.6</td>
<td>6.4</td>
<td>2.1</td>
<td>1.3</td>
<td>0.33</td>
</tr>
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<td>LADH (mm)</td>
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<td>2.7</td>
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### TABLE VI

Study model analysis (mm).

<table>
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<th>Variable</th>
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<th>t-test</th>
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<td>Inmumolar width</td>
<td>4.3</td>
<td>4.9</td>
<td>4.7</td>
<td>5.2</td>
</tr>
</tbody>
</table>

### TABLE VII

**CORRELATION COEFFICIENT (R) FOR THE RELATIONSHIP BETWEEN CHANGE VARIABLES DURING TREATMENT**

<table>
<thead>
<tr>
<th>Variables</th>
<th>r</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>TAFH and (Go-Gn)</td>
<td>0.91</td>
<td>0.0001</td>
</tr>
<tr>
<td>TAFH and (Xl-Pm)</td>
<td>0.89</td>
<td>0.0001</td>
</tr>
<tr>
<td>TAFH and (A-Gn)</td>
<td>0.87</td>
<td>0.0001</td>
</tr>
<tr>
<td>TAFH and FH-MPA</td>
<td>0.98</td>
<td>0.03</td>
</tr>
<tr>
<td>LAFH and (Go-Gn)</td>
<td>0.75</td>
<td>0.011</td>
</tr>
<tr>
<td>Ar-Ln and Go-Ln</td>
<td>0.89</td>
<td>0.001</td>
</tr>
<tr>
<td>Ar-Gn and Xl-Pm</td>
<td>0.86</td>
<td>0.001</td>
</tr>
<tr>
<td>Y-Axis and FH-MPA</td>
<td>0.77</td>
<td>0.01</td>
</tr>
<tr>
<td>SNB and FA</td>
<td>0.74</td>
<td>0.014</td>
</tr>
<tr>
<td>Ar-Ln and amount of distraction (at Device level)</td>
<td>0.72</td>
<td>0.019</td>
</tr>
<tr>
<td>TAH and LADH</td>
<td>0.83</td>
<td>0.003</td>
</tr>
<tr>
<td>TAFH and LADH</td>
<td>0.85</td>
<td>0.002</td>
</tr>
<tr>
<td>L1/Mp and L1/N-E</td>
<td>0.64</td>
<td>0.016</td>
</tr>
<tr>
<td>LL-E line and L1/Mp</td>
<td>0.64</td>
<td>0.047</td>
</tr>
</tbody>
</table>

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Possible Problems of Moulding the Regenerate in Mandibular Distraction Osteogenesis — Experimental Aspects in a Canine Model

Christoph Kunz

Hospital for Reconstructive Surgery, Department of Craniomaxillofacial Surgery, University Hospitals, Basel, Switzerland.

Introduction: Moulding of the regenerate created by distraction osteogenesis has been shown clinically to be efficient and good enough so that for complex three-dimensional deformities, final adjustments by moulding the regenerate may be part of the treatment plan. This study assessed possible drawbacks of moulding a regenerate, taking into consideration compressive and tensile forces acting simultaneously on the fresh callus.

Method: Distraction osteogenesis in 15 Beagle mandibles was performed using custom made devices which allowed for lengthening as well as for angulation. After linear distraction of 10 mm, a defined 20 degrees angulation was performed in one step. The position of the fulcrum of the device allowed simultaneously compression and stretching of the regenerated bone. Effects on bone healing were assessed after 6 and 13 weeks of consolidation respectively and compared with a control group where only linear distraction was performed.

Results: Radiological and histological investigations demonstrated that no significant differences between the biological behaviour of the compressed and the stretched zones of the regenerate
could be found. However, there were signs showing the more critical character of the stretched area. After 6 weeks of consolidation some specimens revealed delayed ossification of the stretched zone. Under stable conditions, this delay was compensated for after 13 weeks of consolidation and complete osseous healing occurred.

**Conclusion:** Under stable conditions, a fresh regenerate can be moulded to a considerable extent without permanently endangering osseous healing. Nevertheless tensile forces acting on the regenerate should be minimized to prevent damage to the new bone. This can be achieved by overdistraction prior to callus moulding or by gradually changing the vector of distraction during the lengthening process
Osteo-distraction in moderately retruded mandibles in 13-15 year old children pre-orthodontics

Paul Lloyd G. Coceancig
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Case presentations are made of children age 13-14 years, demonstrating severe to moderate horizontally retrusive mandibles. All cases have habitual forward posturing habits with associated TMJ problems, and inability generally to properly intercuspate and masticate.

All were treated prior to initiation of formal orthodontic treatment, with distraction of bilateral vertical osteotomies between lower first and second molars. Each site was distracted between 8-12mm. Early removal of distractors allowed for elastic IMF and “callous manipulation” of the occlusion. All patients acquired functioning and inter-digitating Class I occlusions allowing for placement of orthodontic bands.

Comparisons are shown of pre- and post-operative radiographs and clinical facial photographs. Discussion is made of surgical benefits and risks in comparison with classical post-orthodontic orthognathic procedures to correct for moderate to severe Class II skeletal malocclusions.
Osteo-distraction in moderately retruded mandibles in 13-14 year old children ...

Pre-Orthodontics

13 yo healthy ♂

Complains of inability to eat

• Moderately retrusive mandible
• ~ 12mm overjet
• Completely palatal cross bite entire lower dentition
• Orthodontist cannot retain lower bands
• Compensatory vertical maxillary excess
• Child completely unable to masticate
14 yo  

Complains of TMJ problems

- Moderately retrusive mandible
- ~ 9mm overjet
- Lower 7’s un-erupted & mesially impacted
- Some mastication possible, but cannot easily bite into foods
- Mother concerned as to lack of chin
- Lip incompetent and drools whilst asleep
14 yo ♂

Orthodontist cannot get braces on

- Right partial hemiplegic post forceps delivery, with behavioural difficulty
- Moderate retrusive mandible with habitual forward mandibular posture
- Complaint of constant bilateral TMJ pain
- Lip incompetent, phonation difficulty and nocturnal snoring
- Near complete palatal cross-bite posterior teeth
Advantages of Distraction

To correct moderately retrusive mandibles in adolescents

- Allows for treatment when adult dentition has erupted.
- Potentially corrects skeletal base to Class II before abnormal dento alveolar compensation occurs.
- Allows for a normal & quicker course of orthodontics to commence on a class I skeletal base.
- Quicker operation.
- Do not have to wait for growth to end as for conventional orthognathic surgery.
- Instant facial-fix prior to full-development of adolescent adult psyche.
- Potentially creates inter-dental space for intra-arch alignment of teeth.

Disadvantages of Distraction

In moderately retruded mandibles in adolescents

- Hardware very expensive.
- Requires home distraction by parents.
- Multiple visits & 2nd operation required.
- Infection around distractors a problem.
- Lip ulceration over distractors arms.
- Not as precise over conventional orthognathic surgery.
- Open bite development a potential pit-fall.
- Little professional experience with use of distractors.
- Period of IMF required after distractors removed.
- Potential for operative severance of IDN.
Complications achieved in these three patients

- Small nick on mesio-buccal cusp of mesially impacted 47 (evident post-eruption)
  - Fixed with composite restoration by dentist
- Small amount of granulation tissue surrounding distractors 6/52 post cessation of 10/7 distraction period
  - Normal healing after distractor removal
  - Avoided by removing distractor earlier than 2x distraction period
- Small anterior open bite developed in all three patients
  - Cured with either orthodontic or famey IMF
  - Advise removal of distractors at 2-3 weeks after distraction period, with 1-2/52 of strong elastic IMF so as to allow for callous manipulation
- Re-operation to re-mobilise one osteotomy site after found to be “sticking”
  - Avoided by opening up distractors (at placement) about 7mm to check for fluid operation
- Screws pulled out of proximal fragment without effect of distraction process
  - As distraction proceeds distractors become more parallel potentially pulling screws out of proximal fragment
  - Avoided with use of 7-9 mm depth screws placed in flaring pattern
- Ulceration of overlying lip resting against distractor arms
  - Avoided with careful of arms against lower anterior alveoius
  - Avoided with use of 9 mm silicone (fish-tank) tubing placed over distractor arm as sleeve

Surprise of operation

- Pain-free post-operative course
- Distractor activation pain completely avoided with 1 panadol 1/2 hr before turn
- No dysaesthesia post operation or post distraction at all
- Minimal post-operative swelling
- Very high compliance and motivation by patients and parents
- No intra-oral scarring evident
  - even where ulceration occurred behind lower lip
- Dramatic personality changes in boys after treatments. Generally more confident and out-going. All three were reported by mothers as significantly less shy
- Operation generally masculinised and matured the face
**Osteotomy technique**
- Sulcus incision with relief distal lower canine
- Corticotomy cut with fissure bur between 1st and 2nd molars on inferior border
- Fine osteotome between teeth above IDN
- Smith’s distractor to open cut, with fine chisel on medial cortex, until fractured
- Fully mobilise fragments

**Distractor application**
- Vector should be as aligned as parallel as possible with arch
- Splay screws to avoid pull-out
- Personally easier to place distractor after fragment mobilisation
- Pre-curve arm to lie above mental nerve, and around into sulcus
- Once attached open up distractor to desired distance, then close again leaving 1mm separation
- May burr slot in external oblique ridge to accommodate barrel
- Only use a 15mm (short) paediatric distractor. Shorter barrels are easier to manipulate
- Right for right side and left for left side
Variations of technique

- Can apply distractor unilaterally to correct for horizontal ramus under-growth
- Can apply distractors upside down
  - Easier application of distractor
  - Easier removal possible
  - Vectors distraction slightly upwards
  - Lessens chance of open bite
  - Possible impingement of distractor arm on mental foramen
  - Left distractor for right side, and vice-versa

Left unilateral distraction, 14 yo F
Upside down distraction
• Clindamycin 300 mg bd and piroxicam 20mg od, with chlorhexidine soaks tds
• Start distraction 2-3/7 post surgery, 1/2mm twice daily, and titrate to final effect
• Remove distractors no later than 3-4 weeks as you still want a soft callous for bite closure
• Over-distract as can easily re-wind distractor about 4mm to achieve symmetry. Callous can contract a further 2 mm over 2/52
• Open-bite is unavoidable, and totally correctable with 1-2 weeks elastic IMF
• Arms of distractors can bury into lower lip. Avoided with use of silicone tubing sleeves available from Hardware store

Acknowledgement: Dr. Peter Vaughan, BDS, MDS
Specialist Orthodontist of New Castle, NSW, Australia
New technique for the management of condylar fracture using DO

Mine Ozaki
Associate, Kyorin University, Tokyo, Japan

Abstract: To date, there is still a controversy as for the treatment of condylar fracture especially when the disorder involves bilateral condylar heads. Open reduction and internal fixation (ORIF) possibly give precise reposition and rigid fixation, however the risk of several complications such as facial paralysis and uncontrollable bleeding is not negligible. Conservative treatment with intermaxillary fixation (IMF) offers sufficient recovery of occlusion, but length of ramus tends to be shortened and prolonged fixation may result in trismus. With these clinical drawbacks, Terashima and Watanabe et al. recently developed an alternative option. In their method, traction of bilateral ramus with internal distraction devices applied between the zygomatic arch and the angle of mandible provided spontaneous reposition of condylar head and retention of length of ramus without disturbing rotational movement of
mandibular joint during fixation period. In this paper, our experience of this method is described. Between January and December 2006, 6 patients (4 men and 2 women) ranging in age from 15 to 71 years (mean 39 years) underwent traction of ramus with internal distraction device for the treatment of bilateral condylar fractures. All were suffered from concurrent fracture of body of mandible without maxillary fracture. After optimal reduction and rigid fixation of body of mandible adjusted to maxilla, internal distraction device were attached to the surface of zygomatic arch and angle of mandible from preauricular and submandibular small incisions, respectively. After tractions for 3 to 4 months, the device was completely removed. In 5 cases, optimal tractions were attained throughout the fixative period. Trismus which were involved in two patients was less significant than that usually accompanied by traditional conservative therapy and was almost disappeared with a short time after removal of internal distraction device. In one case, a small pressure sore in the marginal area of submandibular incision caused by protrusion of the tip of the shaft necessitated removal of the device 6 weeks after the application. At the time of removal, the condylar head was re-fractured, which resulted in shortening of the ramus. Although paralysis of temporal branch was recognized in one case, it was recovered perfectly in one month. Optimal elongation of shortened ramus and preservation of temporomandibular joint (TMJ) function are most important in the treatment of bilateral condylar fractures. Presented new method is designated to achieve these intentions with easy and safe procedures.

However, we experienced difficulties in deciding the appropriate length of distraction. New type of traction device for this method should be developed to attain optimal traction consistently throughout the fixative period.

**Others Authors**: Suguru Sato, M.D., Masakazu Kurita, M.D., Akihiko Takushima, M.D., Kiyonori Harii, M.D.
The main reasons for facial asymmetry can be congenital as in Hemifacial microsomia or post traumatic as after condylar fracture during birth and early childhood. Distraction Osteogenesis is an accepted method for hypoplastic mandible and maxilla.

All the patients were presented with unilateral hypoplasia of the face that was manifested clinically by deviation of the chin and canting of the occlusal plane. To all the patients posteroanterior cephalometric radiographs were preformed before and after the treatment.

The patients had several treatment stages:
1. Orthodontic leveling of the maxillary and mandibular arches
2. Unilateral distraction osteogenesis of the mandible to elongate the mandible downward and forward and correct the gonial angle

The distraction was preformed by intraoral approach using extraoral or intraoral devices. After a latency period of four days, the mandible was distracted 1mm per day until symmetry was achieved.
During the distraction the unilateral created open bite on the affected side was maintained by an acrylic wafer.

3. In patients up to 14 years old a Le-Fort I osteotomy and adaptation of the maxilla to the mandible was preformed. The bone gap created was filled by bone graft. In patients during the mixed dentition, the maxillary canting was adapted by orthodontic treatment.

Results:

Marked elongation of the mandible and mandibular ramus was achieved. In addition, correction of the mandibular symphisis to the midline and occlusal canting was achieved. The postdistraction posteroanterior cephalometric radiographs demonstrated elongation of the affected ramus and improvement in facial symmetry.
A laboratory study on human jaw osteoblastic stem cell culturing

Javad Faryabi
Oral and Maxillofacial Surgery Department, Kerman University of Medical Science, Kerman, Iran

Patient and methods:
This study performed on 5 specimens obtained from our patients admitted to Oral and Maxillofacial Surgery department of Kerman university of Medical Sciences in southeast of Iran, Our sample size was similar to other studies for culturing of osteoblasts.

Four patients undergo Oral surgery under local anesthesia and one under general anesthesia, the selected patients had no bony and systemic diseases, and all of specimen obtained from upper jaw due to easier access to spongy bone.

Specimen preparation methods:
A block of patient’s jaw bone approximately 5×5×5 mm obtained under strict sterile clinical condition by rinsing the mouth two times by bethadine and after that by sterile salin solution, The bone block prepared by a thin feraze or thin osteotom, or rangure. Also we decided to prepare a periosteal specimen for comparing the culturing ability of osteoblast with two origins (periosteal versus endosteal).

After taking the specimens, we transported them to the laboratory cell culture in sterile tubes in hank’s solution and continue the process of culturing as follow:
1. The preparation steps of culturing endosteal specimens

In laboratory cell culture the bony specimen divided into 1mm pieces of bone by scalpel blade and after irrigating them by PBS (Sigma- America) transferred to a plate contains 5-10 ml EDTA-Trypsinase enzyme (Sigma- America). The plates put in Co₂ incubator for 30 minutes at 37°C and shake every 5 minutes. After digestion process, 0.5 ml of NCS (neonatal calf serum, Gibco, Australia) added to plates to neutralize the enzyme, then the cells transported to sterile tubes for centrifuging at 1500 rpm for 5 minutes, then the centrifuged cells transported to culturing flasks containing DMEM F12 ( Sigma-America), 10% FBS(Seromed, Australia), 100 unit/ml penicillin( Sigma-America), 50 µg/ml streptomycin( Sigma-America), and 50 µg/ml ascorbic acid (Sigma-America).

2. The preparation steps of culturing periosteal specimens

The separated periosteal specimens of patient’s jaw, also transferred to tissue culture laboratory and divided into small pieces and washed by PBS, then transferred to a plate and added enriched culture media similar to endosteal specimens also, 3ml of collagenase enzyme ( Sigma-America) to another plate for evaluating the effect of collagenase, and put them in Co₂ incubator at 37°C for 2 hours, and shake the plate containing collagenase for complete digestion of periosteal pieces, then transferred both of them (plates with and without collagenase) to a sterile tube and centrifuged with 1500 rpm for 5 minutes, the cell deposit transferred to a 25 cm² flask containing environmental culture. These flasks kept in Co₂ incubator at 37°C.

The cell growth of both endosteal and periosteal containing plates evaluated by converted microscope every day. While 85-90% of the cells covered the flask bottom, the cells separated from them by Trypsin, and these suspended cells used for next culture.

The study for documentation of presence of osteoblasts in cultured specimen:

For evaluation the presence of osteoblasts in culture media, we used alkaline phosphatase test (Sigma-America). first of all some
cells from different passage of cells cultured on a lamella, then the lamella containing these cells placed in Acetone-Formaldehye solution for 2 minutes and then placed in diazinium solution for 15 minutes that led to red-purple color formation at the location of ALP pigments. When this lamella stained with Hematoxylin and Eosin (H&E), the osteoblastic cells became red-purple and other cells became gray. Finally the lamella evaluated microscopically by two medical pathologists without informing each other about the results with 4 month duration apart in time. they reported the percentage of presence of osteoblasts on lamellas as follow

**Results**

The mean value of appropriate time for growing cells were 23 days, so the human bone cells have the capability of culturing under special and sterile laboratory condition and we can use from three dimensionlal culturing of them for reconstruction of maxillofacial region defects in the future.
Comparison of Membranous Bone Healing Characteristics in Fetal and Postnatal Periods: An Intrauterine Experimental Study

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Fetal tissue healing is a big mystery for plastic surgeons many aspects. Although much information is available on the biology of fetal soft tissue wounds, there are few reports concerning the membranous bones of the craniomaxillofacial region in the fetus. We investigated membranous bone healing in fetuses and adults and documented the differences by way macroscopic analysis, radiological analysis (micro-computed tomography [CT]), histological examination, histomorphometry, and growth factor levels throughout the healing process in both incisional and excisional bone defects.

Sixteen sheep fetuses and 16 sheep were included in this study. In the fetal group, 5 mm diameter ostectomy, and a 10 mm osteotomy were created in 90th gestational day. In the postnatal group, similar ostectomy and osteotomies were created. In the early period, radiologically similar radiolucencies in the ostectomy areas were seen in both groups. Histologically, fetal bone healing was decreased in the early postoperative period. However, it was accelerated in further time points. Histomorphometric analyses revealed accelerated fetal bone healing. TGF-â1 levels were higher and then lower in early and late postoperative periods respectively in the fetal group. In the
postnatal group, the levels of TGF-â1 were lower and the differences between two groups were statistically significant in all time points (p < 0.05). The FGF and PDGF levels in both areas were higher in early postoperative period whereas lower in the late period in both groups. However, the fetal FGF levels were higher compared to the postnatal group (p < 0.05). The fetal PDGF levels were lower compared to the postnatal ones (p < 0.05).

In conclusion, the fetal and postnatal membranous bone healing different from that of postnatal healing, albeit at an accelerated rate and growth factor profile.

Others Authors: Mustafa Deveci, Serdar, Emin Orhon, Kerrem Safali, Mustafa Sengezer

Acknowledgement: This study performed in Gulhane Military Medical Academy, Research Center Ankara, Turkey
A New Device and Experimental Model for Distraction of Rat Mandible

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**Purpose of Study:** Despite the widespread use of DO in current clinical practice, some questions concerning the osteogenesis process itself and resultant bone still remain to be clarified. Although, the histological and ultrastructural changes associated with DO were investigated to some extent using bigger animal models, molecular mechanisms governing these changes have not been elucidated well until the description of a rat model for mandibular distraction. A rat mandible model for distraction has certain critical advantages in comparison to the models in bigger animals (sheep, rabbit, dog, pig), including availability of molecular reagents, lower cost and ability to perform much more procedures to acquire the data that can be analyzed statistically. On the other hand, studies, in which various rat models described in the literature were used, have proved to have some drawbacks that were thought to stem from the designs of the devices for such a small and delicate mandible.

This study was undertaken to develop a new and a better distraction device, specially designed to rule out the well-known disadvantages and shortcomings of the ones previously described in the literature. In this study, the device we improved were described...
while efficacy of the device was demonstrated with an experimental study.

**Materials and methods:** The custom made distraction device consists of a 12 mm jackscrew and a metal rod with each end embedded in specially designed PVC block, a pair of specially designed pins, an U-shaped plate which was designed to reinforce the posterior pin fixation (Figure-1). Anterior pin was supposed to be secured into the body whereas the posterior one into the angle of the mandible. It is well known that the angular region of the rat mandible is quite thin and delicate, rendering this region prone to pin loosening that may lead to failure of the whole procedure (approximately 0.3 mm). In order to overcome this shortcoming, an U-shaped plate was designed to reinforce the posterior pin fixation. The U-shaped plate was formed in a fashion that the thin bone of the angle barely fit into groove between the open limbs of U when it is placed up from the inferior rim (Figure-2). This special construction of the plate allows its stabilization on the lower rim like a clip, obviating the need for an additional means of securing during the drilling and screwing procedures. Each limb of U has one hole corresponding each other on the same axis. The hole on the medial limb of the U-shaped plate was smaller in diameter than the one on the lateral limb. This feature allowed compression of the bone between two leaves of the U-shaped
plate when the pin was screwed and tightened through these holes as it happens in lag screw principle. Use of this U-shaped plate for posterior pin fixation into the thin bone of angle increased the stability of the device. One-quarter turn of the device provides 0.25 mm separation between the bone edges. Following induction of anesthesia, the devices were applied on a localization that allowed us to perform the osteomies posterior to molar teeth. 30 animals were assigned to either an acute 3mm distraction group (n=7) or a gradual distraction group (0.25 mm twice a day for 6 days after a three-day latency period; n=23). A consolidation period of 4 weeks followed both acute and gradual distractions. At the end of consolidation, distracted mandibles were evaluated by radiological and histological examinations.

Results: Application of the distractor onto susceptible posterior part of rat mandible was easy and practical without demanding complex manipulations that may cause accidental fractures. Owing to U-shaped plate used for posterior pin fixation, all devices maintained their stabilities until the end of the study despite the delicate anatomy of the bone at this region. Radiological and histological investigations of the mandibles following consolidation periods revealed complete ossification of the distraction gaps in gradual distraction group while fibrous unions were observed in acute distraction group.

Conclusion: By this study, it was demonstrated that the device we devised for distraction of rat mandible is appropriate for an easy and safer application and works properly, being able to create ossified regenerate bones that filled the entire distraction gap. Our device can be used for various molecular investigations during DO in the future.

Other Authors: Mustafa Nisanci, Yakup Cil, Mustafa Sengezer, Ayhan Ozcan
Effect of PTH on Osseous healing of distract bones

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Purpose: Low-dose intermittent administration of parathyroid hormone (PTH) through daily subcutaneous injection can increase systemic bone density and has recently emerged as a popular osteoporosis treatment. The purpose of this study was to determine the effects of low-dose intermittent PTH on acceleration the consolidation of new formed bone after distraction osteogenesis in rabbits.

Material and method: Forty rabbits underwent right tibia lengthening by callus distraction. Lengthening was started 5 days postoperatively 1 mm/day for a 10-day period and consolidation of 20 days followed. PTH or vehicle was given every second day beginning 30 days before the rabbits were killed (with either vehicle, 5 g/kg PTH or 30 g/kg PTH). Bone samples were harvested for dual energy X-ray absorptiometry analysis, radiographic and histologic examination postoperatively.

Results: The results indicated that PTH treatment dose-dependently increased bone density in tibia. The 30 g/kg PTH group demonstrated higher bone density, bone mineral content in the distraction sites than those in the vehicle group. Histologically, new
bone tissue in PTH groups is highly mature and thicker than that in vehicle group.

Conclusions: In conclusion, in addition to its well-known anabolic effects in treating osteoporosis, low-dose intermittent PTH has the potential to increase bone density and enhance osseous healing of distract bones in a dose-dependent manner.
Effect of Nicotine on bone regeneration in mandibular distraction osteogenesis

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1. INTRODUCTION

Distraction osteogenesis is a method of generating new bone directly from the osteotomy site by a controlled mechanical traction device. It is the latest endogenous tissue engineering technique in reconstructive surgery, which is capable of producing a large quantity of living bone by a single stage operative procedure without additional bone grafts. When compared with the conventional orthognathic surgery, distraction osteogenesis is less invasive and is more stable. (1) Since the first clinical report on the use of distraction osteogenesis to lengthen the human mandible in 1992 (2), it has gained popularity in the treatment of severe craniofacial deformities. Moreover, distraction osteogenesis provides an excellent platform to study the bone healing and regeneration. It shares many features of embryonic growth, neonatal long bone development, as well as normal fracture healing. (3, 4) The mechanical stimulation generated by gradual traction induces the biological response of skeletal regeneration in a cascade of bone regeneration processes, and the molecular signaling during distraction osteogenesis is amplified and prolonged as long as the mechanical traction is in progress.
Cigarette smoking is a common social problem. The negative effect of smoking on bone healing has been widely reported in scientific literature. (5-8) It is a clinical challenge to treat heavy smokers due to their compromised healing ability, particularly on the need for the reconstructive surgery. Nicotine is the main chemical component, which has been found to be of highest importance in more than 4000 of potentially toxic substances, in tobacco product. (9, 10) Heavy smokers normally have plasma nicotine levels in the range of 10-70ng/ml, while light smokers have nicotine levels less than 10ng/ml. (11) The influence of nicotine on tissue healing has been explored by various delivery systems on different animal models and the results remains conflicting. (5, 9, 12-14)

This study aims to simulate the plasma nicotine levels of heavy and light smokers by implanting different doses of time release nicotine pellets, and evaluate the correlation between plasma nicotine levels and bone regeneration using a rabbit model of mandibular distraction osteogenesis.

2. MATERIALS AND METHODS

2.1. Animal care
The rabbits were kept in a dedicated animal holding facility under veterinary supervision in the Laboratory Animal Unit of Li Ka Shing Faculty of Medicine, The University of Hong Kong. The animal experiment protocol was approved by the Committee of the Use of Live Animals for Teaching and Research.

2.2. Nicotine implantation
Twenty adult New Zealand white rabbits (9 month old, 3.4-4.0 kg) were randomly assigned to four equal groups: sham control, placebo control, low dose nicotine (0.75g), and high dose nicotine (1.5g). Nicotine pellets (60-day time release) or placebo pellets (Innovative Research of America, Sarasota, USA) were implanted in the neck subcutaneous tissue of the rabbits. Total nicotine exposure time was seven weeks.
2.3. Determination of plasma nicotine concentration

3 ml of whole blood was collected from the marginal auricular vein on week one, three and seven respectively after nicotine implantation. Nicotine extraction was performed using the methods presented by Nakajima et al. (15) The plasma nicotine concentration was assayed by high-pressure liquid chromatography (HPLC) composed of a 626 pump (Waters, Milford, USA), a 486 tunable absorbance detector (Waters, Milford, USA) set at 260nm, and a SunFireTM C18 5µm 4.6mm × 150mm column (Waters, Milford, USA). The mobile phase contained 2mM sodium dihydrogen phosphate, 1mM heptanesulfonate sodium, the pH was adjusted to 6.2 with phosphoric acid and 10% acetonitrile was added to the final solution. The flow rate was 1.0 ml/minute. Acetanilide (International Laboratory, CA, USA) was used as the internal standard. All of the reagents were HPLC grade.

2.4. Osteotomy and distraction procedures

One week after nicotine implantation, a standard procedure of mandibular body osteotomy and distraction described by Zheng & Cheung (16) was performed. Briefly, the animals were given a preoperative dose of antibiotic and analgesic (long acting oxytetracycline 30 mg/kg and buprenorphine 0.03 mg/kg), and were anaesthetised by intramuscular injection of ketamine 35 mg/kg, xylazine 5 mg/kg, and acepromazine 1 mg/kg. The skin was incised along the inferior border of the mandibular body with the rabbit’s head hyper-extended. The platysma muscle was dissected and the periosteum was raised from the mandible and reflected laterally to identify the mental nerve, which was located immediately anterior to the first premolar tooth. A straight body osteotomy cut was made with a small Lindemann bur immediately anterior to the first premolar root on one side of the mandible. A custom-made bone-borne distractor was placed along a plane perpendicular to the osteotomy cut and fixed by 2-mm-diameter titanium screws. The periosteum, muscle, and skin were repositioned and closed by 3-0 sutures.
After the operation, an antibiotic (long acting oxytetracycline 30 mg/kg) was administered intramuscularly twice per week for two weeks. For pain relief, buprenorphine (0.03 mg/kg) was administered subcutaneously twice daily for ten days. Each animal remained under close observation by a veterinary technician until it regained consciousness. The clinical condition, weight and food consumption of the animals were monitored. After three day latency period, distraction was activated at 0.9mm once daily for eleven days, and all rabbits were sacrificed after four weeks of consolidation.

2.5. Plain radiography

Each mandibular specimen was placed on an occlusal film with the lingual side touching the film. Plain radiography was performed by an Orthoralix 9200 x-ray machine (Gendex, Des Plaines, IL) under a standard condition of 50 kV, 16 mA.

2.6. Micro-computed tomography (micro-CT)

After plain radiographic examination, the distracted tissue regenerate and a 2–5 mm section of the neighboring normal bone in the distracted mandible were harvested. The specimens were subjected to qualitative and quantitative examination by a micro-CT machine µCT20 (Scano Medical AG, Bassersdorf, Switzerland) using a previously described protocol (16). Briefly, each harvested specimen was placed into a 17-mm diameter sample holder with the sagittal plane vertical to the X-ray tube. Between 120 and 140 cross sectional scans with a slice increment of 100-im were made for each specimen. The serial scanned images of each specimen were inspected on the computer. On each scanned image, the total area of the distraction regenerate was outlined as the region of interest (ROI). The bone volume fraction (the ratio between bone volume and total volume, BV/TV) within the ROI on each section was calculated individually and a mean value of BV/TV for the total regenerate was obtained by pooling from all the scanned sections within the distraction gap. To determine the threshold all ROIs of one specimen were subjected to an adaptive procedure in which the bone fraction was determined
for a range of thresholds. The optimal threshold (120) was defined at the minimum change of bone fraction.

2.7. Histology
After the micro-CT examination, the samples were decalcified in a solution of 14.5% ethylenediaminetetraacetic acid (EDTA) buffer (pH 7.2) at room temperature. The decalcified specimens were processed and embedded in paraffin wax. Axial sections of 5 µm in thickness were cut including the margin of normal bone and distraction regenerate with a microtome and stained with haematoxylin and eosin for light microscopy.

2.8. Statistical test
The differences in the values of BV/TV between four groups were compared by one way ANOVA with version 11.0 of Statistical Package for Social Sciences software (SPSS Inc., Chicago, USA). A statistical result of 0.05 was considered as significant.

3. RESULTS

3.1. Clinical examination
All twenty rabbits completed the experimental process uneventfully. None of the animals experienced postoperative complications, and distractors maintained stable till the day of sacrifice. As a result of the unilateral mandibular lengthening, the rabbits developed a severe lateral cross-bite and overgrowth of lower incisors. After the rabbit mandibles were harvested, they were confirmed to have been lengthened successfully with hard tissues filling the distraction gaps.

3.2. Plasma nicotine concentrations
In the low dose nicotine group, the plasma nicotine concentrations of five rabbits during seven week nicotine exposure were in the range of 5.47-8.15ng/ml, and the average was 7.03ng/ml (SD=0.32). In the high dose nicotine group, the levels were in the range of 20.93-47.43ng/ml, and the average was 32.25ng/ml (SD=1.52). No nicotine was detected in the sham and placebo control groups.
3.3. Plain radiography

Bone union was complete and new cortex appeared partially at the margin of distraction regenerate in the control groups and low dose nicotine group. In the high dose nicotine group, the radiodensity in the distraction gap was lower than that in the other groups, and the height of bony regenerate was not comparable to the conjunctive host bone.

3.4. Micro-CT

The serial CT images of the distraction regenerate showed continuous ossification from the edges to the center in the distracted region. The degree of bone regenerate mineralization increased gradually from the central area to merge with the host bone at the both ends. The quantitative analysis showed that the bone volume in the distracted gap in the high dose nicotine group was significantly lower than that in the sham control (p<0.01), placebo control (p<0.05) and low dose nicotine group (p<0.05). There was no significant difference between the control and low dose nicotine groups.

3.5. Histology

In the control groups, complete bony union in the central area and partial corticalisation were observed in the distraction regenerate. In the nicotine treated groups, the distraction area had a mixture of woven and maturing lamellar bone with a rich loose fibrovascular stroma. Multiple loci of chondrocytes surrounded by a mineralised matrix and small foci of fibrous tissue were noted in all the rabbits in the high dose nicotine group.

4. DISCUSSION

Distraction osteogenesis is an increasing popular tissue engineering technique in clinical bone reconstructive surgery. It obviates the need for taking bone grafts from patients and its associate morbidities from the donor sites and wound healing complications. Moreover, under the controlled mechanical force, distraction osteogenesis provides a convenient platform for bone research. Distraction osteogenesis consists of four clinical phases: 1. osteotomy
at the target site; 2. latency period: the time gap from the osteotomy procedure to the commencement of active distraction, which allows the inflammatory phase of osteotomy healing to subside and thereby enables the distraction at the beginning of the reparative phase; 3. active distraction: the bone fragments are separated gradually by a controlled mechanical traction at a rate of about 1mm/day till reach the proposed advancement. 4. consolidation period: the time from the complete of the active distraction till detaching the distraction device. The distraction regenerate then mineralizes and reaches the mechanical strength to achieve functional activity. The mechanical stimulation by distraction during the active distraction period induces a cascade of biologic processes of bone regeneration including differentiation of pluripotential tissue, angiogenesis, mineralization, and remodeling. When compared with bone fracture, a traditional model to study bone healing in which the molecular signaling only last a few days, the signaling in distraction osteogenesis are magnified and prolonged as long as the mechanical traction is active.

The negative effect of smoking on bone healing has been widely reported. Nicotine is the main chemical component responsible for the tobacco addition. (17) It has been found to be of highest importance among the potentially toxic substances in tobacco product (9, 10), but its influence on bone healing remains controversial. Some studies indicated that nicotine has an adverse effect on bone healing and regeneration (9, 13, 18, 19), while some other reports demonstrated no significant impact (5, 12, 14). The controversial results were likely due to the various dosages and methods of nicotine exposure and the different wound healing models used to study the nicotine influence. Thus it is important to explore a reliable and repeatable nicotine delivery method, and establish a direct correlation between nicotine plasma concentration and the bone healing.

Nicotine can be delivered by drinking water, subcutaneous injection, subcutaneous implantation, infusion by a miniosmotic pump, or smoking chambers where “research cigarette smoke” is pumped into the chamber. Orally administered nicotine is difficult to
achieve the nicotine plasma levels consistent with smokers because it has to undergo a significant first-pass effect from hepatic metabolism (approximately 85-90%). (20) Subcutaneous injection is easy to handle but needs a daily injection to maintain the plasma concentration. Smoking chambers is less favorable due to the multiple agents in “smoke” versus single agent nicotine and interpretation of the results relating to nicotine is difficult. Miniosmotic pump is a reliable way for nicotine delivery, but the life span of the pump is only four weeks. A secondary operation to replace the pump is needed if longer period of nicotine exposure is required. Surgical implantation of the time release nicotine pellets in the subcutaneous tissue can provide a reliable and convenient way to achieve a stable nicotine levels in a long period.

As far as we know, there is limited in vivo information on the direct correlation of plasma nicotine levels and bone healing process. We started by a conducted pilot study in our laboratory (data not shown), of which different dosages of nicotine were test whether the nicotine levels in blood can reach that of light and heavy smokers. We have selected two dosages (0.75g and 1.5g) of nicotine for the proper study. Blood samples were collected on the day of osteotomy, two weeks thereafter, and on the day of sacrifice to determine the plasma nicotine levels. The plasma nicotine concentrations in the rabbits proved to be stable during seven weeks of nicotine exposure. 0.75g nicotine pellet implantation caused a plasma nicotine level of less than 10ng/ml, which is comparable to light smokers (<1 pack/day). 1.5g nicotine implantation caused a nicotine level at 20.93-47.43ng/ml which is comparable to heavy smokers (>1.5 pack/day). This formed the biological basis for conducting further study of the effect of nicotine on bone healing and regeneration simulating light and heavy smokers.

The present study supported that nicotine has a dose dependant influence on bone healing in distraction osteogenesis. At a low plasma level, nicotine was found to have no significant adverse effect on bone healing although the histological images showed that the newly
formed bony trabeculae were not as mature as that in the control groups. This suggested that light smokers or patients who use nicotine medication for the purpose of smoking cessation (plasma nicotine concentrations are less than 10ng/ml) have little risk in bone healing in distraction. At a higher plasma nicotine concentration, the micro-CT study confirmed that the bone volume in the distraction gap was significantly less than that in control and low dose nicotine groups. This suggest heavy smokers have a considerable risk for distraction osteotomy and possibly bone reconstructive surgery.

Tissue healing processes are modulated by the activities of local cells and signaling molecules. When osseous healing exhausts the localized supply of cells and signaling molecules, renewal is contingent upon vascularity and operational activity of endogenous cells during the early phase of bone repair. Therefore the local blood supply performs a critical role in determining the success of bone healing. Nicotine has been reported to have effects directly on the small blood vessels in producing vasoconstriction, systemic venoconstriction, and increasing coronary vascular resistance. (21-23) The intense vasoconstriction that nicotine exerts on the microvasculatures inhibits the angioblastic response during revascularization in the healing area and limits the recruitment of the related factors such as cytokines. These may explain the adverse effects of nicotine on bone healing and has yet to be confirmed. Distraction osteogenesis provides an excellent model to explore the hard evidence of the effect of nicotine on bone regeneration.

Bone is formed mainly through two pathways: endochondral ossification in long bone development and repair, and intramembranous ossification in cranio-facial bone formation. The distraction regenerate in craniofacial distraction osteogenesis mineralizes predominantly via intramembranous ossification without a cartilage intermediate. Endochondral bone formation is considered unusual but could be observed occasionally during the early stage at the periphery of the distraction gap, where the callus outgrows its blood supply. Cartilage provides a suitable material that is less
demanding on oxygen, which bridges the gap temporarily until the blood supply catches up after one to two weeks of consolidation. (24) Any reasons caused ischemia and low oxygen tension in the distraction regenerate may change the predominant bone formation pathway to endochondral ossification. The present study provides direct evidence that nicotine exposure can change the bone regeneration pathway. Obvious chondrocytes surrounded by a mineralised matrix were only noted in the high dose nicotine group, which indicated a decreased oxygen tension in the distraction regenerate when compared with the control and low dose nicotine groups. This is consistent with the previous reports that nicotine may cause vasoconstriction which finally result in delayed healing and proper mineralization.

Patients with heavy smoking habit, radiotherapy history, diabetes or long term steroid therapy demonstrates the similar compromised biological environment of the wound sites, such as vasoconstriction, tissue ischemia, compromised activity and recruitment ability of local cells and signaling molecules. These biological attentions of wound healing have important therapeutic and prophylactic indication to patients. The present study provides not only the medical evidence of the relationship between plasma nicotine concentration and the adverse impact of nicotine on bone regeneration, but also a reliable and convenient in vivo platform to further study the biological mechanisms and therapeutic options of the bone reconstructive surgery on compromised hosts.

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5. REFERENCES


Vertical Distraction Osteogenesis of Fibular Bone Flap in Reconstructed Mandible

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The purpose of study: Excellent functional and aesthetic results can be achieved by using free fibular flap for the reconstruction of mandibular bone defect. However, because of the limited diameter of the fibula flap compared with the height of the mandible, vertical distance between the reconstructed segment and the occlusal plane can be substantial. This is a particular problem in dentate mandible, especially when rehabilitation with dental implants or an tissue borne denture is contemplated. To overcome this problem different technique was introduced including onlay bone grafting and double barrel fibula flap. However, these techniques have met with limited success and have been techniquely demanding. In this preliminary study, we present the results of vertical segmental distraction of fibular flap with using extraoral device for the dental rehabilitation in 3 patients.

Methods: Segmental vertical distraction of the reconstructed mandible were performed for dental rehabilitation in 3 patients who had previously mandibular reconstructions with free fibular bone flap due to extensive bone defect result from gun-shot injury. All the patients had a vertical bone deficit of fibular bone flap that prevent
dental rehabilitation. Fibular bone segments (40-70 mm) were distracted with using extraoral distraction device after a latency period of 7 days. The rate of distraction was 1mm/day and the rhythm was 4 times (4X0.25 mm). Distraction was continued till the desired height was achieved and the distractor left in place for 12 weeks for bony consolidation.

**Results:** During the removal of distraction device, sufficient new regenerated bone was observed in the distraction gap. No minor or major complication such as insufficient ossification or osteomyelitis were encountered. There were no distractor breakages. The amount of vertical height achieved after distraction was between 9 to 13 mm. The increase of vertical bone height was stable and enabled dental restoration of the patients with mandibular removable partial dentures. A significant improvements in speech, masticatory function, and facial aesthetics were achieved in these patients.

**Conclusion:** Fibular flap can be distracted vertically without any complication in order to overcome vertical deficiency causing difficulties for dental restoration.

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Condylar Reconstruction by sliding vertical - oblique ramus osteotomy

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Abstract: In tumoral or pseudotumoral cases condylar reconstruction is indicated when condylectomy is performed. Condylectomy without reconstruction results in a diminishment of the height of the mandibular ramus, premature contact at molar level on the affected side, open anterior and contralateral bite and facial asymmetry when the mouth is open. The classic iliac crest graft has been used for reconstruction of the condyle with varying results due to bone quality (enchondral) and a degree of unpredictable reabsorption. The costal cartilage gives the graft good adaptation capacity and even the possibility for growth which is very important when used in children; however, it also presents problems such as unpredictable growth, separation of the bone (cartilage-bone gaps), and as in any free graft, the possibility of reabsorption and graft loss as well as donor site morbidity. Also, different alloplastic grafts have been used for prosthetic reconstruction. The posterior border of the mandibular ramus can be used as a pediculated graft for reconstruction of the condyle.

By means of the classic preauricular approach, resection of the condylar tumor could be accomplished under direct vision of the same.
At this moment, special care should be given to identify the lateral pterygoidal muscle, that should be dissected from the tumoral condyle for its posterior reinsertion in the neocondyle. Vertical ramus osteotomy is accomplished through the intra or extraoral approach with the osteotomy line designed so as to enable the neocondyle to fit into the glenoid fossa once the posterior mandibular border had been moved upwards. Remodeling of the upper neocondyle and fixation of the lateral pterigoid muscle is performed. Rigid fixation using two miniplates allows immediate mouth opening with stable occlusion. With this condylar reconstruction we obtained optimal interincisal openig with a deviation lower than 4mm towards the affected side, all excursive movements are preserved and correction of the facial asymmetry is achieved without TMJ pain.

LECTURE
In cases of slight condylar agenesia, observation during the growth period is indicated and the development can be very favourable.

In cases of total condylar and mandibular ramus agenesia we should (need to) carry out: costochondral grafts, distraction, replacement of the maxilla, and microvascularized flap.

In cases of condylar tumours, Which is the best reconstruction procedure to prevent esthetical and functional secuelae?

The classic iliac crest graft has been used for the reconstruction of the condyle with varying results due to bone quality (enchondral) and a degree of unpredictable reabsorption. The costochondral graft, ever since Gilles described it (1920) and Ware and Brown popularized it (1981), has been used by many authors with satisfactory results. The costal cartilage gives the graft good adaptation capacity and even the possibility of growth which is very important in children. The external head of the clavicle and the metatarsal bone have also been used as free graft by different authors.

Also, different alloplastic grafts have been used for prosthetic reconstruction of the mandibular condyle, such as plastics materials.
(silastic, teflon, proplast, acrylic), diverse metals like chrome-cobalt alloys or titanium and ceramic materials whose results and complications will not be discussed now.

The posterior border of the mandibular ramus can be used as a pediculated graft for reconstruction of the condyle.

Frank Pavell, (referred by Bell, 1980), in cases of condylar hypertrophies performed an osteotomy of the posterior border along with the condyle and once the hypertrophied zone was remodelled, he replaced the posterior border as a free bone graft. Choung and Nam (1998) described an intraoral approach for the treatment of hyperplasias and condylar fractures using the intraoral and vertico-sagittal ramus osteotomy, repositioning it as a free graft. The reconstruction of the condyle by superior repositioning of the pediculated stump of the proximal condylar segment into the condylar fossa as a local osseous pediculated graft based on the lateral pterygoidal muscle was referred by Loftus (1986) in a case of osteochondroma using a titanium mesh and intermaxillar fixation for three weeks. The sagittal osteotomy for the condylar reconstruction was used by Hickory (1988). Markowitz (1989) refers seven cases (non tumoral) of condylar reconstruction using vertical oblique ramus osteotomies with maxillomandibular postoperative fixation.

I want to show the results obtained after ten years of follow-up with the condylar reconstruction by sliding vertical-oblique ramus osteotomy.

**Technique:**

By means of the classic preauricular approach, the resection of the tumor could be accomplished under direct vision. The use of some holding devices such as a screw or wire allows the mobilization and dissection of the tumor. At this moment, special care should be given to the identify the lateral pterygoid muscle, which should be dissected from the condyle for later reinsertion in the neocondyle. Once the condylectomy has been performed, the new dental occlusion previously determined from study models is verified in order to decide...
if a compensatory contralateral osteotomy is necessary. At this moment intermaxillary fixation is undertaken.

Vertical ramus osteotomy is accomplished through the extraoral retromandibular approach. Osteotomy line is designed so as to enable to fit the neocondyle into the glenoid fossa once the mandibular border had been moved upwards. Prior to the surgery, and by means of a panoramic x-ray in maximum intercuspidation, the following points are identified.

Point A: The highest and frontal point of the glenoideal fossa.
Point B: In the rear of the sigmoid notch, where the condyle neck begins.
Point C: In the inferior border of the mandible, determined by the prolongation of a line from point A to point B. This line should pass behind the channel of the dental nerve. If not, point B has to be repositioned backwards, assuring that this line avoids the dental nerve channel.

(In some cases the affected side of the mandible changes its anteroposterior position with the new occlusion and therefore point B. Normally the tumors displace the mandibular body forward, quantified through the study models, measurement that helps to reposition the mandibular body backwards when the new occlusion is decided, and which have to be transferred to the preoperative panoramic x-ray. To correct the cases of condylar absence, in which the position of the mandibular body is backward, the image of the mandibular ramus has to be advanced those millimetres which the new occlusion indicates).

Point C, in surgery, is easily identified in front of the mandibular angle and its distance from the rear border of the mandible is quantified, bearing in mind the x-ray magnification. The line for the osteotomy is marked by the union of point B with point C, a separator is used as an anchor in point B. The mandibular border is cut with a reciprocal saw from point B to point C. It is preferable to cut it perpendicularly to the ascending ramus of the mandible, because it provides a greater stability.
(The vertical cut in bevel allows to do corrections in the calculations without losing any point of contact between the fragments, but it provides less stability when fixing it into place.)

Once the osteotomy is completed, mobility and viability of the posterior border is verified maintaining internal pterigoid muscle insertions. The upper neocondyle of the mandibular fragment is placed in the glenoidal fossa when moved from the lower to the upper position following the osteotomy line, without losing contact at any level. Slight remodelling of the upper neocondyle stump to simulate a condylar head is performed. Fixation of the lateral pterygoidal muscle to the new condyle is performed using a specially designed harpoon or resorbable screws or in a hole in the bone. When the articular disc is excessively mobile it is fixed posteriorly. (All these manoeuvres are easy to perform as the osteotomized fragment is still freely mobile). By sliding the posterior mandibular border upwards, the stump is placed in the glenoidal fossa in contact with the articular disc. Rigid fixation is performed using two miniplates. Then the functionality of mouth opening and closing, as well as the occlusal stability is verified after releasing the maxillomandibular fixation. Postoperatively, the mouth is maintained open. During the first few days after surgery, the mouth opening is limited, and no condylar translocation movements are recommended. After 10 days, more movements are encouraged. Elastic traction can be used to correct any remaining occlusal errors.

Case 1

A 37-years old male complained of clicking sounds and left temporomandibular joint discomfort for several years. He had been diagnosed 9 years before, of right masseter muscle hypertrophy. Clinical findings revealed mandibular asymmetry with deviation of the chin and mandibular midline to the right by 4 mm; a posterior open bite on the left side, but mouth opening was not restricted. Conventional radiology showed a large increase in the volume of the left condyle mandible with irregular border, but without cortical resorption.
A mass with a maximum diameter of 30 mm was dissected out conserving the articular disc and identifying the tendon of the lateral pterygoid muscle. Using a submandibular incision, a vertical ramus osteotomy was performed following the pre-established line planned using a panoramic radiograph and CT. The new occlusion was blocked and it was not necessary to perform a compensatory osteotomy. The osteomized posterior mandibular border was moved (raised by) 9.6 mm upwards, into contact with the articular cartilage. The stump was remodelled, and in a small hole, the pterygoid lateral muscle was inserted. Two L-shaped miniplates were placed, and occlusal stability was confirmed. Posoperative maxillomandibular fixation was not applied allowing opening movements up to 20 mm during the first 10 postoperative days. After 3 weeks opening of 40 mm was achieved and the patient did not complain of pain. Histological diagnosis was osteochondroma. The postoperative radiograph showed a very good superior reposition of the proximal segment.

(35 month after surgery, the patient did not show any symptomatology, having a stable occlusion with protrusive and lateral excursive movements on both sides and there only appeared a left deviation of 5 mm in the maximum interincisal opening which was 54 mm. The x-rays did not show any signs of reabsorption, but there were signs of remodellation of the mandibular angle. The patient was very satisfied with the aesthetic result of his mandibular symmetry).

Case 2

A 33-years old woman with progressive facial asymmetry and masticatory dysfunction during the last three years; the patient had not experienced any pain in temporomandibular joints. Deviation to the left of her prominent chin, and an increased length of the right ascending ramus and posterior open bite of 8 mm at the 2nd molars was noted. Mouth opening was normal and pain free. By palpation, a markedly enlarged right condyle was noted. Radiography revealed
mandibular asymmetry caused by a mass in the right condyle, its size and form followed the pattern of growth of a tumoral process. The CT scan confirmed this and also showed a slight increase in the osseous density.

With a provisional diagnosis of benign tumour, a condylectomy was performed. The planned occlusion from the study models was checked; using a submandibular approach a vertical osteotomy was performed, the proximal fragment was repositioned 13 mm cephalad into the glenoid fossa; In this case, the line of the osteotomy was not perfect and the remodelled stump was positioned further forwards than desired but a good function of the joint was tested. The histopathology revealed condylar hyperplasia.

One month later, mouth opening of 46 mm was achieved with minimal deviation and lateral excursion was conserved. Neither articular pain nor other complications appeared.

Case 3

A 36-years old male complained of facial asymmetry of several years evolution and pain in the left temporomandibular joint, deviation of the chin, posterior left open bite and crossed occlusion on the right side. Radiographs and C.T. demonstrated anterior and medial growth of a mass with vertical displacement of the left condyle outside the glenoidal fossa. The provisional diagnosis was an osteochondroma. Dissection of the lobulated tumoration was carried out with extreme caution because the tumour extended medially close to the internal carotid artery. The tumour was impaled using a screw to facilitate its removal. The articular disk was preserved and the pterygoidal muscle was identified. A vertical-oblique osteotomy was performed. Remodelling of the superior stump was carried out and reinsertion of the lateral pterygoidal muscle was made using a reabsorbable polilactic acid screw. The mandible was placed in the new occlusion and the posterior border was slid 10 mm towards the glenoidal cavity and was rigidly fixed with two titanium “L” form miniplates. Light elastic traction was advised for 2 weeks to facilitate
the new occlusion. The histology confirmed the diagnosis of osteochondroma. An interincisal opening of 43 mm was noted and all the protusive and excursive lateral movements were normal; there was a maximum degree of satisfaction with reference to functionality and aesthetics.

Case 4
A 54 years old male, Bruxomanus, with an image degenerative in the left condyle, this lesion increased in the two lasts years and caused pain. The same technique was carried out, the histology was “Condyle with degenerative changes” and the aesthetic-functional results were excellent.

RESULTS
In all four cases, an immediate mouth opening with stable occlusion was obtained. The interincisal opening was more than 40 mm after 3 weeks with a deviation towards the affected side no greater than 4 mm. All excursive movements were present in all directions and correction of the facial asymmetry was achieved. There was no T.M.J. pain and all the patients expressed a maximum degree of satisfaction. In the average eight years follow-up there was not change in immediate postoperative results and radiological there was not any evidence of neocondylar reabsorption.

DISCUSSION
The controversy continues right to the present when dealing with deciding which is the better procedure for Temporomandibular joint reconstruction: the use of autogenous tissues or alloplastic prostheses (Macintosh, 2000; Mercuri, 2000). When only the condyle is needed to be reconstructed, autogenous bone-cartilage grafts are clearly preferred.

The use of the posterior border of the mandible as a pediculated graft appears to have some advantages. This technique avoids the risks
of a free graft (resorption, infection and graft loss...) and avoids donor site problems. It gives a bone of a size and shape which is adequate for the new condyle and its histologic characteristics are similar. The vertical osteotomy with the obliquity pre-established pre-surgically can be carried out also by intraoral means, but, with much more difficulty, inasmuch as to achieve the precision in the line of the osteotomy, as well as for its immobilisation upwards and its rigid fixation. The vertico-sagittal intraoral osteotomy could be considered as another possibility with a minor degree of precision and stability. On the other hand, to be used in cases in which a condylar neck doesn’t practically exist, it would demand also, a complementary osteotomy of the portion of the sigmoid notch to increase the length of the newly created condylar neck and a shortening of the temporal muscle is created and a coronoidectomy would be required. Its utility would have to be evaluated when, besides the need of condyle reconstruction, we also need to advance the mandible notoriously (cases of condylar agenesia, old reabsorptions of the condyle, etc.).

The transferral movements obtained with this technique, we believe that is not only due to the reattachment of the lateral terygoid muscle, but also to the transportation of the medial pterygoidal muscle to a more horizontal position.

Mandibular angle defect: we have been able to prove the postoperative remodelling of the inferior step with good aesthetic results, despite the diminishing of the angle. The use of this technique in other pathologies resulting in loss of the mandibular condyle, should be evaluated.

For treatment of active hyperplasia of some fibrous displasias (with high degreee of osification), the removal of the hyperplastic condyle with the posterior border of the mandible, remodelling and reimplanting it following the criteria described by Martinez- Lage (1981) and Egerton (1985) could avoid recurrencies. This would avoid the need to wait until the cease of hyperplasia activity before surgery.
CONCLUSIONS

The sliding vertical-oblique ramus osteotomy provides in cases of condylar tumors, excellent functional and cosmetic results with advantages over other classical condyle reconstruction techniques; The postoperative maxilomandibular fixation is not necessary, the reinsertion of the lateral pterygoid muscle is recommended as well as a meticulous designing in the obliquity of the osteotomy line.
Trouble shooting problems associated with Transport Distraction Osteogenesis in Mandibular reconstruction

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Transport distraction Osteogenesis is an alternative method to reconstruct the mandible after tumor ablation. In this paper we look at some of the problems encountered during transport distraction. We also highlight some of the steps to be taken that can overcome the problems encountered and what could be done to prevent such problems from occurring.

Resected portion of the mandible were ultimately reconstructed using distraction Osteogenesis without the need for complicated bone grafts and satisfactory results obtained with minimal complications.
A New technique of Reconstruction following Hemimandibulectomy using titanium plate suspension - Long term outcome in 20 Oral cancer Patients

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**Introduction:** Reconstruction of mandibular defects following hemimandibulectomy, for malignant tumors of oral cavity poses a considerable challenge. These defects result in significant functional and cosmetic derangement. Some form of reconstruction including temporo-mandibular joint is desirable. Current techniques using allogenic condylar prostheses or autogenous tissue graft are associated with a high morbidity and failure rates especially in advanced oral cancer patients following surgery and radiotherapy. In this study we present our experience of a new technique of mandibular reconstruction using titanium plate suspension.

**Methods:** Twenty Locally advanced Oral cancer patients requiring hemimandibulectomy were included in the study between 1999 - 2002. Following classical hemimandibulectomy a Tiataniium mandibular reconstruction plate is contoured and one end was fixed to the remaining mandible and the other end was suspended from the zygomatic process using ethibond sutures. The plate was covered with a pectoralis major myocutaneous flap. The articulation between zygomatic process and the free end of titanium plate functioned as a pseudo joint. Post operatively all patients with Stage III & VIa were
given radiotherapy. Immediate wound morbidity, long term cosmetic and functional outcome and plate loss were analyzed.

Results: In 10 patients tumor was located in retromolar trigone and in the remaining 10 patients tumor was located in the alveolar region. Twelve patients with stage III and IVa tumors received adjuvant radiotherapy. At the median follow up of 28 months, 3 patients developed local/regional recurrence. No immediate major wound morbidity was encountered and only 3 patients had late plate exposure. Two patients required removal of the plate and in one patient plate was salvaged. None of the patients had significant postoperative trismus, jaw deviation or malocclusion. The overall cosmesis was good in majority of the patients.

Conclusion: Titanium plate suspension is a simple and efficient way of managing hemimandibulectomy defects in advanced oral cancer patients. This technique is associated with minimal postoperative morbidity and acceptable long term functional and cosmetic outcome.

Others Authors: Shukla NK, Sunil Kumar


Zygomatic implants

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Introduction: The rehabilitation of the extremily resorbed maxilla remains a challenge. Despite the fact that some techniques of bone augmentation like sinuslifts or sinusgrafts are well known and well developed, the results remain unpredictable (success rate 60 to 90%). Zygoma bone offers an excellent anchorage for implants and supports the insertion of 2 implants on each side.

In some cases the resorption of the anterior maxilla is so extreme that the insertion of standard implants is impossible. 4 zygoma implants could be considered as a good solution for supporting fixed prosthesis.

Materiel and methods: A serie of 18 consecutive patients all women mean age 58 has been reviewed by the authors. All the patients were provided with 4 zygoma implants. 6 were provided with definitive fixed prosthesis after 6 months, 5 after 2 months and 7 with provisional prosthesis after 48 hours and definitive prosthesis after 3 months. Survival rate after one year is

Results: One patient lost 3 implants after 3 months. Survival rate after 6 months is: 96%
Conclusion: This technique seems to offer predictable results and could be a solution for rehabilitating totally edentulous patients with extreme resorption of the maxilla.

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Distraction Osteogenesis of Alveolar Segments

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The treatment of alveolar defects includes guided bone regeneration using a variety of membranes, onlay grafting of autogenous bone, connective tissue grafting and alloplastic augmentation. Vertical alveolar defects are difficult to overcome in a predictable manner using autogenous bone grafts and often lead to esthetic shortcomings. Distraction osteogenesis of the maxillary and mandibular alveolus permits correction of alveolar defects oftentimes without the use of a bone graft.

Alveolar distraction osteogenesis may offer several advantages over bone grafting alone in the treatment of vertical alveolar defects: no donor site is required; distraction of bone and surrounding soft tissue occurs simultaneously; the transport segment is a form of pedicled graft which is never separated from its blood supply, thus maximizing vitality and minimizing resorption; and it has the potential for better control of vertical height, esthetics and biomechanical loading. Alveolar distraction devices have three basic components: an upper member, a distraction rod, and a lower member/base plate supporting the vertical force of distraction. These devices can be classified as intra-osseous or extra-osseous; uni-, bi- or multi-
directional; non-resorbable or resorbable (not requiring a second surgery to remove distractor components); and prosthetic (can remain in place to be used to support the dental prosthesis) or non-prosthetic (must be removed following distraction and replaced with a dental implant).

This presentation discusses the adaptation of alveolar distraction osteogenesis techniques in the maxilla and mandible and will discuss clinical cases with transport of alveolar segments.

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Alveolar Distraction: Clinical and Experimental Aspects

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Alveolar distraction is a relatively novel procedure by which alveolar bone and underlying mucosa are regenerated. The low predictability of other vertical or horizontal bone regeneration methods has increased expectations for this promising technique. Research into alveolar distraction has studied its latency phase, distraction phase or consolidation phase. Little experimental research has been carried out on this procedure, and most works are clinical studies with a short follow-up period. This presentation tries to show clinical and experimental results of published studies carried out by our research group. Advantages of using dog as biomodel in alveolar distraction are showed, and histomorfometric results after different consolidation period as also presented. On the other hand, different conditioning factors in alveolar distraction are showed, with especial focus in distraction vector.

The selection of an experimental animal biomodel is not clearly defined, with reports in the reviewed literature on dogs, sheep, and monkeys. We show an study where two experimental biomodels (dog and minipig) were compared using an alveolar distraction protocol with a novel prototype distractor. The radiological examination was
carried out immediately after the distraction and at 2 weeks of consolidation. Satisfactory clinical and radiological results were obtained in 2 of 3 beagle dogs after the previous unilateral. During the consolidation, a height gain of approximately 5 mm was observed, with the appearance of radiodense bone trabeculae in the distraction chamber. The distraction failed in all of the minipigs.

Another study is showed where consolidation period is evaluated in mandible of beagle dog. Two different consolidation periods (4 and 8 weeks) using a prototype alveolar distractor. Five beagle dogs were used. Four of them underwent alveolar distraction in an edentulous segment of right mandible. After a seven-day latency period, distraction of 1 mm/day was applied for five days; the consolidation period was four weeks in two dogs (Group I), and eight weeks in the other two (Group II). The fifth dog was used as control (Group III). Clinical, histological, and histomorphometric studies were conducted. One animal from each distraction group was withdrawn from the study because of wound dehiscence that allowed invasion of the mucosa into the distraction chamber, incompatible with bone regeneration. In the Group I animal, a predominance of immature woven bone was observed in the distraction chamber, whereas the Group II animal showed a predominance of immature parallel-fibered bone. Group I and II animals differed in: bone area density in distraction chamber (36.61±9.79 vs. 58.72±8.30), bone perimeter in distraction chamber (262.89±10.46 vs. 201.44±22.64), total height attained (21.31±0.32 vs.18.37±0.50), lingual trabecular width (134±15.56 vs. 229.50±29.24), vestibular trabecular width (90±4.24 vs. 154.50±21.64), lingual osteoid area density (4.08±0.46 vs. 1.61±0.33), and vestibular osteoid area density (3.75±1.28 vs. 2.094±0.79). Quantitative and qualitative differences in neoformed bone were observed after four and eight weeks of consolidation. These preliminary results serve as a basis for further experimental research with larger samples and for clinical studies.

Studies that report on alveolar distraction remain scarce in the scientific literature. The factors that influence the outcome of
osteogenic distraction have been more widely researched in other settings, such as in cranio-maxillofacial or mandibular elongation, or in the elongation of the extremities within the field of traumatology-orthopedics. Biological factors include: the size and method of the osteotomy, latency time, distraction rate, consolidation time, exogenous incorporation of pharmacologic or physical agents, and the age and general health status of the patient. There has been less study of extrinsic factors than of other influences. Biomechanical factors include distractor design (number, diameter, and length of distraction and retention screws, and distractor material), direction of the distraction vector, and intrinsic or tissue biomechanical factors, such as anatomic shape, density of area to be distracted, length of distraction desired, and type of adjacent soft tissues.

Regarding to distraction vector, in alveolar distraction the final position of the distracted tissue must favor the esthetic and functional outcome of the prosthetodontic treatment. Pre-operative planning of the distraction vector can establish the correct placement of the distractor and, therefore, facilitate subsequent implant placement and prosthetodontic treatment. We present some clinical cases and a video where a type of distractor is placed. Q-Multitractor distractor (Trion Titantium, Karlsruhe, Germany) allows correcting distractor vector by means of a pin on the basal area of the device.
Delay in callus maturation following Acute Callus Manipulation – Comparison of two cases

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Abstract: This study presents the clinical and radiological outcomes of 2 similar cases of Hemifacial Microsomia treated with simultaneous mandibulo-maxillary distraction but with different orientation of vectors (one with proper orientation of vector and the other with improper orientation). Distraction was performed at the rate of 1mm/day for a period of 20 days in both cases. At the end of the distraction phase, favourable clinical results were observed in the case with proper orientation of vector, but malocclusion ensued in the other. Direct manual shaping of the callus was performed to correct the occlusal discrepancy. Radiological studies revealed delay in the ossification of the manipulated callus.

Conclusion: Vector orientation is critical for the success of distraction osteogenesis technique and callus manipulation can be applied to correct malocclusion resulting from vector deviation but there may be a delay in the ossification.

Introduction: Hemifacial Microsomia (HFM) is a progressive, asymmetric craniofacial malformation variably affecting structures derived from the first and second pharyngeal arches. It is a relatively common facial malformation, second in frequency only to clefts of the lips or palate.
In patients with Hemifacial microsomia, the temporal bone abnormalities, mandibular hypoplasia and neuromuscular deficits inhibits normal downward growth of the maxilla and mid-face on the affected side. This prevents separation of the piriform rim and maxillary alveolus from the orbit, resulting in a shortened maxilla with a canted occlusal plane (upwards on the affected side), in some cases the orbit is inferiorly displaced and the hallmark of hemifacial microsomia is asymmetry.

Hence the goal of the treatment in hemifacial microsomia is to elongate the hypoplastic mandible (mainly the ramus), increase the vertical growth of maxilla and horizontalisation of the occlusal plane.

Traditional surgical-orthodontic approaches for these patients often do not meet expectations, especially the achievement of normal facial esthetics and proportions, and the stability of the results. Lengthening of the ascending ramus of the mandible by conventional orthognathic procedures was often reported to be unstable.
Distraction Osteogenesis (DO) is a promising alternative to traditional method of bone lengthening, by which a significant skeletal and soft tissue enlargement can be obtained in the hypoplastic area in a short period. Hence distraction osteogenesis is preferred in the correction of congenital and acquired craniofacial deformities, especially in hemifacial microsomia. More than 10 mm of lengthening of the ascending ramus, or a small and abnormally shaped ramus as seen in hemifacial microsomia, are some indications to perform distraction osteogenesis.

The technique of distraction osteogenesis is of benefits to patients with HFM, particularly in Pruzansky’s type I and II A, and in some cases of Type II B where there is a functional ramus and condyle. The vector of elongation should be mainly vertically downward, with slight anterior protrusion of the hypoplastic mandible.

Though DO is a promising technique in the treatment of craniofacial deformities, even meticulous planning may not avoid deviations from pre-planned results. Basic considerations regarding planning and orientation have been published by many authors. The orientation of the vector with respect to the anatomic axis of the bone is one of the vital concepts of the distraction. Any deviation in the vector orientation usually results in distraction failure or malocclusion. Several authors have proposed the method of manipulating the callus, during the beginning of the consolidation phase, to attain the desired occlusion.

This paper presents the clinical and radiological outcomes of 2 similar cases of Hemifacial microsomia treated with simultaneous mandibulo-maxillary distraction but with different orientation of vectors, (one with proper orientation and the other with deviation of the vector) and the effect of manipulation of the callus on its ossification.

MATERIALS AND METHODS:

2 female patients of same age range (27 years) presented with hemifacial microsomia, but on different sides. The patients were
otherwise healthy - did not suffer from any systemic disorders. Clinical examination revealed reduction in the vertical height of mandible and maxilla on the affected side, deviation of the chin towards the affected side and the resultant facial asymmetry. Canting of the occlusal plane was noticed (upwards on the affected side) hence the occlusal and bipupillary lines were not parallel in both cases.

Pre-operative radiological investigations included Orthopantomography and Three-dimensional reconstruction of the Computed Tomographic Scan. The radiological findings were analogous to the clinical features. The maxillary height was reduced on the affected side when compared to the unaffected side. Both cases had a normal but hypoplastic mandible. Marked hypoplasia of the ramus was noticed on the affected side; especially the height of the ramus was markedly reduced than the unaffected side. However the TM joint components including the position of the condyle were normal hence both cases were classified under Pruzansky’s type I hemifacial microsomia.

Pre-operative 3 D C.T. Scan demonstrating reduced vertical height of the ramus over the left side - Pruzansky’s type I hemifacial microsomia (left side)
To correct the facial asymmetry, distraction osteogenesis was opted in both cases.

Cephalometric analysis was undertaken in both the cases to determine the vertical height discrepancy of the ramus over the affected side, on comparison with the unaffected side. The distance measured from the superior-most point on the condylar head (condylion) to gonion, and that from the horizontal supraorbital line to the gonion, over the affected side and unaffected side was taken as a guide to determine the amount of bone needed to be lengthened.
On the affected side, the height of the ramus was 20mm less than the unaffected side in both the cases. Mild deficiency in the height of the maxilla on the affected side was noticed in both the cases. Hence a simultaneous distraction of the mandible and maxilla was planned.

For bone lengthening, the vector (device) should be parallel to the desired direction of lengthening and the osteotomy cut, perpendicular to it. Thus a horizontal ramus osteotomy above the angle of the mandible and a complete Le Forte I osteotomy of the maxilla was performed for the simultaneous distraction of the maxilla and mandible. However in one of the two cases, where the distraction was performed over the right side, the osteotomy cut was not exactly perpendicular to the ramus infact it was inclined at an angle of 20° and the distraction device also could not placed exactly parallel to the ramus due to anatomical difficulties.

After the latency period of 5 days, intermaxillary fixation was done and distraction was initiated at a rate of 1mm/day upto 20 days for both the cases.

During the distraction period, a gradual improvement in the facial appearance was noticed in both cases. However in one of the two cases where the distraction vector was not parallel to the ramus, deviation of the mandible towards the undistracted side and the resultant cross bite was evident at the end of the distraction phase.

Direct manual shaping of the callus, as suggested by Pensler et al, was opted to prevent further deviation of mandible or occlusal discrepancy. After attaining the desired mandibular length, at end of the distraction period the lower screw of the distraction device was removed and manipulation of the callus was performed to obtain the desired position of the mandible thereby correcting the malocclusion taking advantage of the mouldability of the callus. The screw was then re-fixed in the new position.

RESULTS:

In the patient with proper orientation of vector, at the end of 12 weeks consolidation period, ossification of the callus was evident
radiologically. The clinical appearance was improved with increased height of the ramus and the maxilla; the occlusal plane was parallel to the bipupillary line, and the chin was in line with the midline.

In the other patient with improper vector orientation, though the clinical features were improving initially, deviation of mandible and cross-bite was evident at the end of the distraction phase, which was suspected due to the change in the orientation of the vector. The radiological study at the end of the 12 weeks consolidation period showed evidence of incomplete callus ossification. However clinical features were improved after manipulation of the callus. Radiological study at the end of 6th month of consolidation period, showed the ossification of the newly formed callus, but the surface of the newly formed bone was found uneven.

**DISCUSSION:**

The goal of the treatment in hemifacial microsomia is to elongate the hypoplastic mandible (mainly the ramus) and the secondarily affected maxilla as well the correction of canted occlusion. This could be accomplished with distraction osteogenesis rather than the traditional orthognathic surgeries since the latter are associated with higher degree of relapse.

Distraction osteogenesis is a dynamic process interacting with changing soft tissue resistance and vector forces. Its principle is based on the studies of Ilizarov, who showed that osteogenesis could be induced if bone is expanded (distracted) along its long axis at the rate of 1 mm per day. This process induces new bone formation along the vector of pull without requiring the usage of a bone graft. The technique also provides the added benefit of expanding the overlying soft tissues, which are frequently deficient in these patients.

In the present study, both the cases of hemifacial microsomia belonged to the Pruzansky’s type I with reduced vertical height of mandible as well maxilla. If the mandible alone is distracted, it might result in occlusal discrepancy, hence a simultaneous maxillary and mandibular distraction was planned.
The simultaneous distraction of the mandible and maxilla in the treatment of hemifacial microsomia was suggested by Ortiz Monasterio et al. The authors believed that when mandible alone is distracted, the creation of open bite on the ipsilateral side would alter the dental occlusion. In children, following mandibular distraction, the occlusal changes will be minimal during the distraction process and the correction is accomplished by the rapid growth of the maxilla and by minor orthodontic adjustments. But in the adult patients, there may be a necessity for orthognathic surgeries or complex orthodontic treatments to achieve an optimal occlusion. Hence the simultaneous distraction of maxilla and mandible was performed in these adult patients to avoid such occlusal disasters. Also the increase in the vertical height of the maxilla would compensate for the occlusal changes and thereby contribute to the improvement in the facial appearance.

The rate of distraction and the orientation of the vector to the anatomic axis of the bone are important determinants of the technique of distraction osteogenesis.
Ilizarov had reported that the rhythm of distraction has a significant influence on the regenerate. It has been observed in animal studies that a rate of distraction of 2 mm/day resulted in fibrous union or delayed union in the distracted area. On the contrary, a slow distraction rate of 0.3 to 0.5 mm/day produced premature consolidation. Another study by Shearer on the lower limbs of the rabbit showed that a distraction rate of 0.7 mm/d appeared optimal for cell proliferation and bone formation. A distraction rate of more than 1.3 mm/day is biologically unfavorable for bone formation. The rate of distraction in the present study was 1 mm/day for a period of 20 days, in both the cases.

The control of distraction vectors during a three-dimensional bone-lengthening procedure for the correction of severe mandibular deformities is a problem of major impact. Sometimes even meticulous planning and the usage of multiplanar devices may not avoid deviations from preplanned results. In the present study the placement of the device exactly parallel to the desired direction of bone lengthening was possible in one case where simultaneous maxillary and mandibular distraction was performed over the left side, while on the other patient with the same procedure on the right side, placement of the osteotomy cut was not exactly perpendicular to the vertical ramus and hence the distraction vector (device) was also not parallel to the desired direction of bone lengthening due to anatomic difficulties. Thus, the altered vector resulted in transverse growth of the mandible leading to deviation of mandible to the undistracted side and cross-bite.

![Post-operative OPG demonstrating proper alignment of the vector](image-url)
Thus the proper orientation of the vector to the desired direction of bone lengthening is an important parameter for the successful result of the distraction osteogenesis technique. Any deviation of vector to the planned position may alter the direction of growth of the distracted bone and resultant malocclusion.

Thus the concept of manipulation of the callus was adopted to restore the occlusion in the case where the vector was not exactly parallel to the vertical ramus of the mandible. Manipulation of the callus to correct any malocclusion due to change in the orientation of vector is based on the ‘floating bone concept’ introduced by Hoffmeister et al. This concept is based on the presumable mouldability of the callus at the early consolidation phase to correct any occlusal changes resulting from vector deviation. Their method consisted of removal of the distraction devices 2 weeks after the distraction phase and the mandible was guided into the desired occlusion by means of elastics.

Thus mandible is floated into the desired position due to the mouldability of the callus. Several authors have attempted different methods of manipulation of the callus. The ‘direct manual shaping’ of the callus was another method advocated by Pensler et al. (1995) and Kunz et al. (2000). Pensler et al were the first to report on the immediate manipulation of a newly created regenerate to correct minor deviations in a 1-step procedure in 6 of 9 patients. In this method, the distraction devices were removed once the planned mandibular
lengthening had been achieved. The open bite is then closed by manual shaping of the callus to achieve optimal occlusion. Either maxillomandibular fixation or rigid external fixation was opted until bone healing and maturation.

Kunz et al reported 2 patients who underwent successful manipulation of the regenerate to correct an open bite created as a result of loss of vector during linear distraction. ‘Moulding of the regenerate’ is yet another option to control an open bite. In contrast to the previous methods, moulding is carried out during the activation phase rather than the consolidation phase of distraction osteogenesis. According to the authors, the fresh regenerate revealed considerable ability to be moulded, allowing the creation of well-shaped gonion angles and correct occlusion. The authors concluded that manipulation of a fresh regenerate offers corrective options in cases with severe vector deviation. Moreover, it could be integrated into a plan for correction of complex mandibular deformities.

Various authors had reported on callus manipulation to close, open bites resulting from vector deviation, the present study describes the direct manual shaping of the callus in a mandible that exhibited transverse growth instead of the desired vertical lengthening due to vector deviation, following simultaneous maxillo-mandibular distraction.

Callus manipulation has been reported to provide favourable results in correcting malocclusion resulting from vector deviations. Under clinical conditions, acute callus manipulation has been successful, and experimental data revealed that moulding of the regenerate may be safer under long-term aspects. Manipulation of the regenerates is believed to provide precise final result, minimizing the need for secondary corrections and diminishing treatment duration and costs. However during the process of distraction osteogenesis, the newly generated tissue is highly sensitive to mechanical strain.

In the present study, there was a delay in the ossification though the malocclusion was corrected after the callus manipulation.
Kunz et al reported bony union at the end of 49 days consolidation period, in his experimental study conducted in dogs following acute and gradual moulding of the generate to close the open bite following bilateral mandibular distraction. The authors concluded that complete fresh regenerate could be manipulated to a considerable extent without endangering early vascularization and mineralization. But the limits were not discussed in their study.

Radiological study at the end of 3 months consolidation period in the case with proper vector orientation revealed complete ossification of the callus, but the other case revealed the incomplete ossification of the callus at the same follow-up duration, following callus manipulation.
Further radiological studies during the follow-up period in the latter one, revealed gradual ossification of the callus but the surface of the newly formed bone was found uneven at the end of 6 months post-operatively though clinical features were favourable.

Thus there was a noticeable post-operative increase in the height of maxilla and mandible with horizontalisation of the occlusal plane in both cases but delayed in the case following callus manipulation.

Post-operative appearance of both cases demonstrating the occlusal plane parallel to the bipupillary line.

Pensler et al and Kunz et al in their clinical and experimental studies, reported complete ossification of the manipulated callus in the 3rd month of consolidation period and concluded that callus manipulation can offer corrective options of malocclusion, following vector deviation.

The laboratory studies of Luchs et al showed that gradual as well acute manipulation does not disturb osseous consolidation under long-term aspects. But in the present study delay in the ossification was noticed. Several authors have observed that during the process
of distraction osteogenesis, the newly generated tissue is highly sensitive to mechanical strain. Hence the manual shaping of the callus must have caused mechanical strain, resulting in the delay of ossification, during the initial phase of consolidation.

The unevenness on the cortical surface of the newly formed bone was noticed mainly along the direction of the trajectories of the force in the ramus. According to the trajectorial theory of force, the line of orientation of the bony trabaculæ correspond to the pathways of maximal pressure and tension and the bone trabaculæ are thicker in the region where the stress is greater. The vertical ramus is one of the trajectories of the mandible transmitting the forces. Thus the callus due to manipulation should have been subjected to mechanical strain resulting in the delay of ossification, and this might be exacerbated along the ramus, which is an important trajectory of the mandible. Observations based on this study hypothesize that delay in the ossification might result following callus manipulation, especially along the line of transmission of forces of the jaw.

The simultaneous maxillary and mandibular distraction and the callus manipulation had no influence on temporomandibular joint function in both the cases. Mouth opening and mandibular movements were in the normal range and there was no articular noise or pain.

Thus the study implies that, the manipulation of the callus for corrective options of malocclusion following vector deviation yields favourable clinical results, but a delay in the ossification of newly formed callus should be anticipated.

CONCLUSION:

Based on the above study it is concluded that the vector orientation is an important aspect of the distraction osteogenesis process and ‘direct manual shaping of the callus’ can be a reliable option to correct occlusal discrepancies resulting during the distraction process especially with deviation of the vector.

Manipulation of the callus may result in delayed ossification especially along the trajectories of the jaw bones.
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The use of distraction osteogenesis for preparing the alveolar crest for implantation

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Introduction of new devices:
1. Bidirectional Crest Distractor
2. Crest widener

After extraction of the teeth at the posterior segments, we lose vertical height, followed later by horizontal discrepancy. At the anterior upper and lower parts of the dentition the process of resorption is first on the horizontal plan and secondary is the vertical. When we plan to put an implant in the residual bone we encounter a problem of discrepancy between the position of the residual crestal bone of the two jaws, upper and lower. In order to put the implant in the proper position we need either to augment bone to the area or to create a new crest in the right place by distraction osteogenesis.

There are few techniques for crest splitting and bone filling or crest splitting and implantation into the slot, or guided bone regeneration using all sorts of membranes. But we are all confronted with the problems the membrane causes very often and from the experience and the literature, up to 50% and more of the onlay augmented bone is resorbed. So, after these procedures, we are left with less bone and final result is unpredictable.
In the year 1996 Chin and Toth introduced the unidirectional alveolar distractor.

Distraction osteogenesis is often called callus distraction. It is the process of new bone formation between the surfaces of bone segments gradually separated by incremental traction. The area of the callus consists of two zones of mineralization with longitudinally oriented primary osteons divided by a fibrous inter zone with collagen bundles directed parallel to the vector of distraction.

Distraction histiogenesis is the process of distraction of the surrounding tissue of the bone, like skin, mucosa, fascia, blood vessels, nerves, muscles, ligaments, cartilage, and periosteum. This is a significant advantage of the Distraction Osteogenesis over bone augmentation.

A new bidirectional crest distractor will be introduced and cases will be presented. The technique of bidirectional distraction will be presented in stages using guidance for the distraction by partial dentures or omnivac egg shell. Latency period is the time between cutting the bone and starting the distraction, which gives time for callus formation (5-7 days). Frequency of activation is not as important, and can be done every day, every other day, twice a day, etc. The smaller the segment the less marrow, and the slower the rate of activation. The rate per-day is 0.4 mm. Over distraction of 2-3 mm is needed to prevent relapse and shrinkage of the callus.

Consolidation period is two months.

Advantages of bidirectional crest destruction vs. bone augmentation:
1. Accurate crest building
2. Shorter consolidation period
3. Earlier rehabilitation
4. No lack of soft tissue cover
5. Attached gingival is saved
6. No painful donor site
7. No late secondary resorption
Disadvantages:
1. Need at least 10mm of height.
2. Difficult at posterior lower segment.

**Second Part:**

“Crest widening by distraction, an alternative technique to bone augmentation.”

A new technique and a new device will be introduced starting from the prototype of the crest widener and the last version.

Stages of the procedure:
1. 3 initial mucoperiosteal incisions.
2. Minimal exposure of the crest (No periosteal stripping of bone transport!).
3. Bone cuts using scalpel saw or tungsten bur or Piezo machine.
4. Crestal bone cut is widened using a thin osteotome
5. Crest Widener is tapped into the bone cut, ligated and activated.

The classification of the narrow ridge with sufficient vertical height is:

Type 1: Narrow-parallel alveolar crest that requires bodily movement of the buccal plate, and can be treated in two ways: The first is a two stage procedure, and the second is a one stage procedure.

Type 2: Narrow triangular alveolar crest, that requires tilting movement of the buccal plate and is treated in a one stage procedure.

**Advantage over bone augmentation:**
1. Mucosal distraction – no lack of attached gingiva and soft tissue cover (distraction histiogenesis).
2. Implant placement possible after extremely short period, 4-8 weeks.
4. Procedure easily performed under local anesthesia in the dental office
5. No morbidity and painful donor site
6. The periosteum is not stripped from bone transport segment, therefore no post-operative bone resorption.
7. Less technique sensitive
8. Minimally compromised esthetics
9. Enables lateral implant positioning when needed
More clinical trials are needed.
Treatment options in distraction osteogenesis therapy using a new bidirectional distractor system

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Abstract: Aims: There are various reasons for bone loss in the maxilla and mandible. Mainly it is due to trauma, osteotomy performed in the treatment of malignant tumours and “natural” loss of teeth due to induced periodontitis. Tooth loss leads to alveolar resorption especially in sagittal direction. This can be due to avulsion of bone substance during the accident itself or due to resorption of the alveolar crest that takes place afterwards. Shortage of bone can prevent proper positioning of dental implants unless the volume of bone is increased before implantation. Along with the loss of bone a reduction of soft tissues, the attached gingiva, is inevitable. Different methods for augmentation of severely resorbed alveolar ridges exist, but only osteodistraction enables us to obtain sufficient quantitative and qualitative volume of soft and hard tissue. In addition, the disadvantage of a second surgical site and its associated morbidity is avoided. Subject: 21 distraction osteogenesis for vertical augmentation of the (anterior) upper and lower jaw has been done during 2001 - 2004.

Patients: The patients presented with severely atrophic alveolar ridges due to atrophy caused by tooth loss in 8 patients, bone loss by
traumatic accident in 6 patients, to tumour treatment in 5 patients and to tooth aplasia in 2 patients.

**Results:** The average gain of bone was 6 mm. We could insert 61 primary stable dental implants while explantation of distractor device. We achieved good functional and aesthetic results of rehabilitation. During surgery and 2 year follow-up we observed 3 severe complications. It is to be pointed out, that these complications arose during the distraction of avascular iliac crest transplants.

**Conclusions:** Osteodistraction is an interesting and potentially sufficient therapy option for alveolar defects. Simultaneous implant placement in conjunction with extraction of the distractor device leads to good results if the new formed bone is situated in the correct position.

Furthermore distraction of non-vascular transplants and of irradiated jaw bone is risky and needs a special management.

**Introduction:**

The autogenous bone grafting is well established for augmentation of alveolar ridge defects. The distraction osteogenesis (DO) is actually discussed as an alternative method. The exact positioning of crestal bone fragment during vertical distraction of alveolar ridge is necessary for ideal axial loading conditions of implants for prosthodontic treatment of patients.

There are different methods described for distraction of the alveolar ridge:

- the unidirectional distraction with enosseal,
- the unidirectional distraction with subperiosteal devices,
- the bidirectional distraction with subperiosteal located distraction device.

In clinical studies it could be shown that a harvesting of bone height from 5 to 15 mm using subperiosteal positioned distraction devices is possible. The activation screw is described as problematic because of necessary mucosa perforation for activation of distractor
device. Around the perforation side local soft tissue infections due by oral bacteria are responsible for bone resorption.

The hidden location in the bone is an advantage in using enosseal distraction devices. The perforation of activation screw into oral cavity is situated on the alveolar ridge in masticatory fixed mucosa. This kind of specialized mucosa has a barrier function and prevents infection. The down side is described as difficult getting the device in exact positioning in three dimensions. Additionally the necessary denutrition of bone for insertion of such devices could lead to problems during distraction.

The distractor can only be placed on one side (buccal) of the proximal bone fragment, to maintain a blood supply from the other (lingual) aspect. This results typically in the mandible anterior region in the generation of a distraction vector that has a strong lingual component. As a consequence, a dislocation of the distracted fragment to the lingual or palatal side is often seen with the use of the standard unidirectional distractor system. This dislocation often prevents the simultaneous placement of implants during the procedure where the distractor hardware is removed because of bone deficiency in the ideal implant side. The need to perform a secondary osteotomy to correct the position of the distracted fragment or place an additional autogenous bone graft prior to implant placement is not the best treatment outcome.

There are a number of additional factors that can alter the distraction vector. Most importantly, the continuous increase of forces at the distractor system directed toward the coronal aspect of the proximal bone fragment. When applying distraction osteogenesis in the intraoral environment, there are unique features that require special consideration. Most notably, the musculature from the facial aspect, tongue and floor of the mouth, together with the resistance of the lingual periosteum can cause an alteration of the distraction vector. Given the problems noted above, certain technical and surgical conditions need to be met in order to ensure the correct transposition of the bone-fragment. Unidirectional distractor systems appear to be
unable to meet these conditions. To this end, a new bidirectional
distractor includes
a second set-screw, enabling the distraction vector to be changed by
turning this second screw. Using these corrections the distraction
vector can be modified up to 20° as shown in the Table 4.

The purpose of this retrospective study was to compare a new
bidirectional distraction system with a currently used unidirectional system
with particular regard to bone height attained and the need for secondary
graft procedures.

Material and Methods

Patients

Twenty-one patients were participated in this retrospective study. The patients had been referred to the Department by their primary
dentist. All patients exhibited either unilateral or bilateral partial edentulism in the mandible or maxilla in combination with loss of alveolar ridge height. The basal bone height at the surgical sites ranged from 8 to 14 mm prior to surgery. Prior to any treatment, a comprehensive intraoral and radiographic examination was carried out. The intraoral examination included an evaluation of the quality of the remaining teeth, existing prostheses and the condition of the oral mucosa. For the radiographic examination a panoramic radiograph and a lateral cephalogram were obtained. Informed consent was obtained from all prospective participants upon the conclusion of a comprehensive discussion including the potential risks and alternatives to osteogenesis distraction.

Exclusion criteria for study participation were as follows: vertical defects of the edentulous ridge associated with a history of radiotherapy in the head and neck region; chemotherapy for treatment of malignant tumors at the time of the surgical procedure; bone defects following chronic infections; the systemic use of steroid drugs; tobacco use; severe renal and liver disease; non-controlled diabetes; active periodontal disease detected in the adjacent dentition; poor oral hygiene; and a history of general non-compliance with medical or dental treatment.
Two separate cohorts (groups) of patients were retrospective created. For the first experimental group, only the unidirectional distraction osteogenesis was used. This group of 10 patients (7 men and 3 women) was treated during the years 2001 and 2002. In this group, one patient had a mandible reconstructed with a prior free microvascular fibula graft.

All of the individuals in the second experimental group were treated with the bidirectional distraction osteogenesis. This group of 11 patients (7 men and 4 women) were treated in the year 2003. In two of the group II patients, the mandible was reconstructed after tumor resection with autogenous hip bone grafts.

Surgical protocol

As stated previously, two different distractor systems were used, a different system for each experimental group; a monodirectional distractor (Martin, Tuttlingen, Germany) and a bidirectional distractor (Medartis, Basel, Switzerland). The surgical procedure was identical for both systems. All surgical distraction procedures were performed under general anesthesia. Incisions were made at the level of the alveolar crest, elevating vestibular mucoperiosteal flaps, while leaving the lingual mucoperiosteum adherent to the bone. Osteotomy was carried out at moderate speed (i.e., 1000 r.p.m.) with profuse sterile saline irrigation. The bone was prepared to allow for good adaptation of the distractor after the distractor was placed on the bone surface situated in the middle of osteotomized bone. The distraction screws were positioned and the holes for fixation of the extensions were drilled. All screws were temporarily removed.

After all saw-cuts were made, the mobility of the segment was tested. It is critical to note that the survival of the transport disk (crestal bone segment) is dependent on the preservation of the contact between this lingual/ palatal aspect of this segment and the lingual/ palatal mucoperiosteal flap. Bone segments with different length and height measurements were osteotomized. The distractor was permanently fixed to the bone with titanium screws after inspection of the vector of distraction.
The mobility of the bone segment was checked prior to wound closure. The wound was closed in 2 layers to obtain a tension-free closure. One week after fitting the distractor hardware, distraction was initiated at a special protocol. The aim was to increase the height of the alveolar ridge up to a total of 8-10 mm. For those patients in the bidirectional distractor group (Group II), the optimal distraction vector could be changed during the distraction period by adjusting an exposed, additional set screw. Once optimal bone growth had been achieved, the distractor was left in place for 3 months to ensure bony consolidation. Dental implants (Straumann AG, Waldenburg, Switzerland) were placed at the time of distractor hardware removal. Fixed partial prostheses were fabricated 10 weeks after implant placement.

Clinical and radiographic examination
Outcome data collected at post-operative follow-up examinations ranged from 6 months to 2.5 years (mean ± SD).
All radiographic and clinical measurements were made (0, 6, 18 and 30 month) by the same post doctoral fellow in the department of oral surgery who performed calibration exercises with the distractor device. The following clinical parameters were evaluated:
• pain, inflammation around the screws;
• movement of distractor system,
• change of distraction vector/ proximal bone fragment,
• loss of distraction screws,
• need for autogenous bone grafting prior to implant placement,
• loss of implants,
• sensory changes of mucosa and facial skin
The height of the augmented alveolar ridge was measured with the use of panoramic radiographs after active distraction time and before implant insertion. The radiographs made prior to the surgical procedures were compared with radiographs made before placement of the implants and during the follow-up exams to detect bone augmentation as well as possible resorption. The sagittal location of
the bone fragment was demonstrated by lateral cephalograms. The measurements of transversal bone movement through the activation of the second screw were correlated to the amount of turns. The mean follow-up after delivery of the prosthesis was 8 ± 4 months.

Data Analysis

The retrospective clinical data obtained at the recall examinations was entered into an Excel™ data base and transferred to “StatXact” (Cytel, Cambridge, USA) for statistical analysis. Data derived from continuous measures such as bone height and transverse bone movement were analyzed with a one-way analysis of variance, nonparametric data were analyzed with Fisher’s exact test. The dental implant survival data were evaluated with a Kaplan-Meier survival analysis.

Results

A consecutive series of 21 alveolar segmental distraction procedures were done prior to implant placement and prosthetic restoration. In all cases, natural teeth or prosthetic tooth replacements were present in the opposing jaw. The bone gain resulting from the use a monodirectional distractor-system was 5.3 ± 1.8 mm as compared to the bidirectional distractor-systems where 6.1 ± 2.3 mm was attained. Resorption of the crestal portion of the alveolar bone was not observed during the observation time. No significant difference (p=0.4) between the two groups regarding bone height was detectable. Upon removal of the distractor, it was necessary to place six autogenous grafts as a consequence of unilateral distraction, while two grafts were needed after the use of the bidirectional distractor (p=0.08).

Overall, 10 of the 21 procedures led to a complication (crestal bone dislocation, infection). Six of these resulted from the use of the unidirectional distractor, while three were associated with the bilateral distractor (p=0.08). This outcome variable also indicated no difference, but once again there was a tendency towards a significant difference.
between the two methods. One severe complication (bone fracture) was seen, which occurred in the patient that had received nonvascular bone transplants from the iliac crest months before the procedure. 59 implants had been placed in the augmented areas. One implant had to be removed between the 3rd and 4th week post-operatively.

A conventional removable prosthesis was placed in this arch. With regard to implant prosthetic rehabilitation, 16 patients received a removable prosthesis while 4 received a fixed prosthesis. A survival analysis of the implants demonstrated that 94 percent of the implants placed into the bone augmentation via osteogenesis distraction have survived for up to 40 months, with no significant difference (p=0,6) noted between the two methods of distraction.

Discussion

Distraction osteogenesis offers an option for the treatment of vertical alveolar bone deficiencies while also enhancing the width of the ridge and the band of keratinized soft tissue at the alveolar ridge. Vertical distraction generally results in less resorption than autogenous bone graft techniques and eliminates possible disease transmission when compared with the use of allogenic materials.

The technique is not without drawbacks, such as the discomfort caused by the distractor, which may interfere with eating and speaking. The need for absolute compliance of the patient and the family is of utmost importance. A close and frequent follow-up is essential. Usually distractor systems are able to augment bone in a single direction. The distractor needs to be fixed to the bone with a correct primary vector for the transposition. The continuous power of muscle fibers such as those of the M. genioglossus or M. orbicularis oris has the potential to dislocate the proximal bone fragment to the lingual direction with some frequency. When this occurs, the placement in a prosthetically useful location of dental implants upon the removal of the distractor device is not possible. This requires the use of bone grafting procedures post distraction to augment the buccal aspect of the site prior to implant placement. In the cases reported
here, the use of a unidirectional distractor was frequently associated with a need for additional autogenous hard tissue grafting. The expectation that bidirectional distraction would need no additional bone grafting because of the right position of the crestal fragment for inserting implants was not realized.

There were not significant increases of implant failures observed in patients requiring grafting procedures, but some less than optimal esthetic results were noted. Others have found that the combination of bone grafting and implant placement procedures after distraction procedures may be problematic. Jensen observed that all failed implants had required bone grafting of dehiscence areas. This may be attributed to the temporary decrease of blood supply to the newly augmented bone resulting in a reduction of nutritive conditions for the grafted bone. The need for additional augmentation procedures may be eliminated in cases where the distraction vector is optimized. This can be accomplished through a secondary alteration of the vector with the use of a special 3-D-distractor. As with other osseous surgical procedures, vertical distraction osteogenesis performed in healthy patients and in healthy bone should result in fewer postoperative complications. The distraction of previously irradiated and nonvascular transplanted bone requires a different approach. Radiotherapy in combination with surgery is the treatment generally needed for malignant tumors in the craniofacial region.

The comparison between the distraction osteogenesis and onlay bone grafting in vertical bone deficiencies of the alveolar ridge shows in the literature no difference in the bone gain. The advantage of the distraction method described here is the bone gain without harvesting defects in the donor area. The back side of the intraorale distraction osteogenesis is the number of complications.

**Take home message:**

The results reported here provide additional support to the conclusion that the success of alveolar distraction procedures are based on good patient selection, good quality of bone prior to treatment
and a well conceived prosthetic plan in conjunction with the
determination and control of the distraction vector. The correct
movement of the proximal bone fragment requires the ability to change
the distraction vector during the distraction process. This precise
placement of the distracted bone segment provides a basis for
optimized dento-alveolar restoration. A long-term follow-up of dental
implants placed into alveolar bone augmented through osteogenesis
distraction is warranted.

Other Authors : Christina Wolf, Martin Freilich, Witold Zenk
Distraction osteogenesis treatment
A tool for reconstruction
of alveolar bone defects

P. Schleier

Department of Oral Surgery of Stavanger University, Norway

Oral carcinomas

treatment results in soft and hard tissue defects
- osteotomy performed in the treatment of malignant tumors

Dr. Peter Schleier
Department of Oral Surgery of Stavanger University, Norway
Autogenous bone grafting

free fibula transplant (vascularized)
iliac crest with immediate implants for vertical augmentation
cortical blocks from the genial region or ramus

Reference:

Dr. Peter Schleier
Department of Oral Surgery of Stavanger University, Norway

Origin and principles of distraction osteogenesis (DO)

Prof. A. Ilizarov developed basic principles and equipment for DO

<table>
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<tr>
<th>Journal</th>
<th>Year</th>
<th>Author(s)</th>
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<th>Area</th>
<th>Bone span</th>
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<td>uni-directional</td>
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</table>

Dr. Peter Schleier
Department of Oral Surgery of Stavanger University, Norway
3rd Asia Pacific Congress on Craniofacial Surgery & Distraction Osteogenesis

Research hypothesis

Comparison between uni-directional and bi-directional distraction osteogenesis:

- Are there differences in the amount bone gain (distraction height)?
- Are there differences in the complication rate (dislocation of crestal fragment)?

Patients and methods

Retrospective study with uni- and bi-directional DO

<table>
<thead>
<tr>
<th>Patients</th>
<th>Unidirectional</th>
<th>Bidirectional</th>
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<tbody>
<tr>
<td>Total Number</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>Men</td>
<td>7</td>
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</tr>
<tr>
<td>Women</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Median Age (years)</td>
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<td>19-68</td>
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uni-directional distraction device

bi-directional distraction device

Dr. Peter Schiefer
Department of Oral Surgery of Stavanger University, Norway
3rd Asia Pacific Congress on Craniofacial Surgery & Distraction Osteogenesis

Results

Significant difference between the two groups cannot be evidenced.

Complications

<table>
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<tr>
<th></th>
<th>uni-directional device</th>
<th>bi-directional device</th>
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<tr>
<td>during surgery</td>
<td>no</td>
<td>1 Fracture of basal bone</td>
</tr>
<tr>
<td>during distraction period</td>
<td>1 breakage of distraction device</td>
<td>1 Fracture of basal bone</td>
</tr>
<tr>
<td>during retention time</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>during implantation</td>
<td>7 times need for bone grats</td>
<td>1 time need for bone grats</td>
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There is statistically a tendency towards a significant difference between the two methods.
Summary

Research questions
- Are there differences in the amount bone gain (distraction height)?
- Are there differences in the complication rate (dislocation of crestal fragment)?

Results
There is no difference in harvested bone height between the uni- and bi-directional distraction system.
There is a tendency towards a significant difference between the two methods in regards to the complications.

Take home message

1. DO is a sufficient method for treatment of bone defects.
2. We observed dislocation of proximal bone fragment with the uni-directional DO.
   This leads to a need for secondary bone grafting during implantation.
3. DO in non vascularized bone grafts and irradiated bone is related to complications.

Dr. Peter Schieer
Department of Oral Surgery of Stavanger University, Norway
Distraction versus microvascular bone transplants in reconstruction of severe alveolar ridge defects

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SUMMARY

Purpose: Alveolar ridge distraction has become an important supplement in augmentative preprosthetic surgery. One of their main advantages in comparison to conventional augmentation techniques is a better result in extended defect cases. Microvascular bone transplantation is also an alternative augmentation technique used to cover severe defects. In this manuscript the two techniques are compared to each other and the results, complications, advantages and disadvantages are demonstrated and discussed.

Methods: In 31 patients with severe alveolar ridge deficiency caused by trauma, tumour surgery or atrophy a reconstruction of the alveolar ridge has to be performed for later treatment with an implant based prosthesis. 15 patients where treated with different techniques of alveolar ridge distraction and 16 patients with microvascular bone transplants. Here 7 patients were treated with microvascular femur transplants, 5 patients with fibula and 4 with iliac crest transplants.

The patients were treated with dental implants and implant based prosthesis later on.
Intra- and postoperative complications, donor site problems, soft tissue conditions and periimplant conditions were registered 6 and 12 months after implant placement. These criteria as well as the defect design and size, patients history and peri-operative conditions were compared to each other.

**Results:** Both treatment concepts can be used with good success in patients with severe alveolar ridge defects. If penetrating three-dimensional defects are to be corrected or irradiated patients are to be treated microvascular transplantation is the treatment technique of choice. In contrast hereto better soft tissue conditions result by distraction. Furthermore donor site problems can be avoided. There is no significant difference of the success rate for dental implants.

Conclusions: Distraction of the alveolar ridge is still a successful and useful technique for ridge reconstruction in severe defect cases. Depending on the defect size and morphology there are several cases that can not be treated by distraction effectively. If combined bone and soft tissue defects are seen, microvascular transplants can be used for alveolar ridge reconstruction with good success.

**INTRODUCTION**

In cases of severe jaw defects conventional augmentation techniques are often not successful. If combined hard and soft tissue defects with bad transplant bed conditions are to be covered alternative techniques for jaw reconstructions have to be used. Here distraction techniques become more and more important over the last years. Alveolar ridge defects as well as continuity defects of the mandible and maxilla can be covered with the use of callus distraction techniques. As an other alternative techniques also microvascular tissue transfer can be used. Both techniques have become more precise and well developed during the last years. Nevertheless every procedure has their advantages and problems. Therefore it is very important to choose the best technique for a special defect with its special conditions. In this study distraction techniques and techniques
MATERIAL AND METHODS

In 31 patients with severe alveolar ridge deficiency caused by trauma, tumour surgery or atrophy a reconstruction of the alveolar ridge has to be performed for later treatment with an implant based prosthesis.

15 patients where treated with different techniques of alveolar ridge distraction and 16 patients with microvascular bone transplants.

In the distraction group there were 4 patients with severe defects of the anterior maxilla and 4 patients with severe alveolar ridge deficiency of the mandible after trauma. Furthermore 4 patients had severe atrophy of the edentulous mandible with a residual height of less than 8 mm and 3 patients had a severe bone defect after tumour surgery. The patients were treated with three different kinds of distractors. In 5 cases endosseous enoral distractors (DISSIS®-Distraction implant, SIS-Company, Austria) and in another 10 cases extraosseous enoral distraction devices were used (Track®-Distractor, Martin, Germany; Crane®-Distractor, Orthognathics, Switzerland). Distraction started 7 days after surgery and was performed with an distraction speed of 0.5 mm a day. The way of distraction and therefore the augmentation height was between 6 and 15 mm in vertical direction. After distraction a stabilisation and healing period of 3 months followed. The the distractors were removed (10 cases) or the distraction insert was changed to a stabilisation insert (5 cases) and dental implants were placed (41 implants).

In the microvascular reconstruction group there were 4 patients with severe defects of the anterior maxilla and 3 patients with severe alveolar ridge deficiency of the mandible after trauma. Furthermore 5 patients had severe atrophy of the edentulous mandible with a residual height of less than 8 mm and 4 patients had a severe bone defect after tumour surgery.
Seven patients were treated with microvascular femur transplants (Fig.1-4), 5 patients with fibula and 4 with iliac crest transplants.

Anastomoses were performed as end to end or end to side anastomoses between the facial artery, labial superior or inferior artery and the donor arteries as well as between the concomitant veins. In 6 cases enoral anastomoses have been performed to avoid an extraoral approach.

The patients were treated with dental implants (44 implants) 4 to 6 months after reconstructive surgery.

In both groups the dental implants were loaded by fixed or removable prostheses 4 to 6 months after implant placement.
Intra- and postoperative complications, donor site problems, soft tissue conditions and periimplant conditions were registered 6 and 12 months after implant placement. These criteria as well as the defect design and size, patients history and peri-operative conditions were registered and compared to each other.

RESULTS

Distraction group: The distraction segments were between 2.5 cm and 10.0 cm of mesio-distal length. The vertical height of the distraction segments was between 0.4 cm and 1.3 cm. The patients stayed in the hospital for 3 to 7 days.

There were two cases of infection during distraction with a miniplate distractor that could have been treated by incision and antibiotics successfully. Furthermore there was one fracture of a high atrophic mandible. In very case the planed vertical distraction height was achieved. Nevertheless there was seen a lingual or palatal sliding of the distraction segment in three cases with a miniplate distractor. The dislocation of the segment was only of small extent, so that implant placement was performed with no severe problem later on. In every case implants could have been placed in correct position.

Three out of 41 implants did not osseointegrate and were removed. There was no implant loss after loading. There were no severe periimplant problems and healthy periimplant conditions after loading. The mean periimplant probing depth was between 1 and 2 mm.

Microvascular reconstruction group: All anastomoses were performed without complications. The transplants to be harvested were between 2-2-1.5 cm and a maximum of 10-5-1.5 cm in diameter (according to the defects size: mesiodistal – buccooral – craniocaudal diameter). The length of the microvascular pedicle was between 4 and 10 cm. In all patients it was possible to perform the defect coverage in the correct size and design. There was no flap loss. The patients stayed in the hospital for 5 to 8 days.
In 12 patients the donor site was free of complications or problems at the 6 months and 12 months check-up. Three patients had a sensory deficiency of a small skin segment in the lower extremity. In all other patients there was a normal sensibility and muscular function. There was no pain in the donor site region 6 and 12 months postoperatively. The scars were normal in 15 patients. In one patient a hypertrophic scar had to be corrected by second surgery.

Intraoperative photo in the same patient with the anterior mandibular defect after deflection of the mucoperiostium (scar).

Intraoperative photo showing the osteoperiosteal femur flap. The vascular pedicle is already prepared in a length of 7 cm.
In every case, implant placement was possible in the planned position after microvascular bone transfer. Two to six implants were placed in the augmented region. The mean width of the soft tissue layer in the implant region was 2 to 3 mm. The highest values were measured in iliac crest transplants. There was one implant loss. Every other implant was loaded with a fixed or removable prosthesis 4 to 6 months after implant placement.

Good periimplant conditions were seen in all but one patient with an iliac crest transplant. Here one implant showed periimplant bleeding 6 months after implant loading. Periimplant soft tissue correction became necessary.
Function and aesthetics of all prosthetic superstructures were satisfying.

DISCUSSION

Alveolar ridge augmentations prior to implant placement have become more important in recent years. Achieving the best possible implant bed and creating good conditions for satisfying red aesthetics are the main aims for ridge augmentation with the help of free bone transplants. In some cases poor soft tissue conditions make it impossible to cover the free bone transplant. Here a combined hard and soft tissue defect also makes augmentation of the gingiva and mucosa necessary. In some of these cases free bone grafting can be carried out, first causing a worse soft tissue situation after initial surgery which is corrected by later surgical soft tissue management. In the case of severely atrophic edentulous alveolar ridges showing poor regenerative potential in combination with poor soft tissue conditions, alternative techniques like alveolar ridge distraction or microvascular bone reconstruction are sometimes the only safe technique for bone reconstruction. Distraction is the only conservative technique for bone augmentation also resulting in better soft tissue conditions. Furthermore it is the only technique avoiding bone transplantation and therefore donor site problems. Nevertheless a small amount of
bone having a regenerative potential for building callus is necessary. If the distraction segment should not be less than 4 mm of height avoiding necrosis of the transport segment. If distraction should be performed in the high atrophic mandible a residual height of the basal bone of more than 4 mm should be left to avoid mandibular fracture. Therefore a residual vertical height of 8 mm before osteotomy should be given, if major complications are to be avoided. If there is a residual height of the high atrophic mandible of less than 8 mm microvascular bone transplantation should be preferred. Here the well known technique of microvascular fibula transfer is used, if large bone segments are to be transplanted. If smaller defects are to be covered and penetrating defects or defects with a minor amount of residual bone are to be treated a different transplant type is used. Here the microvascular iliac crest is often used. The bony part of the transplant can be shaped individually to the defect by having a higher percentage of cancellous bone easier to be moulded. If microvascular iliac bone transplants are taken, good adaptability is given, but the underlying muscles are often to bulky, resulting in a thick crestal soft tissue layer later on. Here also in our patients a problem of later poor peri-implant condition was registered, that has never been seen in distraction cases. Taking a microvascular osteo-periosteal fibula transplant means the soft tissue layer is thin, taking only the bone covering periosteum to be epithelialized secondarily. In contrast to iliac bone it is more difficult to shape it to the local alveolar ridge defect having only a small portion of cancellous bone. In comparison to these two transplant types, the microvascular osseous scapula is difficult to adapt and has a thick soft tissue layer too. Therefore it cannot be used in defect coverage of localized alveolar ridge defects of a minor extent. Therefore a cortico-cancellous transplant was sought which can easily be shaped and supplied by the local periosteum and which could be harvested in different sizes. Such a transplant taken from the distal femur is used with good success in these cases. This transplant can be taken as a combined mono-cortico-cancellous bone transplant covered by a small periosteum layer. While keeping the periosteum intact, the transplant
can be precisely shaped according to the defect. Furthermore the periosteum can be used for soft tissue coverage when sutured to the local muco-periosteum and being epithelized secondarily. Like in other microvascular transplants, it is possible to place dental implants six months after bone healing while removing the osteosyntheses. Here only a small soft tissue layer of 2 mm in height was seen, which resulted in good periimplant conditions comparable to the local muco-periosteum.

Although a more difficult periimplant situation resulted in a patient after microvascular iliac crest transplantation implant success was similar in both patients groups. After implant loading there was no implant loss.

In contrast to distraction techniques there were no donor site problems in distraction patients but sensory deficiency in 3 patients after microvascular bone transfer and scars in the donor site regions that were no problems for the patients themselves.

CONCLUSIONS

Both treatment concepts can be used with good success in patients with severe alveolar ridge defects. If penetrating three-dimensional defects are corrected or irradiated patients are treated, microvascular transplantation should be the treatment technique of choice. In contrast hereto better soft tissue conditions result by distraction. Furthermore donor site problems can be avoided. There is no significant difference of the success rate for dental implants.

The major problem of microvascular transplants is correct shaping to the defect without damaging vascularisation. New techniques of microvascular bone transfer and anastomoses make better results and minor complications possible. For alveolar ridge distraction better distraction devices and individual distraction techniques also lead to better results by minimal invasive surgery.

Other Authors: H Bürger, FM Chiari
REFERENCES


Rapid Canine distalization and skeletal anchorage

Antonio Korrodi Ritto
Clinica de Ortodoncia, Leiria, Portugal

Abstract: Most orthodontic treatment involves premolar extractions following canine distalization, levelling and alignment. During many decades this was one of the standard procedures for crowding teeth. A few years ago another approach has been introduced with the goal of fasten the treatment. This was called periodontal distraction osteogenesis, and allows a canine distalization in 2 or 3 weeks.

Method: A custom mini distractor device mounted in a telescopic appliance was used to achieve the rapid canine distalization.

Results: Canine distalization was achieved in 2 or 3 weeks, with good radicular control.

Conclusion: This new approach is a safe method and can be employed in specific situations, when the time of treatment is an important factor.

The desire for tissue lengthening was an old dream for mankind. On 1859, Wiscott described the uses of two bars hooked to a telescopic third one in order to achieve maxillary expansion. Codvila for long bone lengthening, used intermittent traction on an osteotomized bone, however, the biological principles for bone lengthening was only
described in the 50’s by a Russian orthopedic surgeon, Gravial Ilizarov and a surgical protocol could be achieved.

Since the studies of Ilizarov, the technique has been widely used on orthopedics, but was only in 1972 that maxillofacial surgeons woke up for distraction. Snyder using distraction for mandibular lengthening was the first to describe the uses on cranio facial skeleton. on dogs and Mac Carthy reported the use of distraction osteogenesis for the correction of micrognathia on four children in 1992. Since these papers, the technique has been used on several applications on cranio facial skeleton.

Although the regular rate of tooth movement during canine retraction is about 1 mm per month, it has been shown that by orthodontically moving the tooth into the fibrous bone tissue just created by distraction osteogenesis in a canine model, the rate of the orthodontic tooth movement could be as much as 1.2 mm per week in the mandible.

The application of dental traction force to treat skeletal deficiencies has been reported since the eighteenth century. In 1876 Farrar reported his “positive system” to retract the canine into the space left after extraction of the first molar. The distal movement was completed after 46 days. In 1887 Angle developed a retraction screw for the same purpose.

Recently, many methods have been proposed to enhance the rate of tooth movement: Accelerated Osteogenic Orthodontics® (Bill and Tom Wilcko), Corticision® (Young Guk Park), injection of biologically active peptides and rapid canine distraction.

Rapid canine retraction can be accomplished by different ways. The interdental distraction osteogenesis followed by orthodontic tooth movement into the rapidly mineralizing bone regenerate is one of the techniques. Osteotomies surrounding the canines are made to achieve rapid movement of the canines in the dento alveolar segment, in compliance with the principles of distraction osteogenesis.

Another rapid canine retraction technique consists of surgically undermining the interseptal bone distal to the canine followed by
rapid tooth movement into the previously extracted first premolar socket – “dental distraction”. The rapid stretching of the PDL accelerates the periodontal cellular response without the initial delay seen during normal orthodontic tooth movement.

There is another procedure for rapid canine retraction which includes bone decorticates (round cuts in internal and external cortical bone) together with alveolar bone removal distal to the canine.

The major drawback with these new approaches are the size and location of the distractors which give discomfort for the patient, and some extrusion and tipping of the canine.

As referred by Farrar, there was non perceptible change in the position of the posterior teeth, suggesting that no anchorage loss occurred. This is due to the lag period of minimal tooth movement that persists for approximately 2 to 3 weeks after applying a light or heavy orthodontic force.

Skeletal anchorage can be applied in two different ways together with dental distraction. When some problems occur during the distraction, such as distractor fracture, debond, bad patient management with the screw…, the lag period can be passed and the anchorage loss appears. In these cases it is suggested to place a micro implant distal to the distractor to stabilize it, and to prevent this situation. The same micro implant can also be used after distraction to paralyze canine root, and to increase anchorage during incisors retraction.

On the other hand, skeletal anchorage can be applied to stabilize the position of the distractor during dental distraction, particularly when there is no braces and orthodontic wires to guide the canine during the distal movement or when the distractor is not mounted in a telescopic arm that is commonly used to avoid tipping due to the space between the nut and the screw. After distractor removal the micro implant can be used to increase anchorage during incisors retraction.
Introduction

Adult orthodontic patients increasingly desire both better esthetics and a short orthodontic treatment time. In order to meet the new demand, clinicians have recommended improved techniques. In them, corticotomy has many advantages such as less expensiveness and less morbidity compared to orthognathic surgery and there are various clinical reports about corticotomy assisted orthodontic treatment.

Chung developed new types of corticotomy assisted orthodontic treatment named Speedy Orthodontics™. In this presentation, we will introduce this new treatment concept and scientific researches about treatment effect, possible complication and solutions, and the clinical applications from teenagers to elderly patients through over eight year clinical experiences.

Speedy Orthodontics

Speedy Orthodontics is defined as perisegmental corticotomy-facilitated orthodontic treatment which combines corticotomy and orthopedic force application. It generates the compression osteogenesis (CO) in the corticotomized segment during orthopedic
traction. This concept started from an observation that the medullar bone around anterior teeth can be easily bent by retraction force if the cortical layer between the basal and alveolar bones is removed.\textsuperscript{3,5}

Orthopedic force should be applied for successful bending of corticotomized segment. Partial osseointegration-based mini-implants named C-impant or plates can easily endure multidirectional heavy forces.

Pre and post retraction X-ray view during Speedy Orthodontics

**Surgical Procedure**

The designated teeth are removed and a corticotomy is performed in the maxilla, and if necessary, anterior segmental osteotomy can be performed in the mandible under local anesthesia.

In the maxilla, a mucoperiosteal incision is made along the palatal mucosa and the bone was exposed sparing the incisial nerve and artery. A vertical and horizontal bone cut is made connecting the first premolar sites.

Two weeks later, to allow reconnection of the palatal soft tissue blood supply, a buccal corticotomy is executed. Fixed osseous anchorage named C-plate, a C-lingual retractor are installed.

**Post surgical orthodontic procedure**

The maxillary anterior teeth are fixated into a single unit with the lingual retractor and a labial bonded wire if necessary. A retraction force of 500–900 gm per side are usually applied skeletal fixtures.
Retraction of the anterior corticotomized segment is usually required under six months, after which the C-lingual retractor is removed. Maxillary anterior brackets are placed to level and align the anterior teeth during finishing stages. Fixed and removable retainers are prescribed after debonding.

Clinical implication and Conclusion
In the clinical study of 29 speedy orthodontic patients, there showed good sagittal correction in facial balance and alveolar bone bending effect after speedy orthodontic treatment. And there were no complications such as bone necrosis and significant apical root resorption after treatment.

Speedy Orthodontics can be used as effective alternatives to the orthognathic surgery in various cases that show the anterior protrusion. Especially it is indicated in the adult patients with bimaxillary protrusion, Class II division 1 upper anterior protrusion, and alveolar protrusion with anterior open bite.

Other Author: Kyu-Rhim Chung

Reference
Ankylosis in the permanent dentition is considered to be one of the most challenging problems in dentistry and usually has poor long-term prognosis.

The typical treatment of such cases usually involves repetitive luxation or removal of the involved teeth to prevent potential development of unwanted pathological conditions.

Bone grafts/implants are normally required to restore form and function when ankylosed teeth are extracted. In order to save the ankylosed teeth and to limit the need for implantation, an alternative approach has been developed using the principles of distraction osteogenesis to move these teeth with alveolar bone as one block.

OBJECTIVES
The purpose of this clinical study was to evaluate the treatment outcome and the stability of ankylosed teeth and or compound implant /alveolar bone segment treated by distraction osteogenesis to restore maxillary vertical dimension and development.
MATERIALS AND METHODS

Four adult patients having ankylosis of two upper central incisors, one upper cuspid and one first permanent molar were included in this study. In addition two more cases with existing implants that suffered from alveolar bone defect were also included. All the patients were treated with osteodistraction of the ankylosed teeth or implant with surrounding alveolar bone.

Treatment required one surgical procedure and two weeks of distraction. Teeth/implants were distracted at a rate of 1mm/day and a rhythm of two turns/day. Teeth /Implants were stabilized with braces following two weeks of distraction to allow for bony remodeling.

RESULTS

The combined teeth or implants/alveolar bone segments were successfully moved by osteodistraction by an average of 6mm (measured at CEJ) and normal aesthetics and function were established at treatment completion.

Post-treatment computer tomography revealed complete bone healing at the distraction site.

DISCUSSION

Our results are in agreement with previous reports that alveolar bone distraction is a viable technique when other treatment options are complicated. The present technique provides a promising approach for treatment of ankylosis and or failed implants due to alveolar bone deficiency without the need for bone graft. The use of ROD5 appliance is unique. It can be bonded to the teeth, is aesthetically acceptable (tooth colored) and is easily handled by the patients, dentists, orthodontists, periodontists, and oral surgeons. This study presented successful results and the relatively easy technique. It provides a new hope for many similar cases.
CONCLUSIONS

Ankylosed teeth were moved into the arch with the combination of a simple surgical procedure and distraction of the tooth-bone block. Each patient wore ROD5 distraction appliance about two weeks. Complete bone growth, healing, maturation and considerable expansion of soft tissue were noted clinically.

This fascinating technique is acceptable by patients and is easily managed by dental surgeons.
Histomorphometrical measurement of the distraction regenerate following continuous motor-driven versus noncontinuous lengthening of the mandible: Experimental study on increased distraction speed in pigs

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**Purpose:** The effect of noncontinuous versus continuous motor-driven distraction of 1mm and 3mm per day was investigated in 20 Göttinger miniaturpigs by evaluation of the distraction regenerate using histomorphometrical measurements.

**Method:** At the right mandibular angle an osteotomy was performed via a submandibular incision. The distraction device (Synthes, USA) was placed subperiosteally and activated 1mm and 3mm per day manually and using a motor system (Maxon, Switzerland). The animals were sacrificed at 4 and 8 weeks and evaluated by high resolution spiral CT scan, contact microradiography and polychrome sequence labeling and microscopically for histomorphometrical measurements.

**Results:** 19 out of 20 animals demonstrated intensive new bone formation with bridging of the distraction gap. Following continuous distraction more primary bone healing and earlier remodeling compared to noncontinuous distraction was demonstrated by histomorphometrical measurements and CT scans. Early subperiosteal bone formation and delayed bone formation in central parts of the distraction gap were noted. The amount of new bone formation
following continuous distraction of 3mm per day was comparable to the results of noncontinuous distraction of 1mm per day. Following noncontinuous distraction osteogenesis of 3mm per day bone formation was reduced and of inferior quality with increased enchondral ossification.

**Conclusion:** Bone formation following continuous distraction was superior compared to noncontinuous distraction. Significant shortening of the active distraction period from 15 days to 5 days by increased speed of distraction showed satisfying bone regeneration when continuous distraction was performed. Due to early remodeling following continuous distraction shortening of the stabilisation period and overall treatment time seems to be possible.

**Acknowledgement:** This study was supported by AO Research Grant 98-S38 and by donation of the distraction devices by Synthes Company, Paoli, PH, USA.

**Other Authors:** Metzger MC, Weyer N, Schmelzeisen R.
Longterm effect of unilateral lengthening of the mandible on TMJ

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**Purpose:** The effect of unilateral distraction of 15mm in the mandibular angle on the temporomandibular joint following noncontinuous versus continuous motor-driven distraction of 1mm and 3mm per day was evaluated in 20 Göttinger miniaturpigs.

**Method:** Following an osteotomy at the right mandibular angle the distraction device (Synthes, USA) was placed subperiosteally and activated 1mm and 3mm per day manually and using a motor system (Maxon, Switzerland). At 4, 8 weeks, and 6 months the animals were sacrificed. High resolution CT scans were performed before the mandibular condyle process was evaluated by contact microradiography, microscopy and polychrome sequence labeling.

**Results:** 19 out of 20 animals demonstrated intensive new bone formation with bridging of the distraction gap. New bone formation in the condylar head and neck area was delayed compared to the bone formation in the distraction gap. Intensive appositional bone formation in the condylar head and neck were increased in the medial aspect on the right and in the lateral aspect in the left condyle due to deviation of the mandible to the nondistracted side.

**Acknowledgement:** This study was supported by AO Research Grant 98-S38 and by donation of the distraction devices by Synthes Company, Paoli, PH, USA.

**Other Authors:** Metzger MC, Weyer N, Schmelzeisen R.
Management of velopharyngeal incompetence in cleft

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**Purpose:** Most patients with cleft palate obtain complete velopharyngeal closure after primary palatal repair. However, some patients may show reappearance of nasality at a later age. The aim of this study is to clarify how functional evaluation relates to structural evaluation in velopharyngeal closure from infancy to childhood in patients with repaired cleft palate.

**Methods:** Subjects were 10 patients with repaired cleft palate. In all subjects, the complete velopharyngeal closure was confirmed by perceptual and nasal endoscopic evaluations at 5 years of age. They were divided into two groups according to the status of velopharyngeal closure at 10 years of age, the VPC group was consisted of 5 subjects with velopharyngeal competence and the VPI group was consisted of 5 subjects with velopharyngeal incompetence. The velar length to pharyngeal depth ratio (adequate ratio) at rest, and the velar elevation, the velar contact length against the posterior pharyngeal wall, and the protrusion of posterior pharyngeal wall during blowing were measured on lateral cephalograms taken at 5 and 10 years of age. Longitudinal changes and differences between the two groups were evaluated.
Results: a. In all subjects, the pharyngeal depth increased larger than the velar length and the adequate ratio decreased. b. The velar elevation and the velar contact against the posterior pharyngeal wall in the VPI group were lesser than the VPC group at 5 years of age. It became remarkable at 10 years of age. c. The protrusion of posterior pharyngeal wall was almost the same between the two groups.

Conclusion: Despite the velopharyngeal competence at 5 years of age, since the subsequent increase in velar length was small, it was suggested that some patients with lesser velar elevation and velar contact against the posterior pharyngeal wall might be at risk of deterioration in their future velopharyngeal function.
Primary Rhinoplasty in Cleft Lip and Palate Patients

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Introduction

The full rehabilitation of a patient with a cleft of lip alveolus and palate is still a challenge for a cleft and craniofacial team.

In the late 1970ties DELAIRE has portrayed a convincing surgical method to (re-)unite the perioral and perinasal muscles in such a functional way that the connection between the nose (nasal septum) as primary growth centre and the zygomatico-maxillary suture as secondary growth centre can be physiologically reconstructed.

This method is also supposed to help creating a natural inner and outer nose by forming a normal nasal floor, a good nasal trip, and symmetric nasal alae.

Material and methods

Beginning in 1994 all primary cleft lip and palate cases (about 40/year) at the University of Leipzig were operated according to the above stated principles.

In close cooperation with the cleft centre at the University of Bruges, Belgium (head: Prof. Dr. Dr. M. Mommaerts) 22 cases of Leipzig underwent a thorough nasal analysis by the centre of Bruges. Three series of pictures were compared:
1) before lip/nose reconstruction (age 4 to 7 months)
2) at age 5 years
3) at age about 10 years

A special nasal analysis had been developed using well defined lines and angles that can be reconstructed relatively to each other so that no 1 : 1 photographs were necessary.

Results

In unilateral cleft lip and palate cases a good symmetry of the nose within the facial structures could be found. There was also a very good symmetry in the width of the heminoses and also intranasally.

The tip of the nose, however, seemed to be still rather broad.

In bilateral cleft cases there was also a good symmetry of the nose within the facial structures and a very good intranasal symmetry (nostril height, width, angulation).

As could almost be expected there was still a low tip to width ratio.

Conclusion

The functional reconstruction of the perioral and the perinasal muscles fosters continuous midfacial growth and gives sure support to the nasal structures. Later corrective rhinoplasties may not be ruled out but will probably be minimised in their extent.

Literature

Precious, D. S.; Delaire, J. Surgical Considerations in Patients with Cleft Deformities

Orthodontics or Surgery

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Orthodontic treatment for abnormal skeletal deformities after growth and development is always stated to be accomplished by a combination of orthodontics and surgery, this method of treatment is confirmed by most textbooks and literatures.

Some patients’ attitude, concern and systemic problems lead orthodontists to look for unconventional methods in order to satisfy the patients needs regarding oral physiology, function and esthetics. In this presentation many cases treated results will be presented to prove that altering the neuromuscular function could effect bone remodeling after growth is ceased and could achieve acceptable result for both the practitioner and patient.

1- Asymmetrical malformation in adult patients traditionally need extensive orthodontic treatment and mostly followed by surgical procedure, in this article the abnormal function will be restored in order to induce bone remodeling in the direction of symmetrical function of the neuromuscular system of the oral cavity to correct the skeletal deformities.

2- Moderate skeletal CL III due to combination of Maxillary retraction and mandibular prognathism which required bimaxillary
surgery were treated unconventionally mostly by approaching the maxillary complex to compensate the anterior posterior discrepancy, transferring the patients to moderate bimaxillary protrusion, this result lead to more satisfaction in regard to the patients initial appearance.
Purpose: Implant surgery has many potential complications that sometimes cause serious injuries to adjacent tissues in addition to loss of bone and implant so we decided to introduce and analyse our experience in previous 4 years.

Method: We conducted a retrospective study among implant cases which were referred to our clinic to treat complications or consultation results. We had 78 cases; we classified the cases in 3 major groups: the first one, bad treatment plan (inproper number, size, diameter,...) included 40 cases; the second group, poor technique (inproper use of instruments, old burs, over heating,...) included 30 cases; and the last group (emergency) included 10 patients. Of course, some of the cases were fall into two or three of categories.

Conclusion: All of the complications can be prevented by a good treatment plan and gentle surgery.

Others Authors: Dr. Amin Yamani, Dr. Farzin Sarkarat.
Supportive Therapy in the Treatment of TMJ Disorders

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Abstract: Internal derangement of the temperomandibular joint is one of the most common afflictions of this particular joint and successful treatment has eluded many who have attempted to treat it.

Internal derangement may be defined as any alteration in the normal disc-condyle positional relationship. Progressively deleterious stages of pathoses and dysfunction are encountered clinically from early synovitis to osteoarthrosis to osteoarthritis (Degenerative Joint Disease, or DJD) and in late stages ankylosis.

Treatment of TMJ disorders can generally be categorized into one of two types
1. Definitive treatment
2. Supportive treatment

Definitive treatment refers to those methods that are directed toward controlling or eliminating the etiological factors that created the disorder. Supportive therapy refers to treatment methods that are directed toward altering patient symptoms.

To prevent the ongoing destruction of articular surfaces within the TMJ it would appear that some surgical intervention (definitive
treatment) is necessary, however impaired function and pain are common sequelae and in the younger patient undergoing the earlier stages of this disease more supportive therapies can afford some significant relief. Treatment options such as physical therapy, moist heat, ultrasonic therapy, tens, soft diet, muscle relaxants, anti-inflammatory medications, dental splints, occlusal equilibration and other non-surgical modalities can provide effective palliative and supportive roles in the management of TMJ disorders.

Most practicing oral and maxillofacial surgeons in Australia and the USA who treat TMJ disease in their patient population generally accept the Wilkes Classification of Internal Derangement. The use of MRI and CT imaging has furthered knowledge of the various degrees of DJD and made the diagnosis of ID, DJD and even ankylosis much clearer as well as assisting in the definitive prescription of the surgical treatment necessary and even the success of that treatment. Technology has provided some new diagnostic tools such Joint Vibration Analysis (JVA) and Electrognathography (EGN or computerized jaw tracking) which can be used along with more long accepted diagnostic instrumentation such as EMG data to provide valuable data to assist in the diagnosis and more accurate staging of TMJ disorders These instruments can be of further value when utilized for monitoring and screening for these conditions and assessment of treatment outcomes.

The author will present these concepts with evidence based literature and clinical case examples.
The Embryologic Basis of Labiomaxillary Clefts: Developmental Anatomy of the Premaxilla and Prolabium

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Abstract:

The premaxillary bone (PMx) is a neural crest derivative, the cellular origin of which is the neural fold genetically-associated with the most anterior zone of the 2nd rhombomere (r2). This is shorthand for saying the neural fold carries the same Hox code as the corresponding region of the neural tube. Because the premaxilla and vomer arise from this anterior zone it bears a special name, r2’. The premaxilla consists of a medial field, containing the central incisor, and a lateral field, which may (or may not) contain the lateral incisor. From the lateral zone a frontal process arises; this forms the internal lamina of the piriform fossa. The bony premaxilla is synthesized in concert with the ectoderm and dermis of the prolabium. These soft tissues all share a common embryologic origin from the most anterior zone of level r2. We shall call this neural crest r2’. The embryologic source for the neural crest of the maxillary complex arises more caudal, from level r2 proper. As these two neural crest populations migrate forward they encounter the mesoderm of the 1st somitomere. The neural crest stream divides into a medial component (r2’) and a lateral component (r2). The mesenchyme of the medial nasal process originates from r2’ neural
crest while that of the lateral nasal process originates from r2. The sphenopalatine artery supplies the ventral zone of both the medial and lateral nasal walls. The split of the sphenopalatine artery into a medial and a lateral branch is a reflection of the original embryology. The combination of Sm1 mesoderm with neural crest from r1 and r2 forms an additional, more anterior pharyngeal arch known as the premandibular arch. The cartilaginous and bony derivatives of this arch, as well as all other pharyngeal arches, depend in great measure to interactions between the neural crest mesenchyme and the endoderm. Genetic identity exists between neural crest and endoderm emanating from common neuromeric level at gastrulation. Differing zones of endoderm contain requisite “programs” that instruct neural crest to form specific structures. Deficits of premaxillary development (be these of endodermal or neural crest origin) explain the complete spectrum of osseous deformities seen in cleft lip and cleft lip-associated cleft palate. A cascade of signals emanating from the PMx field influence the fusion process between the lateral lip element and the prolabium. Details regarding these interrelationships are discussed.

**Introduction:**

The premaxilla (os intermaxillare, os incisivum) has a long and controversial history. The sutura incisiva separating the premaxilla from the maxilla was first illustrated by Coiter in 1573. Although the discovery of the premaxilla is generally attributed to Goethe in 1784, two other anatomists, Broussonet in 1779 and Vicq d’Azyr in 1780, described it independently. Anatomists between the late 19th and early 20th centuries debated the number and location of its ossification centers as well as its defining sutures. Some authors even denied its existence (Ashley-Montague, Vacher, Wood). A recent review by Bartezcko and Jacob provides definitive evidence for developmental stages of the premaxilla and its exact final anatomy.

This article is designed: (1) to review the development and three-dimensional structure of the premaxilla and to detail its separate components; (2) to detail the specific embryologic origin of its
mesenchyme and epithelial coverage; (3) to demonstrate the contribution of the premaxilla to the piriform fossa and its vertical stability; (4) to describe the three-dimensional process of nasal formation; and (5) to set the stage for a subsequent discussion regarding how mesenchymal deficits of the premaxilla and vomer contribute to the pathology of the labiomaxillary clefts.

Development and structure of the premaxilla

The premaxilla is actually two separate bones, together containing the upper four incisors. Each bone develops from three anlagen (Jarmer, Peter, and Shepard/McCarthy) and consists of three developmental fields: (1) the alveolar process and facial process; (2) the palatine process; and (3) the nasal spine (Processus Stenonianus). The premaxilla is separated from its flanking maxilla by the sutura incisiva; the two bones are separated in the midline by the sutura interincisiva. These sutures are continued intraorally.

The gross anatomy of the premaxilla is well appreciated in a five-month fetus.

FIG The frontal process (3) intercalates between the nasal bone (2) and the frontal process of the maxilla (4). This anatomic sequence (nasal-premaxilla-maxilla) is seen in all vertebrate skulls. FIG How is it possible that the premaxilla could be considered absent in humans? The answer lies in the timing and fusion pattern of the incisive suture. Skulls of humans and higher primates reflect increased brain development and foreshortening of the nasal cavity. This evolutionary trend is reflected in the differential growth pattern of the maxilla versus that of the premaxilla. The frontal process of the maxilla (FPM) overtakes and overlaps that of the premaxilla (FPP). Thus the premaxilla becomes “telescop[ed]” within the nasal cavity. The cephalic terminus of FPP ultimately comes to lie beneath the nasal bone and articulates directly with the frontal bone. Incisive suture fusion thus takes place as an oblique process, with FFM sliding over FPP, until the latter is no longer appreciable. The medial border of the incisive suture forms the boundary of the piriform fossa.
The bilaminar nature of the human piriform fossa is of vital importance to all surgeons dealing with facial trauma. Overlapping of the frontal processes of the maxilla and premaxilla makes the piriform rim a bicortical structure. Immediately lateral to the rim, the maxillary wall is monocortical. This embryology explains the well-known buttress principle used in plating of fractures and osteotomies. Human fetal skulls at term demonstrate internalization of the premaxilla. “Disappearance” of the human premaxilla makes no sense from the standpoint of comparative anatomy or evolution. Reports of this phenomenon are likely based on a misconception of the embryology.

Source material for the premaxilla has been the subject of considerable debate. Some consider the medial nasal prominence the sole source (Kolliker) while others conclude that material is delivered to the premaxilla via the medial maxillary prominence. The contribution of neuromeric theory to this question proves most helpful. Essential concepts of this theory will be described below. Suffice it to say that fusion between the maxilla and premaxilla occurs at the interface between two anatomically distinct populations of neural crest cells. Neural crest making the lateral nasal process comes from the neural folds of the hindbrain (rhomboencephalon) at level r2. Neural crest making the medial nasal process arises from the most anterior zone of r2 just behind the midbrain (mesencephalon) at level r2’. These two zones unite at the piriform rim and in the floor of the nose.

In holoprosencephaly, absence of the r1 ethmoid complex prevents proper migration of r2’ neural crest along the inferior border of the perpendicular plate. Absence of the vomer and premaxilla results; a cleft is present. These developmental fields have a common mesenchymal origin from the anterior zone of r2. Congenital deficiencies in either of these populations will cause (respectively) isolated palate clefts or cleft lip/palate. Growth of the premaxilla occurs from the medial nasal process in a medial to lateral direction. The frontal process sprouts upward from the lateral field. Rapid fusion
of this zone with the medial maxilla and its corresponding frontal process occurs early in development, prior to 25 mm. This union allows for admixture of r2 neural crest with r2' neural crest at the interface zone. We shall see that this “mesenchymal mingling” is responsible for the variable location of the lateral incisor with respect to margins of labiomaxillary clefts.

Three-dimensional representations of the developing premaxilla have been depicted at three stages: 25 mm (8 weeks), up to 40 mm (before 9 weeks), and over 40 mm (over 9 weeks). These drawings are helpful to study but can be misleading. First, they only depict the bony structures…but these are mere by-products of the overlying soft tissue developmental fields. Second, the pictures are drawn later in development that the actual soft tissue fields. Mesenchymal “flow” into the future premaxilla has already taken place long before ossification can be detected. The appearance of an ossification center for the maxilla slightly predates that of the premaxilla. Assuming the neural crest ossification follows a similar timetable for both bones, this sequence might falsely imply that maxillary mesenchyme is slightly more “mature” than its premaxillary counterpart. But the fact that a premaxillary ossification center appears just medial to the preexisting maxilla does not imply that the premaxilla is a by-product of the maxilla. In point of fact, we shall see that the completion of flow of r2' neural crest mesenchyme into the premaxillary field may occur slightly later that of r2 maxillary neural crest.

Appearance of ossification of a given field depends on the timing at which the cells leave the CNS and the physical length of the pathway taken by the cells to their final destination. Development of the nervous system from the rhomboencephalon backward follows a rostro-caudal gradient. Recall that the hindbrain begins at the anterior terminus of the notochord (Hensen’s node). Development of the mesencephalon and prosencephalon follows a caudral-rostral gradient. Recall that the midbrain and forebrain are induced from genes located in the cells in front of the node (prechordal mesoderm), The zone of the anterior hindbrain from which r2 neural crest migrates first before the zone
of midbrain from which r1 neural crest is produced. The sequential maturation and migration of neural crest populations is directly responsible for the pathology of the Tessier #3 cleft (vide infra). With these caveats in mind, let us examine two different perspectives of premaxillary embryology.

The earliest time reported for the physical existence of the premaxilla is by Mall at 16 mm. Another report in the U.S. literature by Fawcett documents ossification at 17 mm. In 1919 Felber described five stages: 16.5 mm (6 weeks), 19.4 mm (early 7th week), 20.2 mm (mid 7th week), 9th weeks and 5 months. FIG Comparison of b with a shows the premaxillary ossification point postdates, and is spatially distinct from, that of the maxilla. Rapid fusion of these two zones has occurred in c; the frontal process can be seen developing vertically from the lateral zone of the premaxilla. Its development appears to predate that of the maxilla, from which it remains separate d. The fusion pattern of the two frontal processes is caudal to cranial. By 5 months e both are fully formed. The distal (cranial) margin of the premaxillary frontal process is the biologically “newest” zone. Deficiencies in r2’ mesenchymal volume should occur first in the distal margin. With increasing degrees of severity these deficits should affect progressively “earlier” components of the premaxilla.

Premaxillary development in the horizontal plane was described by Jarmer in three stages: 25 mm (8 weeks), 40 mm (9 weeks), and >40 mm. Delivery of material via the medial nasal process occurs medial to lateral and is complete at 8 weeks at which time fusion has already occurred with the maxilla a. By 9 weeks the palatine process has formed as a coalescence of several islands b; these are separate from the body of the premaxilla. Primary palate formation occurs by fusion of the body with the palatine process c. Just dorsal, two ovoid bones in the median plane appear (the processes Stenonianus); these will form the anterior nasal spine. Thus we can identify three distinct parts of the premaxilla: the alveolar part with the frontal (facial) process, the palatine process, and the processus Stenonianus. In temporal order these represent the dental anlage, a posterior bony
extension vital for closure of the secondary hard palate, and an insertion site for the developing septum.

**Sequence and timing of maxillary developmental fields**

We have stated that the migration of neural crest from the rostral hindbrain (levels r2-r7) is spatially short. These peregrinations are completed before those from the midbrain (levels r0 and r1). Midbrain induction results from genes located at the anterior terminus of the notochord. The source material for the presphenoid bone, the lesser sphenoid wings, and the ethmoid complex is r1 neural crest. These r1 structures provide the “pathway” by which r2’ neural crest flows medially to form the vomer and premaxilla. This makes the r2’ migration route *more circuitous* than that of r2 neural crest. Thus it stands to reason that the r2 neural crest cells responsible for synthesis of the maxillary complex may arrive into location slightly before those from r2’. Ossification of this mesenchyme occurs as an interaction with the local epithelium. Just because r2 maxillary neural crest begins to ossify before that of r2’ premaxillary neural crest does not imply that r2 is more mature. It just got there first.

The maxillary bone complex has several components. These are brought into position by the mechanical action of embryonic folding. In simplistic fashion the maxillary fields are laid down from medial to lateral and caudal to cranial. From a central island the palatine bone is added on posteriorly and the frontal process is added on anteriorly. The medial maxillary wall is made by the inferior turbinate bone (IT). Correct synthesis of the IT field is vital to the construction of an anatomically correct piriform rim. Formation of both frontal processes is predated by IT synthesis. Assembly of FPM and FPP require an intact inferior turbinate as a scaffold. Congenital absence of IT will result in a wide-open communication into the maxillary sinus. Absence of FPM will disrupt the lacrimal system and create a cleft in the medial orbital rim. The clinical presentation of the Tessier #3 cleft is the result.
Fundamental concepts of neuromeres

Anatomic organization of the embryo can be understood in terms of segmental units of the embryonic nervous system called *neuromeres*. The boundaries of each neuromere are defined by a unique expression pattern of proteins each of which possess an identical 180 base pair amino acid sequence known as a *homeobox*. This loop-like structure permits homeobox genes to “unlock” DNA strands. Human homeobox proteins are produced by 38 *homebox genes* distributed on 4 chromosomes. Different combinations of these genes are expressed at each level of the nervous system. Thus each neuromere can be biochemically identified by the unique “barcode” of homeotic proteins it contains. Nomenclature of the neuromeres is derived from neuroembryology. Thus the forebrain (prosencephalon) is made up of 6 *prosomeres* in two levels, alar and basal. The cerebrum (telencephalon) is produced from alar p6 and p5 while the epithalamus, thalamus and hypothalamus (diencephalon) are produced from the remainder. The hindbrain (rhomboencephalon) is made up of 12 *rhombomeres* (r0-r11). The isthmic region abutting the midbrain is produced from r0. The cerebellum and pons (metaencephalon) are produced from r1. The medulla (myelencephalon) is produced from r2-r11. Origins of the midbrain (mesencephalon) putatively involve two *mesomeres* but technically these are coded from r0. The spinal cord has 31 *myelomeres*, one for each pair of peripheral nerves.

The central tenet of neuromeric theory is as follows: *a genetic identity exists between the developmental units of the nervous system and the outlying tissues (ectoderm, endoderm, mesoderm, and neural crest) innervated from that developmental unit.* Particular emphasis must be placed on the preexistent program contained within the endoderm. Neural crest cells encountering this program are patterned into their final derivatives. A particular homeobox gene may participate in the “definition” of neuromeric levels occurring at disparate levels of the body. Thus, an anomaly of that gene may cause seemingly unrelated congenital anomalies. An example of this
is cleidocranial dysostosis. In the skulls of primitive fishes the anterior fin (containing a clavicle and scapula) is located at the terminus of the fish brain (ie. at level r7-r8). This level is responsible for producing neural crest components of the membranous calvarium. With tetrapods came the addition of a neck. The neuromeric location of the clavicle dropped to cervical neuromeres c1-c4. Part of the definition of this zone may well include a homeotic gene that also persists at level r7-r8 as well. In this situation, the anomalous gene could produce absence of the membranous interparietal bone as well as a missing clavicle.

Neural crest migration patterns

Neural crest populations exhibit three distinct migration patterns depending upon which subdivision of the CNS they originate from. Prosencephalic neural crest (PNC) arises from the neural folds above the caudal forebrain. The neural folds above the rostral forebrain are called non-neural ectoderm (NNE). These are devoid of neural crest but do contain structures of anatomic significance. Placodes are specialized regions of neural ridge ectoderm that will retain attachment to the brain. Epithelial zones mark out the territories of frontonasal skin and dermal bones associated with that skin. The fate map of NNE from rostral to caudal is as follows. Structures in prosomeric zone p6 are: adenophyphyseal placode, nasal placode, nasal ectoderm (vestibular lining of the nose), Structures in prosomeric zone p5 are: upper beak ectoderm (nasal skin), optic placode (future lens), and calvarial ectoderm (future forehead skin and frontal bone). FIG

Using a subepithelial plane, PNC migrates forward as a glacier-like sheet to populate the more anterior zones of the rostral forebrain NNE. The neural crest cells congregate around the placodes and activate them. The epithelial zones acquire the mesenchymal substrate for dermis from this neural crest invasion. The zone of p6 dermis along the upper 270 degrees of the nasal lining from the cribiform plate forward to the skin border at the caudal margin of the alar
cartilages. As we shall see below, the mesenchymal growth of the nose occurs due to proliferation of neural crest from rhombomeres r1 and r2 beneath zone p5 and p6. The dermis of the upper 3/4 of nasal lining is likely a mixture of two neural crest populations, p6 and r1. The upper lateral and lower lateral nasal cartilages are derived from r1 neural crest in response to the p6 epithelial “program.”

From that point on zone of p5 dermis extends outward from the nasal rim to include the nasal skin, glabella, and the forehead skin from the eyebrows upward to the posterior border of the frontal bone and laterally as far as the insertion of the frontotemporal fascia. It also includes the columella and philtrum. Due to extensive proliferation of r1 neural crest beneath zone p5, this frontonasal dermis may also be a hybrid. Certainly this mesenchyme is the source of the nasal and lacrimal dermal bones. Interaction between the frontonasal dermis and the underlying r1 dura is responsible for the production of the frontal bone, including the orbital roof. Ordinarily, we think of dura as a signaling source only, but under the right circumstances (recombinant human BMP-2) dura itself may be “tweaked” to produce bone. This embryology has important implications for the existence of sinuses. The frontal bone could consist of two neuromerically-distinct laminae. The outer lamina is of p5/r1 dermal origin while the inner lamina is derived strictly from r1 dura. The orbital roof would have an upper lamina originating from r1 dura above and a lower lamina derived r1 sclera below. Separation between these two layers would nicely explain the anatomy of the fronto-orbital sinus cavity. Indeed, all sinuses may well represent naturally-occurring embryologic separation planes between neuromerically distinct cell populations.

Of all neural crest populations, PNC migration is the most extensive. In the mouse it not complete until the 16-somite stage (the number of somites present being a comparative estimate of embryonic age).

Rhomboencephalic neural crest (RNC) begins functionally at the hindbrain from levels r2 to r11. Some RNC remains epaxial (dorsal to
the notochord), maintaining contact with the CNS. This produces dura. The rest migrates ventrally in a very stereotypical manner as segments into corresponding pharyngeal arches (PAs). All pharyngeal arches are hypaxial structures. With the exception of the premandibular arch (PA0), each pharyngeal arch is associated with a pair of rhombomeres: PA1 = r2-r3; PA2 = r4-r5; PA3 = r6-r7; PA4 = r8-r9; and PA5 = r10-r11. Because neuromeric development takes place in cranial-caudal order, it is not surprising that migration of rhomboencephalic neural crest takes place in two major waves, rostral (RNCr) and caudal (RNCc). RNCr (r2-r7) is completed at the 11-somite stage whereas migration of caudal RNCc (r8-r11) is not completed until the 14-somite stage.

Mesencephalic neural crest (MNC) originates from levels r0, r1, and (very significantly) a substantial fraction of the r2 RNC population. It is not clear at this time if r0 produces a separate population of neural crest cells. For purposes of simplicity in this discussion we shall, by convention, treat r0 and r1 as distinct neuroembryologic entities but will lump neural crest produced at this zone as a single entity, r1. These populations travel forward to create the sphenoethmoid complex (the medial orbit), vomer, premaxilla, and the maxillary complex. MNC migration takes place as distinct streams following pathways in a strict temporo-spatial order. 2nd rhombomere neural crest thus behaves in a bimodal fashion. Some of it remains epaxial and behaves like RNC. It does not participate in the formation of the first pharyngeal arch (a hypaxial structure). It does however create the dura innervated by V2 (the brain being, most assuredly, an epaxial structure). Hypaxial r2 neural crest however, travels forward into the more anterior 1st somitomere where it participates in formation of the premandibular arch (vide infra). In doing so it divides into a medial division (r2’) and a lateral division (r2). MNC pathways are physically longer that those for RNC, so mesencephalic migration times with that of RNCc, being completed at the 14-somite stage.

Despite the similarity mechanism of premaxillary and maxillary synthesis we shall see that, although they come from the same
neuromeric level, their precursor neural crest population display important behavioral differences, based on: (1) the temporal order of their development; and (2) the zone of endoderm with which they become associated. Because r2’ neural crest migrates earlier it takes the most direct pathway available, i.e. a midline pathway. Thus r2’ populate the ventro-medial undersurface of the 1st somitomere. More posteriorly located r2 neural crest by default must occupy the ventro-lateral surface. This spatial positioning explains key anatomic differences between the future derivatives of these two populations, including: relation with the basisphenoid, arterial anatomy, the dropout of the primitive nasal floor through apoptosis (cell death), formation of the primary choanae, biologic independence (each zone can produce a distinct form of cleft), the occlusal relationship with mandible.

**Anatomy of mesoderm**

*Gastrulation* is the process by which an embryo is transformed from a single layer of cells (*epiblast*) into a three-layer sandwich of ectoderm, endoderm, and mesoderm. A change in cell adhesion factors causes epiblast cells to loosen up and “dropout”, creating a temporary second layer of cells (*the hypoblast*) between the yolk and the epiblast.

In the next act of gastrulation the new wave of epiblast cells physically moves into the midline primitive streak and pushes the hypoblast cells out toward the periphery. Thus the *true endoderm* is born. Chemical factors cause the potential space between the epiblast and the endoderm to open up, permitting entry of the next wave of epiblast cells to form the mesoderm. Readers should be aware that this is a very stylized version of reality. Alternative models of gastrulation postulate cell layers to move *en masse*. At any rate, when mesodermal formation is complete, those epiblast cells remaining behind undergo a name change to the *true ectoderm*.

Subsequent to this, the midline neural plate rolls up like a cigar into a neural tube, the precursor of the future nervous system. Process is called *neurulation*. All students of anatomy are familiar with diagrams depicting three distinct populations of mesoderm flanking
the neural tube. Immediately adjacent to the neural axis is a zone of paraxial mesoderm (PAM) undergoes a cranio-caudal process of segmentation into discrete units separated from one another by epithelium. These units, somites, are in exact register with their corresponding neuromere. The zone of mesoderm lateral to PAM remains flattened and is called lateral plate mesoderm (LPM). Signals from the epithelial layers above and below LPM cause it to separate into two discrete laminae. Ectodermal-induction of a somatic lamina (LPMs) is participates in trunk development while endodermal induction of a visceral lamina (LPMv) creates the musculature of the gut. Lying between PAM and LPM is a rod-like zone of intermediate mesoderm (IM) responsible for the genito-urinary system.

Craniofacial development does not follow this system! Classical gastrulation, as described above, begins at the level of the first somite, ie. at the 8th rhombomere. Rostral to this level, gastrulation produces a very different anatomy. Mesoderm produced adjacent to rhombomeres 1-7 becomes reorganized into rounded structures resembling popcorn balls called somitomeres. Somitomeres are incompletely separated from one another and from the remainder of outlying mesoderm that fills up the embryonic cavity. The architecture of each somitomere is organized around a central cavity, or somitocoele. FIG At every given neuromeric level a common genetic definition is shared between the neural plate, the neural crest and the outlying germ layers.

An important semantic and anatomic distinction must be made at this point. The embryo per se does not occupy the entire space of the embryonic cavity. All endoderm and mesoderm anterior to a transverse line through the plane of Hensen’s node, are prechordal tissues. These are the very first cells to make their exit at gastrulation via the node itself. Prechordal endoderm (PCE) pushes the preexistent hypoblast out of the way and prechordal mesoderm (PCM) follows. Some anatomists argue that all mesoderm back to and including level r7 should be simply termed prechordal mesoderm. Thus the traditional subdivisions of mesoderm (PAM, IM and LPM) do not physically exist anterior to the level of the first occipital somite, at rhombomere 8.
In the neuromeric model, PCM (also termed by some head mesoderm) produced by gastrulation from levels r0-r7 shares along with its underlying endoderm a common homeotic code, making each neuromeric zone unique and exclusive. But what about the embryonic cavity in front of the notochord? After all, there is more to life than the hindbrain! Going back to first principles, at completion of gastrulation, genes expressed in the PCM immediately in front of the node and in the midline peripheral ectoderm induce the rostral CNS (i.e. the midbrain and forebrain. Overlapping chemical concentration gradients of these genes quickly specify the ectoderm into developmentally unique zones. Like cans of paint spilled and overlapping, the proteins expressed by Hox- homeotic genes (see below) are critical in setting up the future neuroembryology of the rostral CNS. Because these ectodermal cells have never passed through the primitive streak, the neuromeric anatomy of the extraembryonic ectoderm is unknown and may not by directly neuromeric.

The prechordal mesoderm of the pre-nodal embryonic cavity does however behave in ways that are similar to lateral plate. Much of this PCM becomes dedicated to the production of the heart and great vessels. The mechanisms by which this happens suggest that the patterning of the prechordal endoderm has a neuromeric basis. Both ectoderm and endoderm of the prechordal region participate in cardiovascular genesis by inducing adjacent PCM to develop along differing lines. The former causes formation of the pericardium while the latter results in the endocardium. Three-dimensional folding of the embryo brings the cardiac mesenchyme directly beneath the developing pharyngeal arches. Cardiac mesenchyme expresses different HOX+ genes in specific anatomic sectors. The most logical way for these PCM sectors to acquire homeotic identities is to either emerge from a rostral rhombomeric level or to come in contact with endoderm bearing the same identity. Thus, a model is suggested in which endoderm emanating from levels r0 to r11 fans out in concentric waves to create a neuromeric map that encompasses the entire prechordal

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zone of endoderm. Such a concept might explain the mechanism by which the aortic arches, developing in cranio-caudal sequence, remain in register with their appropriate pharyngeal arch targets.

Beginning at the anterior terminus of the notochord (level r1) each neuromere is flanked by its own corresponding somitomere (Sm). Sm1 is particularly large and extends forward to flank the midbrain. Sm2-Sm7 function in pairs to form the first three pharyngeal arches. Neural crest cells originating from a specific level flow over, and surround the corresponding somitomere like taffy flowing over an apple. Neural crest penetration of PAM creates an internal organization of each somitomere into functional zones surrounding the somitocoele. The first seven somitomeres remain unsegmented and retain this architecture. At the level of Sm8, in the opinion of some, all somitomeres undergo a secondary anatomic transformation into somites. Others restrict the terminology somitomeres exclusively to prechordal/head mesoderm. These authorities refer to somites alone.

Why is this important? The exclusive source for the mesoderm that makes the head and the entire calvarium exclusive of the basioccipital, exoccipital and supraoccipital bones is somitomeric mesoderm from levels r1 through r7. Prechordal mesoderm produces somitomeres; paraxial mesoderm produces somites. The sutures separating PCM bones follow a strict pattern of segmentation, they respect neuromeric boundaries. PAM bones follow a distinct pattern of parasegmentation in which pairs of somites combine to produce osseous structures, (More on this later).

All readers are familiar with the developmental term somite. A somite is a block of PAM that is organized into a dermatome, myotome and sclerotome. Parasegmentation of the human body using the somite system is readily seen in the vertebral column. Each vertebral body is made from a pair of somites, the caudal half of the preceding level and the cranial half of the corresponding level. Thus the 4th thoracic vertebra and rib are produced from the caudal 3rd thoracic somite and the cranial 4th thoracic somite. All somites are separated
from one another by epithelium. Each one has an associated peripheral nerve and segmental artery. Humans have approximately 39 somites. The first 4 occipital somites correspond to rhombomeres 8-11. They fuse together in a complex way to make the skull base and posterior brain case. 8 cervical, 12 thoracic, 5 lumbar, 5 sacral, and 3-5 coccygeal somites complete the picture.

The organization of the posterior pharyngeal arches associated with r8-r11 does not appear to demonstrate parasegmentation. *The hypaxial mesoderm behaves in a somitomeric pattern, producing segmental derivatives*. The posterior pharyngeal arches can be understood as paired somitomeric structures. Sm8-9 produce PA4 and Sm10-11 produce PA5. *The epaxial mesoderm behaves in a somitic pattern producing parasegmental derivatives*. Thus, the basioccipital bone produced from S1 through S4 has three distinct subcomponents revealed on the dorsal surface of the basioccipital bone by three transverse groves of primitive vascular structures. Ref (Anson)

**Introducing a new pharyngeal arch**

Somitomeres are technically not precursor structures for somites. They are produced from prechordal mesoderm and are incompletely separated. *The first seven somitomeres do not undergo transformation into somites*. They are exclusively dedicated to development of the face and anterolateral skull. The first somitomere is quite large and flanks the midbrain. It is associated with rhombomeres r0 and r1. The next two (Sm2 and Sm3) form the mandibular arch, ie. the 1st pharyngeal arch. New data Bronner-Fraser indicate a fascinating and surgically relevant relationship between Sm1 and PA1. For some time, work by Kuratani postulated the existence of an additional pharyngeal arch anterior to, and antedating, the mandibular arch. This so-called premandibular arch (PA0) has, as a source for its paraxial mesoderm, the substance of Sm1. It is supplied by neural crest from r0, r1, and r2. Neural crest migration studies now indicate that the bones of the maxillary complex (maxilla, inferior turbinate, palatine bone, zygoma, and alisphenoid) *do not originate from the first*
pharyngeal arch. These bones are most likely formed by a population of r2 neural crest migrating forward as a stream to contribute to the PA0. In this model we postulate that the vomer and premaxilla come from r2’ and the r1 serves as the source for the presphenoid and the ethmoid complex.

As a rhomboencephalic product, why does r2 neural crest like to flow forward, behaving like MNC? An important factor is the difference between homeobox genes that are HOX+ and those that are HOX-. For those unaccustomed to this terminology, the protein product of a gene is written in roman script whereas the gene itself is written in italics. Thus gene Otx-2 produces protein Otx-2. A further convention deals with human gene nomenclature because it is written in capital letters. Thus mice have Otx-2 whereas humans have OTX-2. Historically, homeobox genes were originally described in Drosophila. Those that are homologous in vertebrates are called Hox+. The term Hox comes from “homeobox in vertebrates.” More recent work has described many new homeotic genes found further forward in the nervous system. These are termed Hox- genes. Rhombomere three is an important genetic watershed. In mammals, all homeotic genes rostral to r3 are Hox- whereas all genes at level r3 and caudal are Hox+. Experimentally Hox- neural crest cells transplanted caudally will function perfectly well according to the local environment but Hox+ cells fail to function when placed rostally. Thus some fraction of r2 neural crest flows forward because the cells are Hox- must therefore behave like MNC.

The structure of the premandibular arch thus consists of prechordal mesoderm from the 1st somitomere admixed with distinct neural crest populations. The dorsal half of Sm1 is covered with r1 MNC. The ventromedial half of Sm1 is covered with r2’ and the ventrolateral half by r2. These neural crest populations migrate dorsally between the PAM and the ectoderm and ventrally between the PAM and the endoderm. FIG The epithelial germ layers that the neural crest cells eventually come to reside within are neuromere-specific and contain genetic programs that will “instruct” the arriving
neural crest cells as to what type of structure to form and in what shape they must assume. The zone of endoderm within which Sm1 resides originates entirely r1.

A word here about blood supply. Throughout the body, no epithelium is capable of forming blood vessels. Paraxial mesoderm in concert with neural crest produces the blood vessels that supply the brain. Formation of the internal and external carotid systems is beyond the scope of this paper. Suffice it to say that neuromeric levels r1-r3 contain the sensory nuclei of V1-V3 while somitomeres 1-3 supply accompanying PAM to the dura covering the forebrain (only the dural possesses dura mater). The migration routes of this mesenchyme over the brain can be traced by study of the sensory map of the dura. FIG The neural crest cells provide the “guiding” pericytes whereas PAM provides both vessels walls and the endothelium. Immoduiuj pp[car efurekerere3[[[pppp

The arterial supply to PA0 is dual. From the midbrain level it receives the ethmoid arteries, the terminal branches of the future anterior cerebral. These are formed from Sm1. From the hindbrain level Sm2 it receives the sphenopalatine arteries, the terminal branches of the internal maxillary. Thus the blood supply to the premandibular arch represents a vascular watershed between the internal carotid and the external carotid systems. We shall later see that the vascular boundaries between these branches may explain the mechanism by which programmed cell death creates the primary choanae.

The existence of a premandibular arch is a very useful surgical concept. The interface between the frontonasal mesenchyme and the anterior boundary of the PA0 is between PNC and MNC. This is demarcated by the lacrimal groove. The interface between the posterior boundary of PA0 and the anterior boundary of PA1 is between MNC and RNC. This is demarcated by the occlusal plane between maxilla and mandible. The genetic program for the dentition exists in the mirror-image relationship between oral endoderm of r1-r2 derivation and that of r3 derivation.
Readers of developmental biology literature may find themselves confused by descriptions of the relationship between neuromeres, somitomeres and pharyngeal arches. Many papers refer to the first three somitomeres as *head mesoderm*. We shall adopt the following simplistic convention. The mesoderm of the premandibular arch originates solely from the 1\textsuperscript{st} somitomere but it receives neural crest from two neuromeric levels, r1 and r2. For this reason, both V1 and V2 provide sensory supply to the premandibular arch. The mesoderm of the mandibular arch originates solely from the 2\textsuperscript{nd} and 3\textsuperscript{rd} somitomeres but it receives sensory neurons from a single neuromeric source, r3. For this reason V3 is the exclusive sensory supply to the mandibular arch.

**The mechanism of premaxillary synthesis**

Beneath the developing midbrain and forebrain the paired 1\textsuperscript{st} somitomeres fuse together in the midline surrounding the tip of the notochord. They form the chondral basisphenoid. Neural crest migrates out from Sm 1 to produce three cartilaginous structures of great importance. Anteriorly, the *polar cartilages* will fuse to become the presphenoid bone. Simultaneously r1 neural crest projects forward as two *trabecular cartilages*. These produce the ethmoid complex. Laterally, paired *orbital cartilages* will form the membranous lesser sphenoid wings. This is an example of *chondroid ossification* by which membranous bone develops via a cartilaginous intermediate.

Flow of r2 neural crest provides source mesenchyme for the maxilla, inferior turbinate, palatine bone, greater sphenoid wing, and zygoma. Development of the r2 maxillary portion of the primary palate occurs via the lateral nasal prominence. Flow of r2′ neural crest into the prolabium and premaxilla occurs via the medial nasal prominence. From the lateral field of the premaxilla sprouts the frontal process. Rapid fusion of this zone with the medial maxilla and its corresponding frontal process occurs early (by 25 mm). This union allows for admixture of r2′ neural crest with r2 neural crest at the interface zone. We shall see that this “mesenchymal mingling” is
responsible for the variable location of the lateral incisor with respect to margins of labiomaxillary clefts.

Just how might this occur? The process involves the manner in which embryonic folding positions the epithelium of the future nasal cavity in such a way that neural crest populations will follow correct planes and move into position to form the cartilaginous and bony structures of the piriform fossa. We must now take on a most difficult task, creating a four dimensional picture in our minds of embryonic cell translocations. As a convention we will make use of images derived from avian embryogenesis because they match almost exactly the mammalian model but are spatially easier to visualize.

Let’s start out with some normal anatomy: a sagittal section of the nasal cavity. The epithelium covering the perpendicular plate of the ethmoid and the septum is of ectodermal origin from prosomere p6. The underlying mesoderm is, of course, r1. It is supplied by the anterior and posterior ethmoid arteries of the internal carotid system. The sensory innervation is provided by V1. Immediately caudal to this lies the epithelium covering the vomer and premaxilla. This is of endodermal origin from r2’ and extends all the way backward to the body of the sphenoid. It is supplied by the medial branch of the sphenopalatine artery and innervated by V2.

We must also consider a sagittal section of the lateral nasal wall. The epithelium covering the superior and middle turbinates is of ectodermal origin from prosomere p1 supported by r1 mesoderm. Once again the blood supply is from the ethmoids and the sensory innervation from V1. At the level of the inferior turbinate the epithelium is of endodermal origin from r2. This extends back all the way to the pterygopalatine raphe. It is supplied by the lateral branch of the sphenopalatine artery and innervated by V2.

There are obvious similarities between the two sides of each nasal chamber. Neural crest from its various sources flows into position beneath these distinct epithelial zones, receives instructions, sets up housekeeping and proceeds to form the cartilages and bones of the nasal cavity. How this anatomy comes into being requires an
understanding of how these epithelial zones come to be folded together to permit this architecture to be assembled. The key to this puzzle is to understand the manner in which the midbrain and forebrain are induced from the anterior tip of the notochord.

We begin with the transition from gastrulation to neurulation. The embryo is now an ovoid three-layer disc floating on a yolk sac. Not all of this trilaminar structure will be come the embryo proper. Only the proximal 2/3 contains the neural plate, based on the notochord. Gastrulation has taken place. The most anterior source of mesoderm is Hensen’s node. This is the site of the future pituitary gland. Paraxial mesoderm flanks only the neural plate hence there can be no PAM anterior to Hensen’s node. All mesoderm anterior to the nodal plane is lateral plate only. The LPM comes into contact with endodermal zones having a neuromeric “memory” imparted during gastrulation. Endodermal signals induce LPM to become the future heart and great vessels. The very first mesoderm to exit from Hensen’s node during gastrulation is an exclusive group of 8-10 cells that constitute the prechordal mesoderm (PCM). Signals from the PCM along with signals from extraembryonic ectoderm anterior to the embryo induce the ectoderm directly in front of Hensen’s node to become forebrain. FIG

Mammalian neural crest migration takes place very early, prior to closure of the neural folds. Rapid CNS growth puts the first three somitomeres in direct contact with the side walls of the prosencephalon. Only the prosencephalon has dura, the mesenchyme of which is neural crest and PAM from levels r1-r3. The migration pathways by which neural crest produces dura are “mapped” by anatomic trajectories of sensory nerves V1-V3. These follow ventral-dorsal and cranial-caudal trajectories over the forebrain. Sphenoethmoid synthesis occurs simultaneously and sets the stage for the arrival of r2 neural crest. The medial half of 2nd rhombomere neural crest (ie. r2’) begins beneath the center of the presphenoid and descends along the perpendicular plate to form the vomer. More anteriorly r2’ proliferates beneath what will become the medial nasal
process as the future premaxilla. The vomer and premaxillary populations are distinct. Pathology can occur in either one independently. The lateral half of 2nd rhombomere neural crest (ie. r2 proper) stays lateral.

**Formation of the human nose**

Okay so far. We have accounted for the early anatomy of the premandibular arch. We know that, just posterior, the mandibular arch is projecting downward just like in the books. Having recourse to the latest edition of Carlson’s embryology text, the discerning reader will ask the following question: “All textbook drawings for the early face show the future nostrils as inverted U-shaped structures, the ventral margins of which are thickened into what are called medial and lateral nasal prominences. And the bottom of each nostril has a wide-open gap going back toward the future pharynx called the primary choana. What’s this all about?”

The answer can best be appreciated by studying three sources. Scanning electron microscopic studies by Hinrichsen and Jirosek, ref the mapping of the neural folds by LeDouarin and Couly, ref and a review by this author. ref Facial SEM taken at Carnegie stage 11 before the mandible has fused disclose an enormous circular nasal placodes on either side of a depressed epithelial zone. If we follow the neural folds inward to the future pharynx we come to a depression, Rathke’s pouch. This is the site of the paired adenophyseal placodes, the future pituitary gland. Just beneath the surface, the paired 1st somitomeres have fused to create the basiphenoid. Looking carefully at the roof of the embryo are two longitudinal bulges extending anteriorly. These are the trabecular cartilages, the future ethmoid complex. Following the neural folds outward from the nasal placode we come to a zone of upper beak ectoderm. In mammals this will be the external nasal skin. Just posterior to this can be seen the beginning optic placodes.

So what cause the nose to project out from the face? Beneath the p5 epithelium surrounding the p6 nasal placode is a seething mass of proliferating mesenchyme from the premandibular arch. Recall that the nasal placode is firmly affixed to the brain. Thus, as the r1
and r2 neural crest populations multiply, they will push forward to create a rounded chamber with the appearance of a Lifesaver® candy. The rim of the Lifesaver is composed of three neuromeric zones of skin. The upper 270 degrees is all p5. The inferomedial 45 degrees is r2' and the inferolateral 45 degrees is r2. At this point in time there is no mouth...the lower jaws have not yet fused, The floor of the chamber is physically intact but is composed of the two populations of r2 neural crest, each supplied by a distinct branch of the sphenopalatine artery. This represents a potential vascular watershed. Midline breakdown along this line causes a communication to form between the future mouth and nose, the primary choana. Later in development when the palatal shelves elevate and close off the nasopharynx the secondary choanae are formed.

A humble analogy for the formation of the nasal chamber is that of a condom placed on a flat surface. The reservoir tip represents the p6 nasal placode. The rolled external ring of the condom represents the p5 nasal skin. Let’s glue the tip down to the surface just as the placode is fixed to the brain. Then, with the external rim secured so that it can unroll without leaking, the condom is insufflated with air. A donut-like structure with a central cavity will result. Differential facial growth brings these two nasal processes together and they fuse. Failure of placode formation will result in a unilateral arhinia without an ipsilateral choanal chamber.

**Soft tissue anatomy of the prolabium and columella**

Hinrichsen’s work (reviewed by) demonstrates how, after formation of the primary choanae, the two medial nasal prominences approximate each other. Both of the medial nasal skin areas are supplied from the terminal sphenopalatine branches coming off at the junction between the premaxilla and vomer. The allows them to be elevated as flaps FIG. In a bilateral cleft lip these r2' skin fields occupy the lateral 1/4-1/3 of the prolabium. But they remain separated by a central island of frontonasal mesenchyme. As development proceeds, proliferation of p5 neural crest mesenchyme creates the
columella and central philtrum. These structures are supplied by the two terminal descending branches of the anterior ethmoid artery, reliably located 4-6 mm apart. This arterial anatomy, described previously explains the surgical elevation of the prolabium off the premaxilla as an “elephant trunk” flap as so elegantly demonstrated by Trott and Mohan.

Rare cases of absent columella exist in the literature. In such cases failure of p5 skin to reach the prolabium results most likely from some vascular compromise of the terminal anterior ethmoids. In such cases, prolabial skin will be entirely made up of r2’ ectoderm and neural crest. The endoderm covering the premaxilla and vomer is, of course r2’ as well.

Fortunately, a shared vascular continuity exists between the p5 lateral columellar walls (as defined by the medial crura) and the lateral r2’ philtral skin and vermilion. Careful paring of the lateral premaxilla results in a flap of substantial dimension dangling from the footplate of the alar cartilage. The blood supply of this r2’ flap is dual: direct from the sphenopalatine and random via the p5 lateral columellar skin. There are two important surgical consequences of this anatomy: (1) separation of the lateral columellar elements from the central columella allows cephalic repositioning of the medial alar cartilage into the dome; and (2) the r2’ skin flap can be inset into the lateral wall of the nose permitting a cephalic rotation of the lateral alar crus. The dogma that the columella and philtrum in a cleft are somehow foreshortened is false. The cleft pathology merely causes these developmental fields to become spatially mismatched.

Under normal circumstances the skin field of r2’ marries up with that from r2 in the floor of the nose to create continuity, permit full synthesis of the lateral field of the premaxilla, and permit the lateral lip element to make contact with the p5 philtrum. The second article in this series will describe how this process happens, the mechanism of interaction between the r2’ premaxilla and r2 maxilla, and the manner in which an r2’ deficiency state leads to various forms of clefts.
Summary

The premaxillary developmental field is a key structure in orofacial development. Cleft formation can be explained in terms of defective premaxillary synthesis. This article summarizes the developmental anatomy of the premaxilla. Particular emphasis is placed on the role of the premaxillary frontal process in forming the bilaminar structure of the piriform fossa. The mesenchymal origin of premaxillary neural crest is described in terms of the neuromeric theory of segmentation. Genetic relationships between developmental units of the neural plate (neuromeres) with local neural crest and outlying mesenchyme and epithelia help to explain the spatial movements involved in frontoorbital and nasomaxillary assembly. This includes the emerging concept of a previously-unrecognized structure: the premandibular arch. The exact manner in which neural crest mesenchyme destined to become premaxilla makes use of preexisting fields migrate into correct position is detailed. Early development of the future nasal cavity explains how the medial and lateral nasal prominences come to be separated by the primary nasal choanae. These concepts set the stage for understanding: (1) primary palate closure; (2) formation of the piriform rim; (3) the mechanism of soft tissue closure between the lateral lip element and the prolabium. These topics, and their relation with cleft formation, will be the subject of the second paper in this series.
The Myth of Metopic Synostosis
Anatomic Pathology of Trigonocephaly

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The face predicts the brain. —William B. Demeyer    —Harvey B. Sarnat
The brain predicts the face. —Michael H. Carstens

Introduction:
Trigonocephaly is a clinical entity well known to all plastic surgeons. It consists of a sharply defined vertical crease in the midline of the forehead and recession of the supraorbital rims. The surface area of the frontal bone is significantly reduced. Although trigonocephaly is not associated with increased intracranial pressure, severe cases can present with mental retardation. Methods of surgical correction vary with the severity of the condition. In its milder form the midline forehead keel can be burred down via an extracranial approach. More severe cases require frontal craniotomy, fronto-orbital advancement using a bandeau and remodeling of the distorted frontal bone. Once the frontal bone is reattached to the repositioned bandeau significant calvarial bone deficits become apparent.

The putative cause of trigonocephaly has been assigned to a premature synostosis of the metopic suture. Several lines of evidence indicate that this concept is false. (1) If trigonocephaly were caused by a midline synostosis, its manifestations should always be bilateral. (2) The orientation of the metopic suture is sagittal. If Virchow’s law is indeed true, suture synostosis should increase the vertical dimension of the frontal bone. The pattern of deformity, including recession of the supraorbital rim and elevation of the lateral canthus,
cannot be attribute to this suture. (4) Orbital position, ie. hypotelorism has no satisfactory explanation. (5) Neuropsychological deficits found in severe cases of trigonocephaly cannot be attributed to structure extrinsic to the brain. (6) New data indicating that normal fusion of the metopic suture occurs far earlier than previously thought call into question the entire hypothesis of premature synostosis as a real pathologic entity.

This communication will discuss in detail the anatomic pathology of trigoncephaly with emphasis on an uncommon, unilateral variant. Clinical findings in such cases provide valuable information regarding the embryology of the anterior cranial fossa. A new model of trigonocephaly as neural crest deficiency state involving specific developmental fields will be presented.

Materials and Methods:

A nine month old boy presented with left-sided trigonocephaly. He was a term product of an uncomplicated pregnancy. Growth and development, including neurological milestones, were age-appropriate. Examination disclosed a midline frontal keel. The left coronal suture was patent. Significant retraction of the left orbital rim was present but orbit was eutopic with a normal-size globe. Although the lateral aspect of the left eyebrow was swept backwards it was otherwise symmetric in size and position with respect to the orbit compared to the opposite side. Malar projection and lateral canthus insertion were unaffected. The frontal hairline was not displaced but the left temporal hairline was lower on the affected side.

Three-dimensional CT scan at 4 months of age demonstrated fusion of the metopic suture; it was shifted to the left of the midline. The entire left frontal bone was smaller in size than the right side. Significant reduction in surface area of the lateral aspect of the left orbital roof was noted. These findings persisted in a follow-up CT scan at 8 months. The coronal suture remained open. The left frontal bone was grossly reduced in surface area compared to the right side.
No upward displacement of the orbital roof or greater wing of sphenoid (the harlequin sign) was noted. Symmetry of malar projection and of the occlusal plane were maintained indicating on-going normal growth of the midface.

Conceptually, this patient demonstrated a *unilateral trigonocephaly* characterized by a reduction in size of the orbital process of the frontal bone. Neighboring bone fields (ethmoid, lesser wing of sphenoid, alisphenoid/greater wing, maxilla, lacrimal bone, nasal bone, zygoma, and parietal bone) were normal in size. These finding indicated that left fronto-orbital advancement would resolve the deficiency state in the orbital roof. The small left frontal bone would require reconstruction using bone flaps and additional bone graft, the anticipated deficit being sizeable.

Harvest of calvarial bone for the frontal defect presented the usual drawback of uncertain resynthesis at the donor site coupled with the difficulties of splitting infant calvarium. Use of rib graft was not an attractive option. Based on our prior experience with recombinant human bone morphogenetic protein-2, we opted to stimulate the existing periostale-dural pocket to synthesize the membranous bone deficit. This technique, termed *in situ osteogenesis* (ISO), is complete within 3 months, although full remodeling may require another 3-6 months. 1-2

Surgical correction began with bilateral elevation of the bandeau. Forward translocation of the left side left a triangular defect in the orbital roof measuring 2.3 x 2.0 x 1.0 cm. Reconstruction of the forehead involved splitting of the metopic suture, rotation and exchange of the frontal bone flaps and replacement of missing bone. It was noted that the right frontal bone, when transposed to advanced left side of the bandeau, was nearly an exact match for the expanded left frontal surface area. This indicated that the right frontal bone field, although somewhat distorted in shape, was essentially normal in size.

After osteotomies and plating with absorbable mesh (KLS Martin, Jacksonville, Florida) two triangular areas of bone deficit remained
with a total surface area of approximately 14 cm². These were replaced using ISO technique as follows. 8.4 cc of Infuse® bone graft (Medtronic Sofamor Danek, Memphis, Tennessee) was prepared by reconstitution of the protein as per protocol and application to a Helistat® absorbable collagen sponge (Integra Life Sciences, Plainsboro, New Jersey). 45 minutes were allowed for binding of rhBMP-2 to the ACS. To create a stable shape a block of absorbable tricalcium phosphate and hydroxyapatite Mastergraft® (Medtronic sofamore Danek) 5 cm x 2.5 cm x 1cm was split into two triangles. The rhBMP-2/ACS implant was then wrapped around each section of Mastergraft and sutured with 4-0 chromic. The grafts were then placed into the calvarial defects and the scalp was closed.

Postoperative recovery was unremarkable save for an alteration in the time course of swelling likely due to rhBMP-2/ACS. Maximal eyelid edema peaked at 48 hours and resolved rapidly by the 5th postoperative day. Good suparaorbital projection was achieved along with a pleasing calvarial contour. CT scan at 3 months confirmed membranous bone formation at the implantation sites.

Discussion
The anatomic pathology of trigonocephaly is characterized by a lack of bone formation involving the lateral frontal bone and lateral orbital roof. Bowing of the metopic suture occurs as a consequence. Most cases are bilateral, so the suture remains in the midline. In the unilateral presentation, a marked shift of the metopic suture toward the deficient side is observed. Surgical advancement of the bandeau reveals the location of the problem. The lateral aspect of the orbital roof is reduced in surface area. So too is the adjacent lateral aspect of the frontal bone. Surrounding bones are perfectly normal in size but with growth may undergo some distortion in shape. This is especially true for the contralateral, normal frontal bone. When transposed and rotated it often provides a nearly perfect match for the requirements on the ipsilateral side.
Synostosis of the metopic suture cannot be the cause of trigonocephaly for six salient reasons. (1) Trigonocephaly has an *ipsilateral variant*, the pathology of which cannot be attributed to a midline structure of the forehead. The scaphocephalic cranium is not twisted. (2) If *Virchow’s postulate* is correct, when a midline suture ceases to grow, its flanking membranous bone fields will be constrained laterally. Thus, true metopic synostosis should behave in a manner consonant with that of sagittal suture synostosis. Vertical elongation of the frontal bone should occur. “Pinching in” of the lateral frontal bone or elevation of the lateral canthus cannot be ascribed to a midline suture. The metopic suture does not extend into the orbital plane. *The two orbital plates are separated by the ethmoid cribriform plate*. The ethmoid is chondral, not membranous bone. There is no anatomic relationship between the metopic suture and the lateral orbital roof. Recession of the supraorbital ridge can result from a reduction in surface area of the lateral orbital plate but it cannot be ascribed to an anatomically distant midline structural defect. (3) Trigonocephaly can be associated are varying degrees of *hypotelorism*, generally mild. New molecular techniques in developmental biology have generated numerous “fate mapping” experiments designed to reveal the pathways and destiny of neural crest populations dedicated to craniofacial development. These studies suggest that the fronto-orbital bone is far from a unitary structure. Instead it is a complex of development fields. The neural crest precursors making up these fields come from distinct sites in the embryo. Neural crest cells (NC) arising from above the prosencephalon are termed PNC, those originating from above the mesencephalon are termed MNC, while still others from above the rhomboencephalon are termed RNC. These populations make separate contributions to the orbital plate, the supraorbital frontal bone and to the frontal bone lateral to the frontotemporal fascia. Hypotelorism in its varying forms of severity can be understood as a deficiency state of these neural crest populations, not as the result of a synostosis. (4) Severe cases of trigonocephaly are associated with varying degrees of
neuropsychological impairment. No pathogenetic mechanism has been established between single-suture synostosis and brain development. Metopic suture malfunction is, quite simply, incapable of providing an explanation for the neurologic findings (when present) of severe trigonocephaly. (5) Cranial base changes have been reported subsequent to surgical correction of craniosynostosis. No clear relationship as yet has been put forth to explain, from an embryologic standpoint, exactly why such changes should take place in the chondral bones of the skull base...especially as related to a suture of membranous bone in the frontal midline. (6) Finally, the term “metopic synostosis” presumes a premature fusion of the suture such that it fails to function physiologically. It is now clear that fusion of this suture is a very normal event as early as two months of age with no consequent fronto-orbital deformity. What has been interpreted as synostosis has simply been a part of the normal spectrum of metopic suture biology. Metopic suture synostosis does not exist. Details of these arguments are as follows.

The primacy of bilaterality

As midline structures, the metopic and sagittal sutures would seem at first glance to have a great deal in common. The embryologic origin of source mesenchyme for the frontal and parietal bones is quite different. The frontal bones are derived from prosencephalic neural crest above zone p6 and p5 (vide infra). The parietal bones are derived from paraxial mesoderm in register with rhombomeres 2 and 3. (Morriss-Kay). Signalling between these sutures and the underlying dura may also be quite different. In a rat model frontal (metopic) suture closure occurs early while the sagittal suture remains patent. (-180 degrees rotation of calvarial strips including the posterior frontal suture and anterior parietal suture causes a reversal of this fusion pattern). Thus regional differences in the dura play a determining role in suture behavior. Such differences also suggest that the dura mater is comprised of distinct developmental populations capable of expressing a unique pattern of genes on a unique timetable. (Jamie)
A great deal of attention has been placed on elucidating the specific nature of these dural signals. Upregulation of mRNA corresponding to TGB[beta]1 and bFGF has been amply documented in cranial suture fusion, following a vector from endocranial to epicranial. In these elegant studies photomicrographs intense degrees of staining of for the cytokine probe are consistently shown on both sides of the suture. It is hypothesized that abnormalities of these proteins are involved in the pathogenesis of premature suture closure. These cytokines are widely distributed in embryos. They are not produced unilaterally. Mutations for these cytokines cannot therefore produce unilateral pathology.

The unilateral variant of trigonocephaly is at odds with this molecular model. An abnormality of the cytokine signal should never be found on one side of the suture only. Furthermore, if the cytokine alone were at fault would not other bilateral abnormalities be found in all expression zones of the embryo? Malfunction of a midline suture cannot cause ipsilateral pathology. Developmental anomalies affecting the right vs. the left side of the calvarium may well reflect regional differences of mesenchyme or the ectoderm which lead to regional differences in suture behavior. Patterns of synostosis may actually reflect events in the formation of the underlying developmental fields which can be traced back to miscues in gastrulation itself.

Is Virchow’s “law” relevant?

Virchow’s law, though frequently invoked in craniosynostosis literature, reflects a premolecular model of skull growth that is likely inaccurate. (1) Calvarial bones possess multiple centers of ossification. (Gray’s) Ossification of membranous bone relates to its biologic “age.” As development proceeds, ossification spreads in all directions from these ossification centers. For this reason, ossification centers have proven useful in studies of postoperative growth. Each frontal bone has two such centers, both located along the axis of the supraorbital artery. The dorsal center lies midway between the coronal suture and the supraorbital
ridge. The ventral center is located at the supraorbital foramen. Frontal bone growth involves over time the maturation of bone at progressively more peripheral zones away from the dorsal and ventral centers. A model of frontal bone development based on the metopic suture as a focus of growth is at odds with these observations.

On the etiology of hypotelorism: MNC vs. PNC

Neuroembryology and craniofacial development are inseparable. The existence of common genetically-defined embryologic zones shared among the brain, the neural crest, and outlying ectoderm/mesenchyme. Pathologies within these zones, known as developmental fields, may provide the basis for understanding craniofacial anomalies. Because these fields ultimately relate to neuroectodermal developmental zones (neuromeres) this new body of knowledge is known as neuromeric theory. Details regarding applications of neuromeric theory to formation of craniofacial structures were reported by this author in 2000 and in subsequent publications. Fate mapping of the neural crest responsible for frontal lobe dura and orbital plate embryogenesis suggests that these neural crest cell populations may arise from a common neuromeric source. Hypotelorism and inadequate cortical development thus become molecular problems, very much unrelated to synostosis.

Orbital growth is largely complete at birth due to the stability of ophthalmic globe size. Dimensional change in orbital position with respect to the cranial base is reflected in the intraocular axis. Burdi demonstrated that the postnatal axis changes by only 2 degrees. Anterior cranial fossa width can be measured using the distance between the fronto-zygomatic sutures. After birth these transverse dimensions change little. Growth of the anterior cranial fossa in the axial plane is largely anteroposterior; it occurs posterior to the FZ-FZ plane. Increasing size of the frontal lobe is accompanied by changes in the frontal bone consisting of a vertical growth vector and a lateral growth vector posterior to the line of fusion of frontotemporal fascia and anterior to the coronal suture.
The transverse position of the eyes with respect to the midline is determined by the mesenchymal volume of two principal developmental fields: (1) the ethmoid complex; and (2) the medial orbital wall/orbital roof. *No frontal bone intervenes between the cribriform plate and the orbital roof.* Reduction in frontal mesenchyme ascribed to the metopic suture cannot cause hypotelorism. Reduction in mesenchyme of the ethmoid complex and medial orbital roof will cause a medialization of the globes. As will be discussed further (vide infra) neural crest dedicated to synthesis of the orbital roof *originates from a different embryonic source* than fated to become the frontal bone.

Mapping of avian neural folds has been extensively investigated by Couly and Le Douarin. PNC populates the surface ectoderm responsible for the skin of the fronto-nasal process. This skin is innervated by V1 and supplied by the terminal branches of the anterior cerebral artery (internal carotid). The most rostral extent of this skin is that lining the roof of the nose and septum. The caudal population of this PNC produces the frontal bone. MNC is the likely source of mesenchyme for the presphenoid, the ethmoid complex, the lesser wing of sphenoid, the orbital roof, the vomer, and premaxilla. New evidence exists suggesting that this mesencephalic neural crest, not that associated with the 1st pharyngeal arch, may be the source of the maxilla. The maxilla may not, in fact, be a first arch derivative at all!

Neural crest arising from the mesencephalic neural folds (MNC) flows forward to surround the inferior and anterior aspects of developing cerebral hemispheres like two hands cupped together, palms upward. MNC has three separate genetically distinct populations called (in cranio-caudal order) r0, r1, and r2. This nomenclature comes from the *neuromere* with which each population of neural crest is associated. Neuromeres are developmental compartments of the nervous system associated with specific neuroanatomic structures. For example, the spinal cord, having 31 pairs of motor and sensory units has 31 neuromeres. The hindbrain (rhombencephalon) has 12 *rhombomeres* numbered r0-r11. The first two, physically located over the midbrain (*mesencephalon*) and isthmus.
The hindbrain has two parts. The cerebellum (metaencephalon) is an r1 structure. The medulla (myelencephalon) is formed from r2-r11.

Each neuromere has a genetic definition, a certain combination of proteins that give it an identity. These proteins have a common structural of 63 amino acids known as a homeodomain, the function of which is to unlock DNA. Homeotic genes are conserved throughout evolution from the *Drosophila* through *homo sapiens* because they determine the segmental organization of the organism. Thus a unique set of these genes serves like the barcode of a credit card to give anatomic identity to each level of the human nervous system. *Tissue outlying the nervous system, such a neural crest, mesoderm and endoderm are organized in the same way.* The first pharyngeal arch is associated with r2 and r3. All tissues innervated by V3 (the sensory and motor nuclei of which lie within r3) share elements of the same r3 genetic definition. Much like a tattoo cell populations associated with r3 maintain their neuromeric identity throughout their ontogeny.

Some of this mesenchyme will become the dura covering all parts of the cerebrum innervated by V1. Beneath the future frontal lobes r1 MNC condenses into first into paired *trabecular cartilages*. From these develop first the presphenoid bone followed by the ethmoid complex and the nasal septum More laterally, the ventral MNC envelops each ophthalmic anlage as it emerges from the ventral aspect of the diencephalon. These neural crest populations become the *orbital cartilages*. They are transformed directly into the membranous bone of the medial orbital wall and orbital roof. This type of bone formation (in which membranous bone is formed via a transient cartilage intermediate) is known as *chondroid ossification*. The anteroposterior axis of the orbital cartilage is the supraorbital artery. When orbital plate neural crest deficiency occurs, it manifests itself in a gradient from the periphery toward this supraorbital axis. FIG This deficiency is most easily appreciated as a triangular defect of the lateral orbital roof but a finite amount of medial wall deficiency must also be present. For this reason, when trigoncephaly is severe, reduction in the medial orbital roof dimension results in obvious hypotelorism.
As previously mentioned, development of each frontal bone proceeds from two distinct ossification centers, each located along the vertical axis of the supraorbital artery. The ventral ossification center represents the orbital roof, the supraorbital ridge, and the zygomatic process of the frontal bone. Deficiency of this latter zone will result in an upward displacement of the frontozygomatic suture. This explains the elevation of the lateral canthus frequently noted in patients with trigonocephaly.

Frontal bone from above the supraorbital ridge develops from the dorsal ossification center. This cell population is of PNC origin. Ossification from this center occurs later in time than that of the MNC population. This is not surprising because studies following the time course of neural crest migration show that MNC migration is completed by somite stage 14 whereas PNC migration is not complete until somite stage 16 (Osumi).

This suggests that the frontal bone is assembled like Lego® set. The dorsal PNC component is built upon the foundation of the ventral MNC component. Anencephalic fetuses demonstrate this nicely. Although entire brain and calvarium may be absent, the face, orbits and supraorbital ridges remain present.

In this model the dimensions of the forehead can never be greater than those laid down by the orbital mesenchyme. In trigonocephaly, the presence of a constricted MNC “basement” will prevent the formation of an adequate PNC “roof.” Surgical separation of the orbital bandeau from the frontal bone flap reveals the surface area of the frontal bone to be invariably inadequate to cover the newly expanded calvarium. This deficiency does not have to be ascribed to a separate lack of PNC mesenchyme. It can be totally explained on the basis of an inadequate MNC foundation.

Is severe trigonocephaly a distinct neuropathologic entity?

All dura covering the forebrain comes from neural crest. Only the forebrain possesses dura. The embryonic source of dural neural crest can be derived from its pattern of innervation (vide infra). The
frontal lobe is innervated by the 1\textsuperscript{st} branch of the trigeminal nerve. The nucleus of V1 resides in the 1\textsuperscript{st} rhombomere (r1) of the neural plate. The neural folds corresponding to r1 reside above the mesencephalon. Thus, MNC provides both the dural covering of the frontal lobe as well as fronto-orbital mesenchyme.

PNC is spatially positioned such that it could also contribute to the dural covering of the frontal lobe. Recall that PNC flows forward from the caudal prosencephalon (the future diencephalon) to populate the neural folds above the rostral prosencephalon (the future telencephalon). These rostral folds are strictly ectodermal. They are devoid of neural crest cells. Formation of dermis covering the forehead, nose and nasal lining cannot take place without this rostral-ward migration of PNC. Thus, the anterior frontal lobes are surrounded by two layers of neural crest. MNC arising from r1 constitutes the internal layer. PNC situated above p6 and p5 constitutes the external layer. A major

\textit{Neuroectoderm is incapable of forming blood vessels.} Two sources of mesenchyme external to the nervous system provide vasculature to the brain. The \textit{subdural system} consists of the internal carotid and basilar arteries. These vessels enter from the skull base and insinuate themselves into the developmental folds of the brain providing penetrating branches into the cortical parenchyma. The \textit{epidural system} consists of large branches derived from the external carotid, such as the anterior and middle meningeal arteries. Along with these large vessels are multiple branches arising from the dura and penetrating into the cortical substance of the brain. The epidural system is dedicated to the telencephalon. These vessels do not supply the diencephalons, nor any other component of the CNS.

Two types of mesenchyme are involved in the embryogenesis of dural vessels. Paraxial mesoderm PAM is the primary source arising from the first three somitomeres. The contribution of each somitomeres (Sm) to the telencephalon can be mapped out on the basis of the sensory innervation to the dura. Vessels penetrating the frontal lobe are likely composed of PAM from the 1\textsuperscript{st} somitomeres that lies directly
in register with the 1\textsuperscript{st} rhombomere. Neural crest mesenchyme provides important “support cells” called \textit{pericytes} to these penetrating dural vessels. Proper vasculogenesis cannot occur without pericytes. Neural crest deficiency/malfunction causes neuropathology of the cortex (most likely atrophy). For these reasons abnormalities of MNC (possibly admixed with PNC) in severe trigonoccephaly could be expected to affect the penetrating vessels arising from dura and penetrating the outer cortex of the frontal lobe.

The final argument relating severe trigonoccephaly to neuropsychological deficits lies in the concordance of CNS developmental fields (neuromeres) with corresponding outlying mesenchyme (PAM and neural crest). Although neuromeric theory is discussed in further detail later it is sufficient to state that the human embryonic forebrain (prosencephalon) is divided into six prosomeres. Subdivision of the prosomeres into the various components of the brain is genetically-based and has a complex topology. For our purposes those the prosomeres can be divided into two tiers, alar and basal. The alar zone of the most rostral prosomeres, p6 and p5, provide all substance of the human telencephalon. Frontal lobe development can be mapped to prosomere p5. A severe disturbance in the neuroembryology of p5 will be likely to affect the neural folds lying above p5. Neural crest cell development in zone p5 would consequently be also affected.

Fate mapping studies reveal that zone p6 neural crest is responsible for the formation of the nasal vestibular dermis and the lateral nasal cartilages. PNC occupying the p5 zone forms the skin of the philtrum, columella, nose and forehead above the supraorbital ridges. The lateral margin of p5 skin is the fronto-temporal fascia insertion (posterior to this line, the skin comes from r2 and is V2-innervated). \textit{Neuropathology intrinsic to the p5 forebrain will also affect p5 neural crest cells}. A small frontal lobe will not demand a large frontal bone cover. In trigonoccephaly, we can hypothesize the existence of a genetic defect that begins with the most rostral population of MNC and spreads forward into the most caudal
population of PNC resulting progressively worsening deficits of both fronto-orbital bone and the anterior cerebrum.

Thus developmental neuropathology occurring in a neuromere can manifest itself in pathologic development of mesenchymal structures of the face and cranium having a common neural crest origin with the affected neuromere. The face does not predict the brain...the brain predicts the face.

**Response to surgery:** “what you see is what you get,”

Trigonocephaly is a developmental field defect in which the soft tissues responsible for the synthesis of a specific zone of bone malfunction. A small or absent bone field is merely the manifestation of an embryologic deficit in the mesenchyme or epithelium responsible for the production of that field. Surrounding fields that are physically in contact with the deficient field are likewise affected. Although perfectly normal in mesenchymal volume, these fields cannot grow normally; they are constrained and may become misshapen over time. Thus, a tissue deficit in a developmental field leads to deficiency-induced field mismatch. For this reason, abnormalities in the cranial base have been documented in the presence of trigonocephaly.

Deficiency states should, in theory, respond readily to surgery. Fronto-orbital advancement using bandeau technique combined with frontal cranial remodeling is highly effective for the correction of trigonocephaly. Operative strategies are well described and outcomes measurements have been reported. The biologic basis for the success of this surgery is simple: it achieves release at two key sites of pathology: the orbital roof and lateral frontal bone. The amount of bone required to fill in the gaps is the exact measurement of the deficiency state. Advancement of bone forward into a normal spatial configuration results in repositioning of the overlying soft tissues. The deficiency state causative of trigonocephaly is not osseous, but resides instead in the soft tissues. This deficiency state will persist in these soft tissue fields even after surgery. Over time, the lateral orbit cannot be expected to grow normally because the biosynthetic fields remain abnormal.
Why then is trigonocephaly surgery so successful? CT evaluation at one year postop demonstrates that anterior fossa dimensions are essentially those achieved at the time of surgery. (Marsh) At the same time whereas the posterior fossa dimensions compared with the maximum width of the skull are normalized. Anterior advancement of lateral orbital rims has also proven to be stable. (Posnick) In other words, the on-table result is predictable of the long-term outcome. Why should this be so? Achieves a lasting volume correction of the anterior fossa while permitting self-correction of the posterior fossa. The answer lies in the “biologic maturity” of the orbit. Even at birth the size of the orbit is near that of the adult; by one year of age, orbital growth is virtually complete. This development of the skull reflects the neuroembryologic primacy of the frontal lobes. Surgical correction is nearly definitive.

Skull base remodeling is a well-documented response to craniosynostosis surgery. In each condition, the endocranial base demonstrates a morphology specific to the suture involved. (Marsh) In trigonocephaly the posterior fossa is widened; the site of maximum width is also more dorsal than normal. Bandeau advancement and frontal remodeling permit the posterior fossa to self-correct. At first glance this should seem absurd but this phenomenon is readily explained by developmental field theory, described by this author elsewhere. The embryology of the cranial base will be the subject of further communications. For the moment it suffices to state that neighboring fields in physical contact with a deficiency site will grow normally but their shape will be altered by the physical constraint of the deficient field. For this reason, even a very anterior condition such as trigonocephaly will be accompanied by alterations of the entire skull base. Surgical release of this constraint permits normal anatomy to become reestablished over time.
Early fusion of the metopic suture is normal: the elephant in the closet

Trigonocephaly is fascinating because it illustrates so much of what we don’t know about the developmental anatomy of the skull. Synostosis of the metopic suture is encrusted in the literature, but recent advances in neuroembryology (fate mapping in particular) make this concept obsolete. Evolution of new research technologies often becomes the engine of change in science. CT scan data regarding the normal course of metopic suture fusion provide a perfect case in point.

Physiologic closure of the metopic suture has been accepted as beginning at 2 years of age. (Cohen NM) but the literature is not uniform on this point. Stricker suggested closure at birth to be the norm. Closure before age two has been reported in monkeys and in humans. (Chopra, Manzanares) To resolve the issue Panchal et a. reviewed 159 CT scans for deformational plagiocephaly or trauma in children 1-24 months of age. The study broke down neatly by age into four groups 3, 5, 7 and 9 months. In the youngest group 33% were closed. At 5 months and 7 months 59% and 65% were (respectively closed. By age 9 months, all patients were closed. A similar study by Bartlett demonstrated in 76 trauma patients demonstrated metopic fusion to begin at the nasion and progress cephalically. Suture closure was complete by 8 months of age in all patients.

These authors studies raise two very important issues: (1) If Virchow’s law is true, how is normal frontal development possible after 8-9 months of age (a time in which forehead growth is far from complete)? (2) Why is it that two patients of the same age group can both have a fused metopic suture with one patient developing normally, while the other demonstrates full-blown trigonocephaly? The answers to these questions are best answered by the application of neuromeric field model to the developmental anatomy of the skull. This approach can be applied to other forms of synostosis as well. The results may well demonstrate an unexpected and surprising
degree of confluence between data stemming from gene-based probes and the molecular embryology of the brain.

Conclusion

The clinical findings and treatment of a case of unilateral trigonocephaly are presented. Trigonocephaly is a well-known condition involving deformity of the supraorbital ridges, forehead with subtle findings including reduction in the surface area of the lateral orbital roof, upward displacement of the lateral canthus, a variable degree of hypotelorism, and compensatory deformational changes in the skull base. Tradition explanations involving premature fusion of the metopic suture cannot adequately explain these findings. A new model of trigonocephaly based on developmental fields and neuroembryology is presented. Cranial remodelling brings out the exact nature of the osseous deficiency in this condition. The excellent postoperative results, along with “plastic” response of the skull base back toward normal, confirm the principles of this model. Surgical treatment based upon the identification and release of a deficient developmental field is effective and accurate.

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**Neuromeres: the clinical significance of the neuromeric map**

Neural crest originating from neural folds associated with rhombomeres r2 to r11 supplies the pharyngeal arch system. When the neural crest cells migrate they swarm over the surface of the
mesoderm lying just outside the neural tube. This mesoderm is called paraxial mesoderm (PAM) and is segmented in direct register with the neuromeric system. Each segment of PAM is called a somitomere (Sm) and is shaped like a ball. The first 7 somitomeres (corresponding to r1-r7) are incompletely separated. All somitomeres from Sm8 caudally undergo anatomic rearrangement into somites. Thus, Sm8-Sm11 form the four occipital somites. Sm 12 becomes the first cervical somite. Developmental biologists refer to mesoderm from Sm1-Sm7 as cephalic mesoderm.

Each mesenchyme of pharyngeal arch consists of mesoderm from two units of PAM (somitomeres or somites) plus the neural crest. The original number of pharyngeal arches in primitive aquatic vertebrates was seven. With the tetrapod transition to a land-based existence this number was reduced to five. Thus, the mesenchyme of each pharyngeal arch (PA) is composed of PAM and neural crest associated with a pair of rhombomeres. Neural crest migration is a physical process in which the cells move along (1) pathways of least resistance (anatomic cleavage planes) or (2) molecular “guide wires” such as vimentin. Neural crest cells swarm over the surface of PAM somitomeres like taffy poured over an apple. The neural take three routes. (1) They can move laterally outward in the plane between the non-neural ectoderm /endoderm and the somitomeres; (2) They remain interposed between the neural tube and the somitomeres. (3) They migrate ventral to the neural tube and then travel caudally stopping along their way to form the sympathetic chain.

At this juncture we must take note of a caveat that applies to concepts about prosomeres held widely within the scientific community. Many descriptions of brain anatomy extent in the literature assign four neuromeres to the forebrain, two for the telencephalon and two for the diencephalon. These are known respectively as T2/T1 and D2/D1. This nomenclature is elegantly presented in the brain development section of texts such as that of O’Rahilly and Muller. (36-38) Based on sophisticated gene mapping techniques previously unavailable, the Rubenstein-Puelles model has
by no means been universally incorporated into the thinking of neurologists, neuropathologists, and researchers. However, from the standpoint of craniofacial surgery the R-P model constitutes an extremely sensitive instrument with which to analyze patterns of deformity. Hence we shall make use of this terminology in our discussion.

The clinical significance of the neuromeric model is that it enables us to map out the anatomic site of origin for all zones of ectoderm and mesoderm supplied by a given zone of the nervous system. Neural crest structure in these zones can be assigned to a neuromere of origin. This type of fate-mapping has practical consequences. Pathology occurring in the r1 “premaxillary zone” (be it of inadequate cell number, defective migration, abnormal post-migratory rates of mitosis or cell death) will lead to a small or absent premaxilla. Furthermore if the premaxillary MNC has several subsets, aligned in craniocaudal order along the neural fold (ascending process, lateral incisor and central incisor) then the spectrum of deficiency states seen in the premaxilla of cleft patients can be understood as progressively greater degrees of disturbance in this precursor population.

Understand the development of frontal-orbital requires a firm grasp of the differences between PNC, MNC, and RNC as well as contributions from the first three somitomeres. Once grasped, these concepts will lead to reader to understand this region as a “field map” in which individual mesenchymal units are assembled, much like Lego® pieces, into a complex whole. Many well-known craniofacial anomalies such as orbital clefts and synostoses, can be understood as the consequence of deficiency states or outright absence of a developmental field. Remaining fields in anatomic continuity with the abnormal field will collapse inward toward the side but will continue to grow normally. As a result they undergo a deformation over time. This is termed deficiency-induced field mismatch and it is a problem in four dimensions. Attempts to achieve surgical correction through purely geometric maneuvers create surgeon-induced field mismatch that results, with time, in predictable patterns of relapse.
Before venturing further into the development of the forehead and orbit we need to get a little more terminology under our belts.

Segments, somitomeres, and somites (including their historical context)

Segmentation as a concept is highly intuitive. Repetitive functional units are observed in the centipede, in the multiple ribs of the snake, and in the dermatomes of the human thorax. All vertebrates possess the fundamental elements of a vertebral body, muscle units attached thereto, sensori-motor nerves arising at that same level to innervate those muscles and well-defined geographic zones of skin. All the future spinal cord all vertebrate embryos have primitive organizational blocks of mesoderm called somites. Each somite is preceded by an earlier, incompletely segmented structure, called a somitomere. These flank the neural tube from the cranial base to the tail. Each vertebra at a given neuromeric level is the combination of the caudal half-somite from the neuromeric level above immediately rostral to it and the cranial half-somite at that same neuromeric level. Human embryos possess 42-44 pairs of somites: 4 occipital somites contribute to the posterior brain case. These followed by 8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 8-10 coccygeal somites. The rostral 1st cervical somite contributes to the foramen magnum and its caudal half to the atlas. For this reason there are eight cervical nerves but only seven visible vertebrae.

Other Authors: Ann Marie Flannery, Mark Urata
Stratification of Palatal Clefts by Embryologic Etiology: Why the Surgical and Speech Literature is Confusing

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**Purpose:** The literature on palate clefts is rife with studies regarding post surgical speech which bundle together cleft palate associated with cleft lip (CL(P), isolated clefts of the secondary palate (CP), clefts associated with other craniofacial anomalies such as holoprosencephaly (HPE-CP) and isolated soft palate clefts (CPS). In microtia, levator veli palatini ipsilateral to the ear deformity is almost universally weak with decrease palatal elevation observable. The embryology of the levator palatini and its relationship to the formation of the ear points to a malfunction in the 3rd pharyngeal arch as the cause of CPS. If this is the case, up to 4 distinct embryologic mechanisms of palatal clefting exist. This theoretical perspective permits stratification of cleft results by embryologic means.

**Materials and Methods**

A new model of CNS embryology based upon genetically defined sectors of the neural plate called neuromeres has been extensively described dating back to 1994. Origins of craniofacial structures (particularly those derived from neural crest) can be “mapped” to individual neuromeric levels. Pairs of neuromeres provide neural crest
cells to each pharyngeal arch, producing dermis, cartilage, bone and fascia. The third pharyngeal arch (PA3) is in register with rhombomeres 6 and 7 of the hindbrain; these contain the nuclei of cranial nerve IX. Application of neuromeric theory will predict correlations among structures of the soft palate and external ear previously unappreciated. Children with unilateral microtia can be predicted to have ipsilateral weakness of the levator veli palatini. Neuromeric theory also predicts that, in isolated cleft palate (CP) vomerine deficiency should occur.

Results

Neuroanatomic findings in microtia and clefts disclose common sources of mesenchyme of a number of key structures. The two nuclei of cranial nerve IX reside in rhombomeres 6 and 7 from which the dermis of the most of the pinna is derived. The cell source for the levator veli palatini is from somitomeres 6-7. The origin of the LVP is from the petrous apex. The petrous temporal bone is produced from somitomere 6 while the mastoid comes from Sm7. This suggests that the dysplastic or mal-inserted musculature seen in CPS may result from pathology within the 3rd pharyngeal arch. Neurovascular analysis of the vomer and premaxilla demonstrates the structures to arise from neural crest mesenchyme flowing forward from the 2nd rhombomere beneath the perpendicular plate of the ethmoid. Superior constrictor arises from somitomeres 6 and 7 as well.

Premaxillary field insufficiency is the etiology of clefts of the primary palate. In unilateral cleft lip and palate, the vomer is attached to the non-cleft palatal shelf. This means that its vertical dimension is unaffected. 100% of children born with isolated CP have significant degrees of vomerine insufficiency in the vertical plane. The deficiency is worst posteriorly, becoming normal at the point of fusion of the palatal plane. In unilateral microtia, clinical observation demonstrates an observable incidence of LVP dysfunction in 80% cases.
Conclusions

Recent work regarding the neuromeric origins of craniofacial tissues suggests that multiple embryonic mechanisms are involved. In the case of CL(P) the problem is a deficiency state in the premaxilla such that a critical distance from the maxilla is exceeded and field fusion cannot occur. In isolated CP, a deficiency in the vomer takes it out of the plane of palatal shelf fusion. HPE-CP lacks the perpendicular ethmoid plate without which the vomer cannot form. Clefts of the soft palate (CPS) represent a deficiency state in the third pharyngeal arch. The frequent occurrence of velopharyngeal insufficiency in CPS may be due to a common field “hit” occurring at level r6-r7 such that both levator and constrictor are affected in mesenchymal mass or neurologic function.

Cleft palate involves at least 5 distinct embryologic mechanisms. Stratification of surgical and speech results using this model should afford a more accurate assessment of treatment outcomes.

**Other Authors:** Mark Urata, John F. Reinisch
The Orbital Roof Field in Unilateral Trigonocephaly: The Myth of Metopic Synostosis

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Purpose:
Trigonocephaly is commonly attributed to premature closure of the metopic suture. The pathologic features of trigonocephaly include (in addition to the midline ridge) lateral supraorbital recession, hypotelorism and (in severe cases) developmental delay. A midline suture defect cannot explain this anatomy, particularly in its unilateral presentation. The purpose of this presentation is to show that the clinical facts of unilateral trigonocephaly disprove the dogma of metopic suture synostosis. An alternative explanation of this problem using neuromeric theory is proposed. Timing of metopic suture closure and its irrelevance to the pathology of trigonocephaly will be understood. Relationships between the development of the frontal bone and the frontal lobe will be explored in terms of the embryologic origin of the frontal neuroectoderm and the mesenchyme that surrounds it.

Materials and Methods
Two patients underwent surgery correction for unilateral trigonocephaly. Frontal orbital advancement of the bandeau was done
bilateraly. Frontal bone remodeling was carried out using absorbable fixation plates. Bony anatomy was documented photographically and correlated with 3-D CT scans pre and post operatively. Findings were correlated with known neuromeric models of craniofacial bone embryology. A diagram of frontal bone developmental fields is presented showing the relationships between the frontal lobe dura and the frontal soft tissues (including the periosteum). All these fields are innervated by V1, the nucleus of which resides in the 1st rhombomere of the midbrain-hindbrain isthmus. The neural crest forming the dura and pericytes of the frontal lobe is of r1 origin. The blood vessels penetrating the frontal lobe are derived from paraxial mesoderm from the 1st somitomere (Sm1), located just outside the r1 zone of the neural tube. The neural crest forming the frontal dermis is of derived from the caudal prosencephalon while the vessels serving the forehead come from Sm1.

Results

The surface area of the ipsilateral orbital roof is significantly reduced. The overlying supraorbital rim is likewise recessed.

Conclusion :

A p5 mesenchymal deficiency in the orbital roof can readily explain the topology of the supraorbital margin and also the tendency toward hypotelorism with an intact ethmoid. Correlations with brain embryology of the p5 regions may explain functional neurologic deficits. Deficiency states of r1 may be additive to those of p5, causing reduction of the ethmoid developmental fields as well. The soft tissue fields responsible for synthesizing the frontal bones join in the midline over the fusion plane of the rostral prosencephalic fields. Defects in this system are intimately related to other craniofacial anomalies such as anencephaly, midline clefts, and holoprosencephaly. The brain predicts the face. The concept of metopic suture synostosis is incapable of explaining the findings of trigonocephaly and should be dropped from the literature.
Main Objectives of the Presentation

1. Timing of metopic suture closure and its irrelevance to the pathology of trigonocephaly will be understood.

2. Relationships between the development of the frontal bone and the frontal lobe will be explored in terms of the embryologic origin of the frontal neuroectoderm and the mesenchyme that surrounds it.

Other Authors: Mark Urata, John F. Reinisch
We’ll present our 10-year experience and technique in bilateral sagittal split osteotomies of the mandible with particular attention to possible damages to the inferior alveolar nerve. More than 1000 patients with class II or class III malocclusion were treated by a modified technique of short oblique osteotomy (BSOO- Bad homburg short oblique osteotomy) with a conventional combined orthognatic and surgical approach. The osteotomy was carried out using an oscillating saw (Aesculap). Compared to the classical techniques using saws, chisels or burs by conventional sagittal split osteotomy the BSOO technique shows a lot of advantages like minimal trauma, protection of nerve, minimal risk of unfavorable fracture, minimal dislocation of TMJ, no removal of wisdom-teeth necessary and a good control of the surgical procedure with a high level of precision.

Procedure and results, risks and limits are demonstrated as an alternative to former techniques.
Long term outcomes of ultra-thin polyethylene implants used for orbital floor reconstruction

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Abstract: Purpose: The objective of this article is to present the long-term outcomes of ultra-thin polyethylene implants used for orbital floor reconstruction in facial trauma patients.

Materials and Methods: From 1998 to 2004, 38 patients underwent orbital floor reconstruction with porous polyethylene implants with a mean follow-up of 4 years. A subciliary incision and preexisting facial wounds or scars were used. The boundaries of the maxillofacial injury and the orbital volumes of both orbits were assessed by computed tomography images obtained pre- and postoperatively. In all patients, ultra-thin porous polyethylene implants in various sizes were used to reconstruct the orbital floor defect.

Results: None of the patients needed removal of the implants during the follow-up. The volume increase of the traumatized orbits ranged from 0.04 to 6.18 (average 3.12 ± 1.48) mL compared with the intact orbit (P < 0.01). This difference was not significant postoperatively (P > 0.01). Postoperative ectropion in three cases was corrected under local anesthesia. Persistence of complications were as follows: enophthalmos, 3 in 28; diplopia, 1 in 16; dystopia, 1 in 4;
and infraorbital nerve hypoesthesia, 3 in 31. One patient underwent late enucleation of the globe because of initial penetrating trauma.

Conclusions: We recommend the use of ultra-thin porous polyethylene implants in the reconstruction of the orbital floor defects in facial trauma patients. The implants are durable in the long-term and mimic the anatomy of the thin orbital floor and avoid the morbidity of autogenous bone grafts.

Others Authors: Serdar Ozturk, Mustafa Sengezer, Fatih Zor
Distraction Osteogenesis in treating craniofacial deformities – An Indian Armed Forces experience

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Abstract: Objectives: To assess the stability, functional improvements, quality of bone radiologically & histologically and soft tissue changes after treating various cases of craniofacial deformities with the science of distraction osteogenesis.

Methods: 106 cases of varied craniofacial deformities were treated in this centre since the year 2002 with distraction osteogenesis. The deformities ranged from craniofacial deformities as a result of trauma and operated cases of tumors (both benign & malignant), post TMJ ankylosis cases, syndromic cases, congenital deformities like midface deformities due to clefts, Mandibular hypoplasia, cases of obstructive sleep apnea (OSA), craniosynostosis etc. Cases of mandibular deformities treated were 63 (59.43 %), maxillary deformities were 16(15.09 %), vertical augmentation of microvascular fibular graft for replaced mandible were 14 (13.20 %), 03 (2.83%) cases of craniosynostosis and 10 cases (9.43 %) in various combination. Pre surgical analysis of the craniofacial skeleton with cephalometry, CT scan and other relevant investigations were done as indicated. Methods applied ranged from the use of Rigid External Distractors (midface deficiency), Cranial distractors to intra oral distractor devices (1/
Oral Mandibular ramus / body (Adult & Paediatric), I/Oral midface, I/Oral vertical distractors, I/Oral Transport distractors etc). Pre & Post surgical orthodontics was done wherever indicated. Use of prosthodontic rehabilitation was done in 26 cases (24.52 %). In 10 cases, revisit to the distraction site was done and biopsy of the bone was obtained with consent of the patients.

**Results** : Satisfactory & stable results without significant complications were achieved in 97 cases (91.50 %). Post surgical evaluation of cephalometry revealed significant improvement in the soft tissue profile. Bone histology revealed well formed, mature lamellar distracted bone. Pre & Post surgical orthodontics gave excellent postoperative functional occlusion. Prosthodontic rehabilitation was successfully done subsequently as implant based prosthesis in 16 cases (15.09 %).

**Conclusions** : Distraction due to its versatility has established itself as a procedure of choice in a multitude of specific conditions. Cases treated with this technique show better stability with good quality of bone with long-term stability.

**INTRODUCTION**

Deformities in the human body are represented in the hard or soft tissues. Craniomaxillofacial region, due to its anatomical peculiarities, pose a challenge to the maxillofacial surgeons for correcting various deformities. Various procedures ranging from orthognathic surgery to bone grafting are in practice for correction of these deformities. The latest in the treatment of these deformities is the technique of distraction osteogenesis which is fast turning to be the treatment of choice in correcting such deformities.

**MATERIAL & METHODS**

A total of 106 cases with age ranging from 04 years to 27 years of varied craniofacial deformities have been treated in this centre since the year 2002 with distraction osteogenesis. The deformities ranged from craniofacial deformities as a result of trauma and operated cases
of tumors (both benign & malignant), post TMJ ankylosis cases, syndromic cases, congenital deformities like midface deformities due to clefts, Mandibular hypoplasia, cases of obstructive sleep apnea (OSA), craniosynostosis etc. Out of these, 103 cases (97.16%) have been completed in totality and 03 cases (2.83%) are presently ongoing.

Cases of mandibular deformities treated were 73 (68.86%) and were subdivided into categories comprising of 35 cases (47.94%) of body distraction, 15 cases (20.54%) of ramus distraction, 18 cases (24.65%) of vertical distraction of alveolus / microvascular fibular graft, 03 cases (4.10%) of transport distraction to form neo-osteogenesis of body mandible and 02 cases (2.73%) of mandibular transverse distraction (SARME). One case (1.36%) of Treacher Collin syndrome, aged 04 years, on tracheostomy from birth was treated for mandibular distraction and was successfully weaned from tracheostomy within 04 months of completion of distraction.

Midface deformities treated were 21 (19.81%) and were subdivided into 12 cases (11.32%) of midface distraction with 07 cases (58.33%) treated with intraoral device and 05 cases (41.66%) treated with RED. Other mid face deformities treated were in the form of 05 cases (23.80%) of SARPE and 04 cases (19.04%) of alveolar distraction.

Others comprised of 10 cases (9.43%) of dual jaw combination distraction for facial asymmetry and 02 cases of (1.88%) craniosynostosis operated for distraction.

All cases were subjected to presurgical imaging comprised of cephalometric evaluation, both lateral & postero-anterior views as per indication, to determine the extent of deformities, orthopantomography, maxillofacial CT scans, routine x-ray comprising of occlusal views, IOPA etc and other and other relevant investigations. Both pre & post digital photographic records and pre / post surgical dental cast recording were done as a comparison. Volumetric facial analysis was done as an when indicated, specially in cases of facial asymmetry and syndromic cases like hemifacial microsomnia.
Other than the cases of craniosynostosis and alveolar distractions, all cases (81.13 %) were subjected to pre and post surgical orthodontics. 26 Cases (24.52 %) had to undergo prosthodontic rehabilitation to replace congenitally missing teeth or after extraction of unsalvageable teeth.

In 10 cases, revisit to the distraction site was done and biopsy of the bone was obtained with consent of the patients with a view to study the stages of maturation of the distracted bone with successful results.

RESULTS
Satisfactory & stable results without significant complications were achieved in 97 cases (94.17 %) out of the completed 103 cases. Post surgical evaluation of cephalometry revealed significant improvement in the soft tissue profile. Bone histology revealed well formed, mature lamellar distracted bone. Pre & Post surgical orthodontics to correct dental compensations or malocclusion gave excellent postoperative functional occlusion. Prosthodontic rehabilitation was successfully done in 26 cases (24.52 %) and implant based prosthesis was given in 16 cases (15.09 %). A review period of averagely one year for almost all patients was followed. Post operative plain radiograph & CT review after one year showed consolidated distracted bone in excellent osteointegration with the host site. Complications faced were transient open bite in 03 cases, sinus with device extrusion in one case, distractor device failure in one case, incomplete corticotomy in initial first case of Mandibular distraction, undesirable transport vector etc. All these complications were intercepted as and when detected successfully.

DISCUSSION
Distraction Osteogenesis is a biologic process of new bone formation between the adjoining surfaces of bone segments that are gradually separated by incremental traction. Ever since the technique was propounded by Illizarov [1] in orthopaedic surgery, it has gained

The basic concept of the procedure is induction of new bone formation along the vector of pull obviating the need for a bone graft. Finally, the increase in resulting bone stock will provide more reconstructive options in the future for traditional orthognathic surgical techniques. The common indications for the use of distraction in maxillofacial region are: Congenital deformities (Nagers syndrome, Treacher Collins syndrome, Pierre Robin syndrome, Cranofacial scoliosis, Hemifacial microsomia), sequelae of TMJ ankylosis, Syndromic Craniosynostosis, CLP, Trauma etc.

Ilizarov initially used Distraction osteogenesis for the treatment of skeletal deformities of long bones, both congenital and acquired. Through the careful observation of natural biological phenomena and the correct interpretation of their interaction, he was able to develop a therapeutical protocol that imitated the works of nature. Various factors influence this technique. These include biological, bone and distraction factors. Under certain pathological circumstances, the inflammatory process that is elicited during tension leads to tissue repair through an intramembranous ossification process, which terminates with the formation of new bone tissue. By artificially creating a fracture, a repair process is triggered initiating cell duplication.

The application of a continuous stretching force on the two bone segments through the use of a device triggers the conditions for growth. The undifferentiated cells in the bone marrow evolve into osteoblasts and begin formation of interlaced bone tissue orientated into parallel lines. Muscle and soft tissue mass increase via a process referred to as distraction histogenesis. Clinically, this offers a distinct advantage as several craniofacial anomalies have soft tissue hypoplasia, in addition to deficient bony structures. Neurovascular
elements contained within distracted bony segments also are stimulated to regenerate. In all our cases we found healthy new bone in the distraction zone both radiographically and clinically during the removal of the distractors. Osteocyte viability is essential to provide an adequate source of osteoblastic activity at the distraction site, hence careful surgical technique to minimize thermal or mechanical bone injury must be ensured. Similarly, an adequate blood supply to the distraction site & an intact periosteum and endosteum are critical to osteogenesis. In our surgical protocol, the bone cuts were restricted to osteotomy aimed at preserving the endosteal tissues thus facilitating an optimal bone healing.

The latency, rate, and rhythm of distraction are all known to influence the quality of the regenerate. Of these factors, the effect of latency is the most controversial. Most maxillofacial surgeons recommend waiting 4-7 days following osteotomy before initiating the distraction process. In younger children, the high rate of bone metabolism would favor a shorter waiting period. Waiting too long prior to distraction substantially increases the risk of premature bone union. In all the cases managed, distraction was started on the 4th day. In contrast to latency, the rate and frequency (i.e., rhythm) of distraction are considered important variables. If widening of the osteotomy site occurs too rapidly, then a fibrous bridge resulting in nonunion results, whereas if the rate is too slow, then premature bony union prevents expansion to the desired length. Most studies have described a rate of 1.0 mm/day to be ideal.

The ideal rhythm is a continuous form of distraction; however, this is impractical on a clinical basis. Therefore, distraction frequencies of 2-3 times daily are followed. All cases treated were subjected to two cycles of distraction per day at the rate of 0.4 mm per cycle. The length of the consolidation phase has been recommended to range from 4-6 weeks. We followed a gap of 8 weeks after the last distraction cycle before removing the distractors. Finally, appliance rigidity during distraction and consolidation is a critical element to ensure that bending or shearing forces do not result in micro fractures of the
immature columns of new bone within the regenerate, which lead to focal hemorrhage and cartilage interposition.

Distraction due to its versatility has established itself as a procedure of choice in a multitude of specific conditions. Cases treated with this technique show better stability with good quality of bone with long-term stability.
Correction of Mandibular Hypoplasia Using Distraction Osteogenesis

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SUMMARY

Distraction osteogenesis (DO) is a technique used to gradually lengthen bone that allows the body’s natural healing mechanisms to generate the new bone for augmentation. DO is an effective technique for correcting facial asymmetry, such as temporomandibular joint hypoplasia, cleft lip and palate, craniofacial deficiency, and maxillary or mandibular retrognathism. This article presents a case of mandibular hypoplasia. A 22-year-old female visited our clinic to have facial asymmetry corrected. She had mandibular hypoplasia because a left condylectomy had been performed 12 years earlier. We planned to use DO to lengthen the mandible in conjunction with a Le Fort I osteotomy for decanting; we first performed a bilateral sagittal split ramus osteotomy (BSSRO) and genioplasty. Progressive distraction at a rate of 0.5 mm every 12 hours was initiated on postoperative day 8 and continued for 15 days. A satisfactory result was obtained in our patient. DO can be used successfully for functional and aesthetic reconstruction of the mandible.

KEY WORDS

distraction osteogenesis, mandibular hypoplasia, 22-year-old female
Introduction

Distraction osteogenesis is a method of lengthening bone by forming new bone on each side of an osteotomy. After Ilizarov first reported this method for lengthening the extremities, it has been used in various clinical settings. In 1989, McCarthy et al. performed distraction osteogenesis in the maxillomandibular complex in patients with hemifacial microsomia by applying a distraction device in the mandible. Different clinical techniques are still being developed for applying distraction osteogenesis in various fields of dentistry; the procedure is especially effective for improving appearance and function when jaw surgery and orthodontic treatment are needed in patients with facial deformity. We report a case in which DO in conjunction with orthognathic surgery was used to successfully correct mandibular hypoplasia, together with literature reviews.

Report of a case

In 2004, a 22-year-old female visited our department because of an asymmetric jaw line. The patient underwent condylectomy in 1992 to treat fibrous ankylosis of the left lateral mandible and had undergone orthodontic treatment since 2002 in our department.

Clinical evaluation showed a bird face due to undergrowth of the mandible, and the chin was deviated 15 mm toward the left. The patient complained of pain in the joint area of the left lateral mandible when she opened the mouth maximally (40 mm). The examination of the mouth showed that the occlusion of the right and left posterior teeth was Class I, Class II molar key, with 10 mm overjet, 5 mm overbite, and 12 mm occlusal canting. Radiographic evaluation showed hypoplasia of the left mandibular ramus. With the diagnosis of hypoplasia of the left mandible, a treatment protocol was proposed in which the lagging mandible would be distracted by applying ramal distraction osteogenesis; a Le Fort I osteotomy would be performed to correct the tilting of the maxilla, followed by bilateral sagittal split ramus osteotomy (BSSRO) and genioplasty about 1 year later to improve her appearance and function.
Front view at the time of the initial visit. Oral view at the time of the initial visit. CT at the time of the initial visit.
The first surgery was performed on 29 March 2004 with the patient under general anesthesia. After performing the Le Fort I osteotomy, the right side was decanted by 5 mm in the upper portion, and the left by 5 mm in the lower portion and fixed using a metal mini-plate. In the mandible, the dissection was performed from the affected left mandible angle to the condyle, and an L-shaped osteotomy was made. A ramal distractor was placed, exposed externally, and the wound sutured. After a 1-week latency period, distraction osteogenesis was begun at a rate of 1 mm a day by distracting 0.5 mm in the morning and evening for 15 days. The patient complained of slight pain, but no infection was present. After allowing a 12-week hardening period, the distractor was removed on 21 July 2004. Slight facial nerve paralysis was observed immediately after removing the distractor, but disappeared within 1 week. No other complications occurred.
A second surgery was performed on 20 July 2005 with the patient under general anesthesia. BSSRO was used to advance the right side by 2 mm and the left by 10 mm. Genioplasty was done to shift the end of the chin 6 mm anteriorly, fixed with a metal mini-plate, and the wound sutured. Although bleeding occurred in the left mental foramen immediately after surgery, it was stopped with Vaseline gauze. Temporal computed tomography (CT) was taken to confirm a fracture in the anterior wall of the external auditory canal. The fracture site was protected, and improved, by packing the area for 1 week using vaseline gauze. Auditory testing was normal. Although the inferior alveolar nerve was damaged in the left mentum immediately after surgery, it recovered within 1 month. No other complication occurred. No relapse was observed 2 years 6 months postoperatively, when the patient was satisfied with her appearance and function.
Front view after the completion of surgery.

After the completion of surgery.

Oral view after the completion of surgery.
Discussion

Distraction osteogenesis, which is also called callus distraction, is a method of distracting a piece of bone to form new bone on each side of an osteotomy. The force applied to the bone is also exerted on the soft tissues surrounding the bone, so that the soft tissue is also distended for potential reformation, with the resulting bone lengthening. This process involves a histologic reformation process rather than lengthening of the soft tissues at one time, as in the case of bone grafting, so that any soft tissue shrinkage is reduced. Furthermore, the hospitalization period, surgery period, and surgery risks are smaller than with conventional methods. Distraction osteogenesis is drawing interest as an effective alternative to treat facial deformities, such as a small chin, cleft palate, mandibular or maxillary prognathism, and facial bone defects due to trauma or tumor removal.

However, the surgeon must be highly knowledgeable about bone physiology and bone healing patterns to maximize the outcome of distraction osteogenesis. The latency period is defined as the time between osteotomy and the beginning of distraction. During this period, capillaries and fibroblasts emerge in the blood network between the fractured pieces of bone. Distraction is usually started 1 week after osteotomy in adults, but can begin sooner in younger people. The distraction rate is determined by considering the distraction period, rate of blood flow, area of the osteotomized end, and distraction distance. On average, it is 1.0 mm/day for the mandible and up to 2.0 mm for a maxilla with good blood flow. Incremental distraction is recommended in those areas where the patient feels pain and from the perspective of bone formation. Incremental distraction done twice a day was also effective in our patient, who felt little pain. After the distraction period, a consolidation period of 8 to 12 weeks allows the newly formed bone in the distracted portion to harden and gain strength. After this period, the distractor can be removed. It takes an average of 1 year for the bone quality to equal that before osteotomy during what is called the
remodeling period. Based on this criterion, corrective jaw surgery was performed about 1 year after distraction osteogenesis in this patient. No significant difference, clinically and radiographically, was observed between the newly formed bone and existing bone at 1 year. It is essential to make an accurate diagnosis and treatment protocol when applying distraction osteogenesis, and CT can substantially aid this effort\(^6\). The prognosis can now be predicted by simulating the outcome with a computer. The distractor used for distraction osteogenesis can be either intra- or extraoral. Usually, the direction of distraction can be controlled when a multidirectional extraoral distraction device is used, so that the ideal length and shape are obtained\(^1\). However, an extraoral device can result in a scar on the face. An intraoral device does not leave any scar, but distraction osteogenesis could fail if it is not installed correctly\(^1\). We used an extraoral device in our patient to obtain the desired amount of bone, and the facial scar left by this device disappeared gradually, so that both the surgeon and patient were satisfied. The complications of mandibular distraction osteogenesis are related to the device (screw loosening, device breakage), infection, nerve damage, and ramus resorption\(^7\). These complications can be minimized by carefully planning the treatment protocol with an accurate diagnosis and skillful surgery.

Our patient felt pain in the ramus region in the early stage of distraction, but we believed that this was a temporary situation caused by the ramus exerting force on the glenoid fossa. The issue of infection can be also resolved with preventive antibiotic administration and dressing the site daily. Relapse is another problem with distraction osteogenesis and has been after long-term follow-up of those patients with hemifacial microsomia despite a good outcome after the initial mandibular distraction osteogenesis\(^9\). Of course, this problem should be considered fully in growing patients. Although we cannot be absolutely certain in our patient, due to the short follow-up period, relapse is unlikely in fully grown patients.
Distraction osteogenesis is an excellent technique for facial reconstruction. It is effective for improving appearance and function when jaw surgery and orthodontic treatment are needed by patients with facial asymmetry. However, it should be technique-sensitive, device-sensitive, and patient-sensitive, and an accurate diagnosis and treatment protocol are required. It is also essential to predict and counter any intra- and postoperative complications. Distraction osteogenesis is not done at once. Its outcome heavily relies on patient compliance, so that patient education should be thorough and he/she should be followed closely to increase the success rate. We obtained a satisfactory outcome as a result of complete patient cooperation and by establishing an accurate diagnosis and treatment protocol.

References
Histopathological and immunohistochemical changes in the craniomandibular joint, according to the extent of mandibular lengthening in the rabbit

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Abstract
We sought to investigate the histopathological changes in the craniomandibular joint, according to the extent of mandibular lengthening.

Osteotomy was performed on the left mandibular body of rabbits, and then a unilateral distraction device was deployed. Prior to lengthening of the mandible, a 5-day latency period was allowed. The mandible was lengthened by 0.5 mm once daily for 6 days (group 1), 0.5 mm twice daily for 3 days (group 2), 0.5 mm once daily for 10 days (group 3), or 0.5 mm twice daily for 5 days (group 4). This was followed by a 14-day consolidation period, after which the rabbits were killed and the craniomandibular joint subjected to histopathological and immunohistochemical examination.

No degenerative changes were observed in the craniomandibular joint in any of the groups. On the distraction side, histopathological examination showed hypertrophic thickening of the cartilage zone; endochondral ossification was more evident, and osteoblasts were more active in groups 3 and 4. On the non-distraction side, no major changes occurred, except for the appearance of osteoclasts in groups...
3 and 4. Immunohistochemistry revealed tenascin immunoreactivity in bone marrow mesenchymal cells on the distraction side in group 4, which indicated that chondrocytes increased more in that group. Connexin immunoreactivity did not markedly change in any of the groups. Osteocalcin was observed on the distraction side in group 2, which suggests that bone formation increased to a greater extent. Nitric oxide synthase 2 immunoreactivity was observed on the distraction side in group 2, which indicates a relationship between stress and inflammation.

We conclude that as the extent and frequency of distraction increased, hypertrophy of the cartilage zone became more pronounced and endochondral ossification was more evident, but no degenerative changes occurred.

I. Introduction

Several diverse methods have long been used to reconstruct congenital or acquired bone defects or deficiency. The representative methods are bone grafting using autologous or heterologous bone, insertion of bone substitute materials, and flap surgery. Potential problems are the resorption of grafted bone and infection, new defects in the donor area, and rapid changes in, and insufficiency of, the surrounding soft tissues. Distraction osteogenesis compensates for such disadvantages; that is, the donor area is not required and distraction is achieved simultaneously with adjacent tissues. Thus, with distraction osteogenesis, the problems associated with rapid changes in the adjacent tissues, soft tissue deletion, and limits to the length of the graft area are ameliorated.

Distraction osteogenesis is a technique involving corticotomy or osteotomy in which the gradual lengthening force is delivered using fixation devices; thus, traction is performed on the space between bone fragments to form new bones. It was described for the first time by Codivilla in 1905. In 1989, Ilizarov reported the tension stress principle, which posits that distraction maintained at an appropriate rate induces bone formation, and that the bone is lengthened and
bone continuity maintained. Upon termination of distraction, bone
formation is also terminated and bone consolidation is achieved.
Ilizarov\textsuperscript{2,3}) thus established the theoretical basis for the procedure.

In the oromaxillofacial field, distraction osteogenesis is applied
to alveolar bone defects; on alveolar bone showing severe atrophy, it
has been used in many cases as a presurgical technique prior to
subsequent prosthetic treatment or implantation. Recently, it has been
used frequently for the reconstruction of congenital or acquired
deformities, such as unilateral or bilateral microsomia in the mandible
or the cleft palate. In particular, in cases of unilateral microsomia,
numerous studies have been performed on the craniomandibular joint,
which may become a problem if distraction osteogenesis is performed
on the mandibular body or the mandibular ascending ramus.

Our purpose was to examine immunohistochemical changes
occurring in the craniomandibular during unilateral distraction
osteogenesis at different speeds and extents, and to perform
histological and immunohistochemical evaluation of the distraction
and non-distraction sides.

II. Materials and methods

1. Materials

Twenty healthy rabbits, weighing \textasciitilde2-3 kg, were divided into two
experimental groups of eight animals (distraction and non-distraction
sides), with four rabbits in the control group. The experimental groups
were divided again, according to the extent and frequency of
distraction. Extent of distraction was 3 mm in groups 1 and 2, and 5
mm in groups 3 and 4; four animals were assigned to each group
(Table 1) and maintained with solid animal feed under identical
conditions.
Table 1. Study design

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of rabbits</th>
<th>Total rate of distraction</th>
<th>Frequency of distraction</th>
<th>Period of distraction (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>4</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Group 1</td>
<td>4</td>
<td>3</td>
<td>0.5 mm once daily</td>
<td>6</td>
</tr>
<tr>
<td>Group 2</td>
<td>4</td>
<td>3</td>
<td>0.5 mm twice daily</td>
<td>3</td>
</tr>
<tr>
<td>Group 3</td>
<td>4</td>
<td>5</td>
<td>0.5 mm once daily</td>
<td>10</td>
</tr>
<tr>
<td>Group 4</td>
<td>4</td>
<td>5</td>
<td>0.5 mm twice daily</td>
<td>5</td>
</tr>
</tbody>
</table>

Distraction osteogenesis devices were made by adding self-curing resin to 5-mm expansion screws (FöresaDent, Pforzheim, Germany), and for device fixation, 8-mm self-tapping screws (Jeil, Seoul, Korea) were used.

2. Experiment methods
   (i) Corticotomy and device fixation

   General anesthesia was induced by injecting 5 mg/kg ketamine HCL (Ketara; Yoo Han Yang Hang, Seoul, Korea) intramuscularly, and additionally injecting 0.3 mg/kg xylazine (Rompun; Bayer Korea, Seoul, Korea). Prior to surgery, to prevent infection, 5 mg/kg gentamicin (Gentamycin; Green Cross, Yongin, Korea) was injected intramuscularly, and hairs on the left side of the mandibular inferior border were removed and sterilized. To stop bleeding, 2% lidocaine HCl (containing 1:100,000 epinephrine) was injected into the surgical area, and into the extraoral area. Following the mandibular inferior border, a skin incision was made from the mandibular angle to the cuspid, and vertical osteotomy was performed using a fissure bur in the first premolar area of the mandible. While performing osteotomy, water was sprayed to minimize heat generation. In the corticotomy area, a device was made to serve as the resection surface, placed in the center, and fixed to the mandible with self-tapping screws.
The osteotomy area was sutured, and gentamicin (5 mg/kg) was injected intramuscularly once daily for 5 days after surgery to prevent infection.

(ii) Latency, distraction, and consolidation periods

A 5-day latency period followed corticotomy and device fixation, and a second experiment was performed to expose the distraction device. General anesthesia was induced, and the distraction device was exposed by opening the suture area and locating the black silk suture. Distraction was carried out after performing the secondary surgery. In group 1, distraction was 0.5 mm once daily for 6 days, giving a total of 3 mm; in group 2, distraction was 0.5 mm twice daily for 3 days, giving a total of 3 mm; in group 4, distraction was 0.5 mm twice daily for 5 days, giving a total of 5 mm distraction. In each group, 14 days of consolidation was allowed.

(iii) Preparation of tissue sections

After the latency period (5 days), distraction period (6, 3, 10, and 5 days), and consolidation period (14 days), the rabbits were euthanized at 25, 22, 29, and 24 days, respectively, along with the control group. Half of the specimens were prepared as decalcified samples and examined under a light microscope, and the other half was prepared for immunohistochemical staining.

To prepare the decalcified samples, tissues were kept in 10% formalin for 24 h, and subsequently decalcified with nitric acid (De-Cal Rapid; Pational Diagnosis, Atlanta, GA, USA) for 24 h, embedded in paraffin according to conventional methods, sectioned to ~5 µm thickness on the sagittal plane, and stained with hematoxylin and eosin (H&E).

For immunohistochemistry, paraffin-embedded blocks were sectioned to 5 µm thickness, mounted on 2% 3-aminoprophyltriethoxy-syran-coated slides, deparaffinized, and dehydrated. Sections were incubated for 30 min in phosphate-buffered saline (PBS) solution containing 1% bovine serum albumin, and
treated with PBS containing 0.01% protease type XXIV (Sigma, St. Louis, MO, USA) at room temperature for 10 min. After washing with PBS, sections were incubated with rabbit antihuman tenascin (1:50; Serotec, Oxford, UK), rabbit anti-connexin (1:100, Zymed Lab, San Francisco, CA, USA), goat anti-osteocalcin (1:100; Santa Cruz Biotechnology, Santa Cruz, CA, USA), and goat anti-NOS2 (1:100; Santa Cruz Biotechnology) at 4°C. After washing with PBS, tissues were incubated with biotinylated goat ant-rabbit IgG antibody diluted to 1:200. The samples were subsequently incubated with 0.1 M Tris-HCl buffer (pH 7.2).

III. Results

1. Macroscopic findings

After surgery, the condition of the rabbits was good; infection in the vicinity of the distraction device was detected, and dislocation of the distraction device was not observed. In addition, the resistance caused by manipulating the distraction device increased during the early period; nevertheless, with the progression of distraction, it showed a tendency to decrease. As a result of the unilateral distraction of the left side, the mandible was found to be deviated to the right. The formation of new bones in the bone distraction area was not detected.

2. Light microscopy findings

The condylar surface was covered with an avascular fibrous connective tissue layer containing some cartilage, with collagen fibers running in parallel on the condyle surface. Beneath the surface, proliferative, fibrocartilaginous, and hypertrophic cartilage zones, and subarticular bone were observed.

On the distraction side of group 1, we observed increased cartilage in the proliferative zone, thickening of the fibrocartilagenous zone and the hypertrophic cartilagenous cell layer, and cartilagenous ossification. An increase in osteoblasts in the subchondral bone was also detected.
Photomicrograph of the control group showing a normal craniomandibular joint (H&E stain, ×40).

Photomicrograph of the distraction side in group 1 after treatment. The hypertrophic cartilage zone thickened and the number of chondrocytes increased.

Photomicrograph of the non-distraction side in group 1 after treatment. No marked changes or increase in chondrocytes were observed.
On the distraction side of group 2, we observed increased cartilage cells in the proliferative zone and thickening of the fibrocartilagenous and hypertrophic cartilagenous cell layers. In addition, cartilagenous ossification was also detected. However, on the non-distraction side, ossification did not occur, and an increase in osteoclasts was seen.

On the distraction side of group 3, the number of cartilage cells in the proliferative zone increased to a level comparable to that in groups 1 and 2. The thickness of the fibrocartilaginous cell layer was shown to be thickened, and cartilagenous ossification was observed.

On the distraction side of group 4, cartilage cells in the proliferative zone increased, and the fibrocartilagenous cell layer was thickened. In addition, we observed an increase in cartilagenous ossification in the subchondral bone.

3. Immunohistochemical results

The immunohistochemical reaction to tenacin was observed in group 4, which implies an increase in cartilage cells. In addition, gap junction-forming connexin was not expressed in the bone and cartilage. We detected a distinct difference in the expression of osteoclastin, a factor associated with bone formation that is expressed in response to osteoblasts, as well as the relative expression of nitric oxide synthase 2, a factor associated with stress and inflammatory reaction, on the distraction side in group 2.

IV. Discussion

Distraction osteogenesis is a technique that restores bone defects caused by trauma, tumors, and congenital deformity by applying the biological healing process of the bone. Clinically, distraction osteogenesis is performed in four stages. First, osteotomy is performed in the area requiring distraction and a distraction device is implanted; however, prior to performing distraction, we allow a latency period for the formation of the primary callus, similar to the fracture healing process. At that time, if the latency period is too short, fibrous union
Photomicrograph of the distraction side in group 2 after treatment. The hypertrophic cartilage zone thickened, chondrocytes increased, and osteoblasts appeared.

Photomicrograph of the non-distraction side in group 2 side after treatment. No sign of ossification was observed; osteoclasts appeared.

Photomicrograph of the distraction side in group 3 after treatment. The number of osteoblasts increased and endochondral ossification appeared.
or nonunion may develop instead of the primary callus, and if the latency period is too long, ossification of the osteotomy area occurs\(^5,6\). Next, the distraction period allows the formation of soft callus, which stimulates the formation of new tissues by delivering the distraction to tissues between the resected bone fragments. The consolidation period occurs between the completion of distraction and the removal of the distraction device, and is the time when the new bones formed after distraction become more mature and obtain the required strength. Distraction osteogenesis performed by such procedures has been investigated continuously in efforts to overcome the limitations of traditional bone grafting. Numerous studies have been conducted on the facial area, and changes not only in the newly formed bone tissues, but also in muscles, nerves, and temporomandibular joint have been reported.

Recently, distraction osteogenesis has been applied to the reconstruction of congenital deformity of the mandibulofacial area. Mandibular microsomia is congenital in origin in most cases, and is a sequela of trauma, rheumatoid arthritis, and radiotherapy, as well as tumor resection. However, compared to costa graft, which was performed previously, distraction osteogenesis has certain advantages; for example, lengthening the mandibular bone does not incur discomfort or impairment of the donor area, it can be performed in cases in which costa graft has failed or on patients who do not desire a bone graft, and it can overcome the limitations due to changes in the vertical, horizontal, or anteroposterior length\(^7\). Its shortcomings are that it may cause infection or mandibular joint impairment, and malocclusion has been noted. Therefore, appropriate presurgical plans to compensate for such shortcomings, accurate evaluation of patients, and control of the distraction device in a precise direction are required\(^8\).

The greatest problem with mandibular distraction may be that the changes in the temporomandibular joint caused by distraction cannot be considered separately, and thus numerous studies have been conducted accordingly. McCarthy \textit{et al.}\(^9\) described mandibular
Photomicrograph of the non-distraction side in group 3 after treatment. No ossification occurred; osteoclast activity was activated.

Photomicrograph of the distraction side in group 4 after treatment. Activated osteoblasts and ossification were observed.

Photomicrograph of the non-distraction side in group 4 after treatment. Activated osteoclasts were observed.
distraction using extraoral devices in humans, and showed that the mandible was successfully lengthened applying bone distraction in four unilateral microsomia patients. Kulewicz et al. demonstrated that unilateral mandibular distraction performed on 2- to 15-year-old growing patients was effective; nonetheless, they asserted that appropriate corrective treatments were required during the consolidation period. Hamada et al. reported retrusion of a section of the condyle area, with no major changes in the mandibular joint being detected. In addition, Kusnoto et al. reported that unilateral mandibular distraction in growing unilateral microsomia patients did not lead to any major problems pertinent to their growth. Gabbay et al. studied the use of a conventional Matthew device and distraction in hemifacial microsomia patients, and found that no major changes occurred in the initial period; however, with regard to long-term recurrence, conventional surgical treatments were more effective. Ko et al. treated growing patients with unilateral distraction, and obtained stable results. Similarly, Shetye et al. found no major problems in growing patients with mandibular microsomia treated with unilateral distraction. Harper et al. described bone distraction of the mandibular midline, and observed thickening of the fibrous layer in the mandibular joint and the cartilage layer; furthermore, the reaction of osteoblasts was shown to be active but later recovered. Copray et al. reported that when a small continuous force is delivered to the condyle, proliferation of the subchondral cell layer is stimulated, and that its proliferation is reduced by intermittent force. For matrix formation, the subchondral cell layer is active when intermittent force is delivered. Nakai et al. reported that an intermittent compression force stimulates ossification within cartilage, and that such reaction facilitates the growth potential of condylar cartilage; moreover, it was resistant to external change, and induced stability of the growing mandibular condyle. Sambuukov et al. stated that in performing the stress analysis during distraction, the rotation of the condyle axis was induced by the lateral rotation of the mandible and the distraction of the midline of the mandible, and thus the device must be implanted parallel to the distraction side. Ahn et al. reported
Immunohistochemical staining for tenascin in the craniomandibular joint in group 4 after treatment. Increased tenascin immunoreactivity was observed on the distraction side.

Immunohistochemical staining for connexin in the craniomandibular joint in group 3 after treatment. No marked immunoreactivity for connexin was observed.
that during the unilateral distraction of the mandible, the effect of force is more noticeable on the distraction than on the non-distraction side, and in the posterior versus the anterior area. The thickness of the articular disk recovers gradually with time, the articular cartilage in the temporal bone and the mandibular condyle decreases, and the osteoid seam becomes gradually initialized.

Kofod et al.\textsuperscript{23,24} studied the stress in the mandibular joint area during unilateral mandibular distraction in patients with arthritis, and found that the stress was delivered to the posterior side of the non-distraction side, although overall, the force partially increased. Nevertheless, the stress in the mandibular joint area was low, and in a simulation, the stress was more focused during unilateral distraction and became identical to that on the non-distraction side. Kim et al.\textsuperscript{25} examined the mandible in rabbits during unilateral mandibular distraction and did not detect degenerative or inflammatory changes, although endochondral ossification was observed on the distraction side. Thurmuller et al.\textsuperscript{26} examined the mandibular joint in pigs after mandibular distraction, and found thinning of the medial articular disk. When the distraction speed (4 mm/day) increased, the condyle and the articular disk exhibited degenerative or inflammatory changes, but when the distraction speed was reduced (1 mm/day), such changes disappeared. Zou et al.\textsuperscript{27} studied the distraction speed and changes in the mandibular joint, and found that when the distraction speed was 1 mm/day, inflammatory changes in the condyle and cartilage occurred, and at 2 mm/day, degenerative changes were induced. Liu et al.\textsuperscript{28} reported in white rats that excessive increases in the rate of distraction led to degenerative or inflammatory alterations of the condyle and cartilage.

In the present study, we examined changes in the craniomandibular joint in relation to distraction speed and extent during unilateral mandibular distraction using light microscopy and immunohistochemistry. The results showed an increase in the number of cartilage cells in the proliferative layer on the distraction side, and an increase in the hypertrophic cartilage layer. As the speed and extent
of distraction were increased, the number of cartilage cells increased accordingly. Immunohistochemically, degenerative changes were not detected as the speed and extent of distraction were increased. However, our study was performed by killing rabbits immediately after the consolidation period, and the changes on the distraction side, as well as the non-distraction side, that could have developed with time could not be examined. In addition, the study was based on a restricted distraction of up to 5 mm.
V. Conclusion

Degenerative changes were not detected during unilateral mandibular distraction of rabbits. As the extent of distraction was increased, we detected the expression of osteocalcin on the distraction side due to an increase in osteoblasts, and as the distraction speed was increased, we observed the expression of nitric oxide synthase 2 due to stress and inflammatory reaction. During unilateral mandibular distraction, degenerative changes dependent on the extent and speed of distraction were not detected. We recommend that future studies focus on greater increases in the extent and speed of distraction and evaluate their effect on the craniomandibular joint according to the time after the consolidation period.

Other Authors: Sin-Young Ahn
Glossopharyngeal neuralgia treated using microvascular decompression

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A 61-year-old female reported intermittent piercing pain from tongue to pinna on the left side. Although she had been prescribed carbamazepine and has undergone attempted nerve block on several occasions, no pain relief has been achieved. MVD was thus attempted using a lateral suboccipital approach. The offending vessel, which was PICA, had adhered to the glossopharyngeal nerve and was repositioned laterally away from the nerve by interposition of a felt cushion. Pain disappeared immediately after surgery and has not recurred. In the literature, MVD for glossopharyngeal neuralgia has been performed using a transcondylar approach to achieve minimally invasive surgery. However, the sensory distributions for the floor of the oral cavity and tongue involve 4 overlapping nerves: the trigeminal nerve, sensory components of the facial and vagal nerves, and the glossopharyngeal nerve. In typical cases, it seems that the transcondylar fossa approach is appropriate for glossopharyngeal neuralgia. If the pain occurs in the place involving an overlapping nerve, the lateral suboccipital approach might be necessary.

Others Authors: Shigeru Ohyama, Shuichi Oki, Masayuki Sumida, Naoyuki Isobe, Makoto Kureshima, Yasuharu Kurokawa
Clinico-Statistical Study of Midface Fractures

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Department of Dentistry, Oral and Maxillofacial Surgery, Jichi Medical University

Introduction: Maxillofacial fractures occur for various reasons such as traffic accidents, industrial accidents, and sports injuries, and the types of injury tend to be diverse. Among these, midface fracture involves not only functional disorders such as occlusal abnormality and dysmasesis, but also cosmetic concerns, and these two aspects must be considered when determining the treatment. We have evaluated the clinical statistics on midface fractures patients who visited our department and studied the cause of injury as well as the reasoning behind the choice of treatment, and we would like to report the results of such cases.

Material and Methods: Clinical analyses were conducted regarding age, gender, cause of injury, referral route, length of time between the injury and hospital visit, the injured area, and the course of treatment, etc. A study was conducted on 45 midface fracture patients who visited and were treated in our university hospital during the eight-year period from 1998 to 2006, based on their medical charts, images, and surgical findings.

Results: A breakdown by age shows that there were 27 cases in the under 30 group, which was the largest group(fig.1). A breakdown
by gender shows that there were more male cases, with 32 males and 13 females, and a male–female ratio of 2.3:1(fig.2). As for referral route, 30 cases were referred from other hospitals, accounting for the majority of cases, and 14 cases were referred from our ER(table 1). The most common cause of injury was car accidents, accounting for 30 cases, followed by occupational accidents(table 2). With regard to the length of time between injury and hospital visit, 21 cases visited the hospital on the same day of the injury, thus indicating that approximately half of the patients were seen by physicians at a relatively early stage(fig.3). Fractures of the limbs and pelvis were the most common associated injuries, 14 cases, followed by cephalic injury, and then thoracic injury(table 3).

As for the fractured area within the midface, the maxilla bone was fractured in 37 cases, which was the most common case, followed by a fracture of the cheekbone(fig.4). Surgery was performed in 32 cases, among which, plate fixation was performed in 30 cases. Moreover, in 5 cases, the jawbones were reconstructed by means of plate fixation and bone transplantation(fig.5). Intermaxillary fixation was performed in 27 cases for an average length of 17.1 days(fig.6).
Table 1. Referral route

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>%</th>
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</thead>
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<tr>
<td>Other hospitals</td>
<td>30</td>
<td>66.7</td>
</tr>
<tr>
<td>Our ER</td>
<td>14</td>
<td>31.1</td>
</tr>
<tr>
<td>Independent gait</td>
<td>1</td>
<td>2.2</td>
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Table 2. Cause of Injury

<table>
<thead>
<tr>
<th></th>
<th>Cases</th>
<th>%</th>
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<tbody>
<tr>
<td>Car accidents</td>
<td>30</td>
<td>66.7</td>
</tr>
<tr>
<td>Occupational accidents</td>
<td>7</td>
<td>15.6</td>
</tr>
<tr>
<td>Falling accidents</td>
<td>3</td>
<td>6.6</td>
</tr>
<tr>
<td>Beating, Fighting</td>
<td>2</td>
<td>4.4</td>
</tr>
<tr>
<td>Sports</td>
<td>2</td>
<td>4.4</td>
</tr>
</tbody>
</table>
3rd Asia Pacific Congress on Craniofacial Surgery & Distraction Osteogenesis

![Pie chart showing the distribution of cases based on the time between injury and hospitalization.]

**Regard to the Length of Time between Injury and Hospital**

**Fig. 3**

<table>
<thead>
<tr>
<th>Table 3. Complication</th>
<th>Cases</th>
<th>%</th>
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</thead>
<tbody>
<tr>
<td>Cephalic injury</td>
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<td>23.3</td>
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<tr>
<td>Cervical vertebrae and Thoracic vertebrae injury</td>
<td>5</td>
<td>11.6</td>
</tr>
<tr>
<td>Thoracic injury</td>
<td>10</td>
<td>23.3</td>
</tr>
<tr>
<td>Abdominal injury</td>
<td>4</td>
<td>9.3</td>
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<tr>
<td>Limbs and Pelvis injury</td>
<td>14</td>
<td>32.5</td>
</tr>
</tbody>
</table>
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![Skull Diagram]

- Temporal: 16 (35.6%)
- Orbital floor: 5 (11.1%)
- Maxilla: 37 (82.2%)
- Frontal: 14 (31.1%)
- Nasal: 9 (20.0%)
- Zygoma: 33 (73.3%)

![Pie Chart]

- Operation 52 cases
  - Plate fixation 20 cases
  - Bone fixation 32 cases
  - Plate fixation and bone fixation 2 cases

![Bar Chart]

- Term of Intermaxillary fixation
  - Fig. 5
  - Total 27 cases
  - Average 17 days

481
Conclusion: In our department, the choice of treatment method for midface fractures takes both cosmetic implications and functional recovery into consideration. In many cases, surgery has been selected as the first method of choice, and we believe that this choice has enabled us to achieve satisfactory results. In the future, we anticipate different types of fractures, as well as changes in the awareness of patients, and therefore treatment that responds to these factors will thus be necessary.

References:
Orthodontic and Orthognathic Surgery in severe class II skeletal malocclusion

Albert Surya Prawira
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**Abstract**: Patients requiring correction of large anterior open bites have historically been among the most challenging treatments for orthodontists. Correction of esthetic and functional problem is especially important. This is a case report of an adult female aged 17 years who complained of difficulty in chewing and talking. Patient was diagnosed to have a severe Class II skeletal malocclusion with an anterior open bite of 9 mm. Treatment included combined orthodontic and orthognathic surgical approach. Surgery included maxillary impaction of Le Fort I osteotomy and mandibular advancement of bilateral sagittal split osteotomy. Although the discrepancy was severe using this combination of treatment, an aesthetically pleasing and stable result was achieved.
Quantification of backscatter doses between scattering titanium dental implant

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Gülhane Military Medical Academy, Ankara, Turkey

Objectives: In this study, quantification of backscatter doses between scattering titanium dental implant and the thermoluminescent dosimeter (TLD100) radiation detector at axial beam irradiation-angle range of 0 to 90 degrees in head and neck radiotherapy is done to evaluate irradiation angle dependency of dose enhancement contributing to osteoradionecrosis. Methods: A cylindrical titanium dental implant with diameter of 4mm and length of 9mm was implanted into a specially-designed human mandible phantom with TLD100 chip placed on the buccal site and irradiated with 6 MV X, 25 MV X and Co-60 gamma sources at 19 different irradiation angles. Results: Our results show that dose enhancement on a buccal site of the titanium implant depends on the incident beam angle. At angles of 650, 600 and 400 the maximum detected scatter doses over the titanium implant are 36%, 32% and 23% for Co-60 gamma, 6 MV X and 25 MV X ray respectively. The dose enhancement at different beam angles was less pronounced in 25 MV X and more pronounced in Co-60 gamma irradiation.

Conclusions: For the different radiation beams studied, the irradiation angle between scattering titanium dental implants and the central axis does not significantly affect the total dose that may lead to osteoradionecrosis of the mandible.

Others Authors: Bedri Beydemir, Mehmet Dalkiz, Jülide Ozen
Gold Weight Implantation for Rehabilitation of the Paralyzed Eyelid

Mehmet Dalkiz

Gulhane Military Medical Academy, Dental Sciences Center, Department of Prosthodontics, Ankara – Turkey

Patients with complete facial nerve palsy are at risk of severe eye complications due to corneal exposure. Gold weight implantation improves function, cosmetic appearance and morbidity. Three patients with nerve palsy underwent insertion of precisely prepared gold weights between May 2000 and December 2001. Individual gold weights were implanted into a small pocket between the orbicularis oculi and the tarsal plate of the upper eyelid, fitting the curvature of the eye. According to follow-up examinations (after at least five years), none of the gold weights had extruded; all patients experienced marked improvement of their dry-eye symptoms and expressed a high degree of satisfaction. Implantation of gold weights is effective and should be considered in all patients for the management of paralytic lagophthalmos.

Other Authors: Hasan Suat Gokce, Asým Aydin, Bedri Beydemir
Immediate Prosthodontic Reconstruction After Maxillectomy

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Maxillectomy often results in a high level of morbidity with significant psychological and functional implications for the patient. Such disabilities include inability to masticate, deglutition, and speech disturbance. Unfortunately, little is known about the nature of the speech disturbance and the influence of the class of surgical defects in this group of patients. Immediate reconstruction of maxillectomy defects has been described as an alternative to immediate prosthetic rehabilitation to close the oral cavity. The aims of the present study were to assess the effectiveness of the maxillary obturator as speech rehabilitation aid and to examine the influence of dentition on speech intelligibility, to restore the patients’ regular daily activity as soon as possible, and to maintain the patients’ psychological well-being throughout the treatment.

Forty-one consecutive patient treatments of palatomaxillary immediate and definitive reconstruction at facility, The Gulhane Military Medical Academy (Ankara-Turkey.), were reviewed. Patients aged between 20 and 73 years with surgically acquired partial maxillary defects were included in this study. All patients were rehabilitated with immediate and definitive obturators. The patients
were given immediate surgical obturators which were adjusted to
the defect area with tissue conditioner. By this procedure and relining
with tissue conditioner weekly, immediate obturators were used in
the interim stage of the treatment. As interim obturators, protheses
were used for two to three months until healing and resorption were
found satisfactory after which the definitive obturators were
fabricated.

Other Authors: Fuat Tosun, Mustafa Gerek, O Cumhur Sipahi,
Bedri Beydemir
Prosthetic Rehabilitation of GAPO Syndrome

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GAPO syndrome is a rare autosomal recessive disorder whose main manifestations are: growth retardation, alopecia, pseudoanodontia and optic atrophy. We presented three cases with the clinical, the biochemical (routine blood and urine analysis), and radiological findings, prosthetic applications, and the effect of prosthetic restoration on the relationship between the jaw and face, and cephalometric evaluations. We conducted cephalometric measurement in all three cases but removable complete denture was applied in two males, except female patient who refused prosthesis. The cephalometric evaluation revealed that measurement of either middle part of the face or jaws was normal. This finding is contrary to the previous literature. The difference is based on the cephalometric measurement in ours versus inspection in all others. We concluded that patients with GAPO syndrome can reasonably be treated by prosthetic applications.

Other Authors: Davut Gül, Bedri Beydemir
Use of the Intraosseous Screw for Unilateral Upper Molar Distalization and Found Well Balanced Occlusion

Bedri Beydemir

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The aim of this study was to present a temporary anchorage device with intraosseous screw for unilateral molar distalization in a case. The screw was placed and immediately loaded to distalize the left upper first and second molar. The average distalization time to achieve an overcorrected Class I molar relationship was 3.6 months. There was no change in overjet, overbite, or mandibular plane angle measurements. Mild protrusion (0.5 mm) of the upper left central incisor was also recorded. In conclusion, immediately loaded intraosseous screw–supported anchorage unit was successful in achieving sufficient unilateral molar distalization without anchorage loss.

Other Authors: Ibrahim Erhan GelgorMehmet Dalkiz, O Cumhur Sipahi
Correction of Dental Class II Malocclusion with Help of the Intraosseous Screw Supporting

Cumhur Sipahi
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Recently, studies on implant and/ or onplant supported molar distalization appliances to reduce patient cooperation have increased. The aims of the present study were, 1) to investigate the efficiency of intraosseous screws for anchorage in maxillary molar distalization 2) to investigate the sagittal and vertical skeletal, dental and soft tissue changes following molar distalization using intraosseous screw-supported anchorage unit in the maxilla.

Eleven subjects (9 girls and 2 boys; 11.3-15.6 years of age) with skeletal class I, dental class II malocclusion were participated in the present study. For molar distalization an anchorage unit was prepared by placing an intraosseous screw behind the incisive canal and a safe distance away from the midpalatal suture following the palatal anatomy. After placement the screws were immediately loaded to distalize upper 1st molars or the 2nd molars when they were present. The average distalization time to achieve an overcorrected Class I molar relationship was 4.1 months. The skeletal and dental changes were measured on cephalographs and dental casts, obtained before and after the distalization. In cephalographs, upper 1st molars appeared to be tipped 10° and moved 3.6 mm distally on average.
On dental casts, the mean distalization was 5 mm. The upper molars were rotated distopalatally. Mild protrusion (mean 0.7 mm) of the upper central incisors was also recorded. However, there was no change in overjet, overbite and mandibular plane angle measurements. In conclusion, immediately-loaded intraosseous screw-supported anchorage unit was found to be successful in achieving sufficient molar distalization without major anchorage loss.

**Other Authors:** Ibrahim Erhan Gelgor, Mehmet Dalkiz, Bedri Beydemir
Restoration of gunshot maxillofacial injury using a dental implants

Bedri Beydemir
Gü lhane Military Medical Academy, Ankara, Turkey

Abstract: Purpose: A self-inflicted gunshot maxillofacial defect was restored with dental implants and different attachments. Material and Method: Following mandibular surgical reconstruction, a fixed full arch implant-supported prosthesis was fabricated. The maxillary defect was restored with an obturator retained with bar clip and ball attachments. Crowns with an unfavorable crown root ratio were used to rectify a compromised unilateral interocclusal space. Results: Functional rehabilitation was achieved without any pathological sequelae and maintained over one year observation period. Conclusion: Provision of an implant-retained mandibular fixed prosthesis opposing a specific design for a maxillary obturator provided short-term and optimistic prognosis in the management of a serious traumatic injury.

Others Authors: Julide Ozen, Bedri Beydemir, Cumhur Sipahi
Denture Retention for Xerostomic Patients

Mehmet Dalkiz
Gülhane Military Medical Academy, Ankara, Turkey

**Purpose:** The purpose of this study was to determine the effect of oral moisturizing agents, denture adhesives, and surface treatments on the retention of an acrylic resin test base dislodged from the maxillary alveolar ridges of xerostomic radiotherapy patients.

**Materials and Methods:** Acrylic resin test bases prepared for 10 edentulous xerostomia patients were subjected to 8 treatment methods. After each treatment method, a tensile testing apparatus was used to dislodge the inserted test bases and force values (N) were recorded.

**Results:** No significant difference was found between retention force values of methods 1, 5, and 6 (p>.05). Method 2 was significantly higher than Method 5 (p<.05). Methods 3, 4, 7, and 8 displayed significantly higher retention values than 1, 2, 5, and 6 (p<.001). No significant difference was found between methods 3, 4, 7, and 8 (p>.05).

**Conclusion:** Protefix application (Methods 3, 4, 7, 8) significantly increased the retentive force of acrylic resin test bases (p<.001). Biotene treatment (Method 2) displayed higher retention forces compared to sandblasted (Method 5) test bases (p<.05). Sandblasting did not increase the retention. No significant difference was found between methods 3, 4, 7, 8, and between methods 1, 5, 6 (p>.05).

**Others Authors:** Julide Ozen, Bedri Beydemir, Cumhur Sipahi
Surgical Rehabilitation in Facial Palsy

Alexander Berghaus

Head, Department of Otorhinolaryngology, Head and Neck Surgery, Grosshadern Medical Centre, Ludwig-Maximilians-University, Munich, Germany

Patients with facial nerve paralysis are seen quite often with cranial base surgery. There is a variety of surgical techniques that can help patients with paralysed faces from a functional and/or esthetical point of view. Dynamic correction with nerve reconstruction or hypoglosso-facial(-jump)-anastomosis is not always possible.

Concerning the eye, incomplete closure with lower lid ectropion leads to lagophthalmos, dryness, conjunctivitis, astigmatism and potential corneal ulceration. In addition, brow ptosis may cause reduction of the visual field. Surgical correction has to address to the functional defects of the brow, the upper and the lower lid individually.

Concerning the brow, endoscopic lifting is superior to skin excision, and in many cases additional upper lid blepharoplasty is helpful.

For correction of upper lid paralysis, implantation of a weight (lid loading) has become very popular, and flexible platinum chain implants have a number of advantages compared to formerly used gold weights. Ectropion of the lower lid is corrected primarily by lateral and / or medial canthopexy.
For correction of the paralysed corner of the mouth, semi functional solutions can be found in transplanting parts of the temporal or masseter muscles, or by suspension to the zygomatic arch using anchor screw sutures.

In single cases, face lift procedures or excisions to the lip may be helpful.
Implants in Rhinoplasty

Alexander Berghaus

Head, Department of Otorhinolaryngology, Head and Neck Surgery, Grosshadern Medical Centre, Ludwig-Maximilians-University, Munich, Germany

The presentation examines implant materials currently used in rhinoplasty. In revision cases, the most desirable autogenous grafts from the septum are often unavailable in adequate quantities. The ‘ideal’ implant has strict requirements concerning biocompatibility, plasticity, stability of form, resistance to infection, and removability.

Silicone implants continue to be used in spite of frequent reports of rejection. In spite of its described absorption, conserved cartilage can help in preserving profiles. Increasingly, good results are being reported with porous polyethylene, although Proplast is sometimes used in its place. Despite the fact that AlloDerm is partially absorbed, it can still be useful. GoreTex is effective for smaller defects. Mersilene mesh is not absorbed and retains its stability of shape. ‘Turkish Delight’ (diced cartilage with a wrapping) seems to be absorbed when the wrapping is made of Surgicel, but a wrapping of autogenous fascia provides lasting results.

**Summary:** Several alloplastic materials do have a place in nasal surgery. Provided that the correct techniques are employed, side effects from their use may be no greater than the complications resulting from the use of autogenous costal cartilage, with the intervention necessary for its harvesting.
The expression of nerve growth factor and it’s receptors in the Rat Dento-Alveolar Complex incident to orthodontic tooth movement

Akbar Sham Hussin
School of Dental Sciences, Universiti Sains Malaysia, Kelantan, Malaysia

Abstract: Stress during orthodontic tooth movement causes distortion of nerve fibres and neuroreceptors leading to the sensation of pressure and pain, and inducing the release of neurotrophins1. Neurotrophins are believed to play an important role in bone remodelling1,2. Nerve growth factor (NGF) is a polypeptide neurotrophin essential in the development, maintenance and survival of sensory and sympathetic nerves3,4. NGF and its receptors, p75 and tyrosine receptor kinase A (Trk A), have been demonstrated to increase their expression during trauma, nerve transection, and orthodontic tooth movement5,6. The influence of NGF modulation of orthodontic tooth movement is unknown. In particular, PDL and bone remodelling may be influenced by NGF inhibition. mRNA for NGF has been detected in human periodontal ligament cells and gingival fibroblasts in vitro, and was reported to increase DNA synthesis as well as expression of mRNA for bone-related proteins and alkaline phosphatase4. The aims of this study were to test if orthodontic tooth movement induces changes in expression of NGF and/or its receptors and whether antibodies to NGF (anti-NGF) influence that expression. Orthodontic separators were placed between the right maxillary first
and second molars of Sprague-Dawleys rats which were then divided into test and anti-NGF groups. The left side served as internal control. The animals were sacrificed at days 0, 3, 7 and 14. Immunohistochemistry for p75, Trk A, CGRP and NGF was performed.

Results showed staining intensity increased at day 3, with a peak at day 7 and decreased intensity at day 14. Anti-NGF injected animals showed reduced staining at all observation periods. We speculate that injury induces expression of NGF leading to sprouting and invasion by calcitonin gene-related peptide-positive nerve fibres. Injection of anti-NGF abolishes NGF expression and prevents innervation by CGRP-positive fibres.

This study raises the prospect that NGF may allow modulation of the rate of tooth movement. NGF may be used to induce nerve sprouting and facilitate movement of teeth in normal situations or perhaps, in a case of ankylosed teeth, to mobilise them. NGF may be used to mediate repair of tissue during orthodontic tooth movement by upregulating expression of neuroreceptors. It may be possible to alter the local levels of NGF and so possibly modulate the tissue remodelling process. Such an ability to locally modulate the tissue remodelling process may present important clinical opportunities such as the regulation of tissue repair, control of tooth movement, retardation of root resorption, and inhibition of pain during orthodontic tooth movement via upregulation of neuroreceptor expression.

References


Others Authors : Wayne J Sampson, Craig W Dreyer, Ian A Ferguson

Acknowledgement : Australian Society of Orthodontists Foundation
Long-term Stability after Craniofacial Distraction Osteogenesis: Systematic Review

Al-Dagherer
Flores, El-Bialy

AIM: To systematically review the long-term stability of craniofacial distraction osteogenesis.

METHODS: An electronic database search of Medline, Pubmed, Embase, Web of Science and Cochrane Library databases was conducted including all languages. Key words used in the search were craniofacial dysostosis, craniofacial abnormalities, craniofacial, distraction osteogenesis, osteodistraction, stability and relapse. Abstracts which appeared to contain 3 years post-surgical data were selected. The original articles were thereafter retrieved and evaluated to ensure that they really had 3 year long-term data after treatment conclusion. The references were also hand-searched for possible missing articles that were not indexed in the searched databases.

RESULTS: Only a few articles reported long-term stability after craniofacial distraction osteogenesis. Sample sizes were minimal and the methodological quality of the studies was poor.

CONCLUSION: Different degrees of relapse after distraction osteogenesis were reported. The main factors associated with relapse were age, patient’s growth potential, presence of a syndrome, musculoskeletal dysfunction and which part of the bone was distracted. Methodologically sounder studies are required to shed more light into the long-term effects and stability of craniofacial distraction osteogenesis.
Primary definitive nasal correction in patients presenting for late unilateral cleft lip repair in rural hospitals

B K DAS
Somajvittik Medical College, Bangladesh. (A concern of Gonoshasthaya Kendra, Dhaka, Bangladesh)

Background and Study aims:
Correcting unilateral cleft lip is never aesthetically acceptable without correction of nasal deformity. More than 80 percent of the world population lives in the developing world. Most of these patients live in rural areas and many of them can’t reach the surgeon. So they suffer from cosmetic problems as well as social problems. More than 25 percent of unilateral cleft lip and palate patients present with their deformity on their teens or later year in the developing world. The patients at this age are very much concerned with the aesthetic outcome. Staged correction of cleft lip-nose deformities under general anesthesia is not applicable to these patients due to poverty and remote living places. At this age, primary correction of unilateral cleft lip nasal deformity can be done under local anesthesia at rural hospitals. Several issues need to be addressed, but the author limits here to the correction of the nasal deformity with lip only.

Patients and methods:
Twenty-eight patients (eighteen female and ten male) with unilateral cleft lip deformity presenting between March 2005 to March
2006, are included in this study. Age of the patients ranging from 10 years to 30 years. Of these 16 had cleft lip alone, 6 also had cleft of the alveolus, 6 had a cleft of the palate continuous with cleft lip, 8 had short columella. The corrective procedures on the nose included columellar lengthening, sub mucous resection of nasal septum augmentation along the pyriform margin, nasal floor repair, correction of nasal sill, and reposition of lower alar cartilage. To facilitate alar cartilage manipulation, alar marginal rim incision given in affected side. All of the patients were operated under local anesthesia on rural hospitals as a day case basis.

Results:
Photographs and arthropometric measurements were used to evaluate the results. Nasal tip projection, columellar length and nasal width were measured pre and post operatively. Clinical follow up ranged from six months to one year. All the patients showed good nasal tip projection, increased columellar length, almost symmetrical nasal width and nostrils.

Conclusion:
Aesthetically good results can be achieved by primary nasal correction under local anesthesia during unilateral cleft lip repair in rural hospitals. It is safe and cost effective. So for the developing world it is an effective procedure.
The Role of Springs in Craniofacial Surgery

Charles Davis
Central & Southern New Zealand Craniofacial Program, Wellington, New Zealand

The clinical utilization of springs in craniofacial surgery was pioneered by Professor Claes Lauritzen in Sweden and 4 craniofacial units worldwide are currently using springs. In selected clinical situations the use of springs allows minimalization of the extent of surgery without compromising clinical outcomes.

We reviewed all craniofacial cases performed in our unit since the introduction of springs to assess their relative role in the techniques available to a craniofacial surgeon. Over a 28 month period our unit performed 94 transcranial craniofacial cases. 19 cases were a spring assisted cranioplasty. This technique is particularly suitable in cases of craniosynostosis where there is a symmetrical deformity provided treatment is instituted within the first 6 months. This paper discusses the way in which clinical experience, particular complications and outcomes have led to the evolution of the way springs are currently incorporated into clinical use. We have shown the use of this technique to be safe and in selected situations to offer significant advantages over other current methods of treatment.
Augmentation Techniques

Emiko Tanaka Isomura
Osaka University Graduate School of Dentistry, Suita-city, Osaka, Japan

A procedure involving 2-stage alveolar distraction osteogenesis using eccentric distraction devices for the augmentation of resorbed transplanted iliac bone following mandibular tumor resection is presented.

A 6-month consolidation period was allowed between the first and second distractions, and endosseous implants were placed 4 months after the second distraction.

Computerized tomographic images obtained before the implantation revealed that, 10 months after the first distraction, the bone generated still showed lower density compared with the basal bone, but the bone from both distractions showed enough maturity for implantation.

It may be concluded that 2-stage alveolar distraction osteogenesis can be a useful and safe procedure for excessive alveolar lengthening if a sufficiently long consolidation period is allowed.

Others Authors: Seiji Iida, Tamaki Nakano, Katsuhiko Amano, Mikihiro Kogo
Anchylosis of the temporo-mandibular joint with reduced or no mobility of the mandible is a worldwide problem for the actual patients.

The underlying reasons for TMJ-ankylosis may be malformation from birth, trauma to the joint, infection, rheumatoid diseases, previous surgery to the joint region.

Whatever the cause of the problem the surgical solutions are limited and few reports of success from surgery have been published.

In our clinic the treatment of the TMJ-ankylosis can be divided in mainly three options.

1. Surgical release of the ankylosed joint by gap osteotomy and condylar reshaping.
2. Surgical release of the ankylosed joint and reshaping the area for reconstruction with rib graft.
3. Surgical total extirpation of the ankylosed joint and reconstruction of joint and fossa with TMJ-prostheses and artificial fossa.

In our clinic we have experience of all the procedures in a limited number of patients (n = 30). The patients have all been included in long-term follow-up (between 2.5-20 years).
There is a high relapse frequency by use of only gap-osteotomy although in some patients this kind of surgery seems enough. Frequent mandibular opening exercises are necessary to achieve positive results. The same regimen is also necessary for patients with rib graft reconstruction where the relapse is less frequent as in the first group but still risk for reanchylosis.

The TMJ-prosthesis is the last option for solving the patients problems. The Lorentz prosthesis with fossa and joint reconstruction has been in use for several years now and has an acceptable function outcome also in the most difficult cases.
Periosteal Expansion Osteogenesis

Kensuke Yamauchi

Kyushu Dental Hospital, Kitakyushu, Fukuoka, Japan

Purpose: There are many methods to augment atrophic alveolar ridge for dental implant therapy, for example, autogenous bone graft, guided bone regeneration and alveolar distraction osteogenesis (ADO). However, grafting technique induces patient morbidity and has the risk of bone resorption or soft tissue management. Although ADO has researched and developed for about ten years, it still has some clinical problems so that vector control, secondary surgery and costs.

Material and methods: Three beagle dogs were examined in this study. Their premolars and first molars were extracted. 10 weeks of healing, horizontal incision around the mucogingival junction was made and the mucoperiosteal flap was reflected, exposing the lateral surface of the mandible. The fA-tricalcium phosphate block (OSferion, Olympus, Japan) was placed at their bone surface. And two titanium screws (MODUS, Medartis, Switzerland) were inserted from lingual aspect to push the block to the buccal side. After checking the movement of the block, these screws were turned back to the initial position. After a latency period of 8 days, during which primary wound healing occurred, the lingual screws were activated about 0.5mm/day for 8 days. The dogs were sacrifice 8 weeks after finish
of the activation. And calcein injection for bone labeling was performed at 1 and 8 days before sacrifice.

**Results:** Infection into the fÀ-TCP was not occurred in all animals and no material problem was observed during this experiment. New bone formation was observed in the gap between original bone and fÀ-TCP block, and also lateral surface of the fÀ-TCP block. Moreover, the replacement of large parts of the fÀ-TCP with newly formed bone was observed in the fÀ-TCP block area.

**Conclusion:** Periosteal expansion osteogenesis using the fÀ-TCP block have some advantages over the conventional augmentation technique included ADO.

**Others Authors:** J.Y.Paeng, T.Takahashi
Snoring for thousands of years was looked upon an annoying sound that certain people have and it was thought that they have to live with it. It wasn’t until early twentieth century that scientist began to relate that to a problem during sleep. Now we believe that in some cases snoring in fact is a sign of very common but yet under-diagnosed sleep disorder in which a person’s airway becomes blocked during sleep, preventing air from reaching the lungs and oxygen from getting to the blood.

Globally there are over 1.6 billion people who are either overweight or obese. One of the associated illness with being overweight is snoring and obstructive sleep apnea. The rate of obesity has tripled in most developed or developing countries during the last 20 years. Looking back at history anatomy of sleep was first studied by Edward Binns in 1846. It took a whole century to truly understand the physiological basis of sleep. Many more decades passed until the discovery of devices and surgical techniques to treat snoring and sleep apnea. As of today unfortunately the most modern equipment and the “gold standard” to treat sleep apnea is an air pump; continuous positive air pressure (CPAP) which forces air into patient’s airway
allowing the individual to breathe and receive air as they sleep. Although a lifesaver, but CPAP at best is a cumbersome nasal mask that only relies on patient compliancy for its effectiveness. If a patient decided not to use it every night they could be at a significant risk of obstructive apnea complications that at worst could be heart attack, stroke or even death.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Initial Effectiveness</th>
<th>Total # of Patients</th>
<th>% of Relapse Or Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAUP</td>
<td>75%</td>
<td>980</td>
<td>50%</td>
</tr>
<tr>
<td>LA-UPPP</td>
<td>75%</td>
<td>7024</td>
<td>25-35% (8 Years)</td>
</tr>
<tr>
<td>UA-UPPP</td>
<td>75%</td>
<td>56</td>
<td>25-35% (8 Years)</td>
</tr>
<tr>
<td>Partial / Total Tonsillectomy</td>
<td>100%</td>
<td>382</td>
<td>0%</td>
</tr>
<tr>
<td>(In office)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pillar Implants</td>
<td>50-75%</td>
<td>35</td>
<td>60%</td>
</tr>
<tr>
<td>(in selected patients)</td>
<td></td>
<td></td>
<td>Up to 3 Years Post-op</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Ineffective for OSA</td>
</tr>
<tr>
<td>Palatal RA</td>
<td>40-75%</td>
<td>560</td>
<td>60%</td>
</tr>
<tr>
<td>(in selected patients)</td>
<td></td>
<td>Somnus/ Coblatic/</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Elman</td>
<td>(9 years)</td>
</tr>
<tr>
<td>Nasal RA</td>
<td>25-75%</td>
<td>3,200</td>
<td>30%</td>
</tr>
<tr>
<td>(nasal snoring &amp; chronic congestion)</td>
<td></td>
<td>Somnus/ Coblatic/ Elman</td>
<td>(9 Years)</td>
</tr>
<tr>
<td>Tonsilar RA</td>
<td>85% Obstructive Tonsils</td>
<td>156</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Somnus/ Coblatic/ Elman</td>
<td>(6 Years)</td>
</tr>
<tr>
<td>Tongue Base RA</td>
<td>75% OSA</td>
<td>18</td>
<td>75%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Somnus</td>
<td>(7 Years)</td>
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<tr>
<td>Injection Snoreplasty</td>
<td>50%</td>
<td>12</td>
<td>90%</td>
</tr>
<tr>
<td>(in selected patients)</td>
<td></td>
<td>Sotradex (sulfate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Sclerosing agent)</td>
<td>5 Years</td>
</tr>
</tbody>
</table>
Surgical treatments, which historically started in 1969 by Tracheostomy, have been now replaced with laser, ultrasound and radioablation procedures; also cannot grantee elimination of obstructive sleep apnea. In this chapter we look at various surgical methods of treatment and describe the detailed techniques of the most relevant soft tissue procedures available to surgeons to treat these conditions. The surgical practitioners must chose the most appropriate procedures based on the patient’s history, clinical findings, laboratory studies of sleep related disorders as well as their level of expertise to perform such procedures. Of course no surgical procedure is free from unwanted risks and complications and those issues must be addressed as well.

Summarizing our experience with several various procedures during last 15 years of treating patients who suffered from severe snoring and /or obstructive sleep apnea will be the goal of our presentation. The important column is the one on the right side where percentage of relapse is shown. We will stress success and failure of most commonly available surgical procedures in detail.

References:

Effect of Retinoic acid on palate formation during rat embryogenesis

Myoung Hee Kim

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All-trans Retinoic Acid (RA), an active derivative of Vitamin A, is required for normal pattern formation during embryogenesis. High concentration of RA in embryos results in fetal malformations, such as cleft palate, cleft lip, outflow tract of cardiovascular system, and unascended kidneys, etc. Craniofacial abnormalities including cleft palate has been reported to be induced by the ectopic expression of HoxA7 during murine development. As this phenotype is similar to that induced by RA, we have studied the expression pattern of Hox genes in RA-treated embryos. Since the development of craniofacial structure started at day 11 p.c (E11), RA (100 mg/kg suspended in DMSO) was injected intraperitoneally into the pregnant female rat at E11, and then embryos from E13 to E17 were isolated and analyzed. The overall developmental process was shown to be delayed in the RA-treated embryos and the cleft palate was clearly detected after E16. After isolating the total RNA from the head region deleting mandible, the expression pattern of several genes such as, Hox, Bcl-xl, Bcl-2, and Bax were analyzed through RT-PCR technique. The expression of Hoxa7 reached its peak on day 13 then slowly declined in the normal embryos. Whereas in the RA-treated embryos, the
expression peak was observed on day 15, then declined subsequently. In the study of Bcl-2 family genes, uniformly strong expression of anti-apoptotic and pro-apoptotic genes was observed from day 13 to day 17 of normal embryos, whereas anti-apoptotic gene expressions were decreased after day 16 in the RA-treated embryos. Additionally, a dramatic decline of pro-apoptotic gene expression was observed from day 13 to day 15 of the RA-treated embryos. These results altogether indicates that RA is a potential factor actively involved in the cleft palate formation. Moreover, it seemed to be linked with the regulation of Hox and Bcl-2 family gene expression leading to the embryonic malformation.

Other Author: Â Meang Sub Cheng
In the beginning of the new millennium, great interest in skeletal anchorage emerged in the field of orthodontics. This interest developed in response to anchorage loss, one of the major problems that orthodontists encounter in their daily practice. The anchorage loss problem has been seen not only in extraction cases, but also in molar distalization and space closure of large edentulous spaces through molar protraction. Skeletal anchorage arose as the solution to this anchorage problem; furthermore, it has allowed the clinician to achieve tooth movements that were once considered rather impossible to attain with conventional orthodontic treatment, such as significant molar intrusion and distalization of lower molars.

As with any other new clinical technique, skeletal anchorage should be evaluated under three broad categories: 1) Is there a need?, 2) Is there any evidence to support the new method? 3) Is it cost-effective?  

Of these three questions, the first one can be answered affirmatively for skeletal anchorage. There is a definite need for skeletal anchorage in the field of orthodontics, although the specific situations where it is absolutely necessary are yet to be defined. With
any new technique, there is an inherent risk of over utilization. A perfect example in the orthodontic field was experienced with distraction osteogenesis. It was thought that distraction osteogenesis would be the solution for the extraction/ non-extraction debate, but time and clinical research have resulted in refined applications for this technique and currently its use is limited to specific clinical situations. Thus, we should carefully evaluate those clinical situations where temporary anchorage devices (TADs) offer a clinical advantage over efficient and well-established orthodontic treatment protocols.

Is there any evidence to support the new method. The evidence to support TADs is still in its infancy. Most of the published literature is based on case reports. These reports have shown applications for the correction of almost every orthodontic problem, ie. correction of crossbites, absolute A-P anchorage, and space closure of long edentulous spans. In addition, TADs have been used as aides to almost every orthodontic tooth movement ie. distalization of molars, intrusion of incisors and molars, and protraction of molars, etc. However, more evidence needs to be collected through well-controlled prospective clinical trials; more importantly long-term data is essential. Perhaps the most interesting question for the clinician is related to the cost effectiveness of TADs.

Is it cost-effective? When cost effectiveness in orthodontic treatment is analyzed, some interesting questions arise: Is the appliance used to correct the problem best suited for the correction? Is the cost in terms of treatment time (office visits and duration of treatment) and materials justify the use of the appliance? Are side effects prevented with the appliance?

One good example to illustrate this concept is found in patients where absolute A-P anchorage is desired in space closure. Do TADs provide any clinical advantage (superior outcome) over intraoral anchorage obtained through techniques such as differential moments or differential forces in the non-compliant patient? In this situation the clinician should consider if a temporary anchorage device is really necessary.
Another example where cost effectiveness becomes relevant is the patient with a long edentulous span. The clinician needs to select between two different options of skeletal anchorage, the restorable implant (conventional endosseous dental implant) and a nonrestorable temporary anchorage device. The TAD will serve as anchorage to achieve a significant amount of molar protraction. On the other hand, the conventional endosseous dental implant will occupy partially or completely the edentulous space resulting in less amount of space closure needed. Additionally, the dental implant could be used as an anchorage device to achieve the desired movements of the adjacent teeth to later be restored prosthetically. Thus, the patient will save on treatment time, but the cost in materials and procedures could be increased. In summary, when looking at the possibility of skeletal anchorage the clinician should consider cost and time when giving the informed consent to the patient.

Cost efficiency is another important element to evaluate, and also intimately related to cost effectiveness and biomechanics. Efficiency can be defined in orthodontics as achievement of the delineated objective in the least amount of time with the least amount of side effects. This aspect has yet to be analyzed with TADs, although it has been implied that skeletal anchorage may reduce treatment time. Moreover, although side effects may be negated in the anchorage unit, these are still expected and need to be controlled in the active unit when using TADs, as the application of the forces even with these devices aren’t precisely through the center of resistance of the teeth in all the planes of space.

Altogether it has been shown that anchorage control is significantly enhanced with the use of skeletal hardware. It would then seem obvious that the concepts in biomechanics, essential for anchorage control, would become less relevant or even obsolete with the use of TADs. However, in reality the opposite is true. Over the last few years, many interesting case reports have been published in the orthodontic literature with creatively designed appliances that intelligently apply the concepts in biomechanics. A solid
understanding of biomechanics allows one to determine ideal cost effectiveness (minimal amount of skeletal anchorage devices and the maximal mechanical advantage) as well as the proper placement site for TADs. Additionally, understanding biomechanic principles will aid in preventing the unwanted side effects of TADs and may help in the selection of the most appropriate skeletal anchorage device from the myriad of systems that have emerged in the marketplace.

This chapter will describe different clinical scenarios where skeletal anchorage may provide an advantage to conventional treatment mechanics. Different fundamental concepts in biomechanics will be reviewed, which properly understood, are useful in determining the best site for TAD placement (least amount of undesired reactive forces or where the reactive forces can be used advantageously) and thus, the most indicated skeletal anchorage system for a particular orthodontic movement.

### Biomechanics

Anchorage from TADs can be obtained in two different ways: directly and/or indirectly. Direct anchorage is the application of a force directly from the skeletal anchorage device to a tooth or groups of teeth. Thus, it can be described as a TAD-tooth interaction. The line of force is usually at an angle to the occlusal plane with this type of anchorage, resulting in an ever-present intrusive force when direct intra arch anchorage is applied. On the other hand, indirect anchorage is a tooth-tooth interaction. The anchor unit or reactive unit (tooth or group of teeth) is attached rigidly to the skeletal anchor device; therefore, the force is generally applied along the occlusal plane. The latter approach can be easily integrated to the straight wire technique or any other traditional orthodontic technique.

The most common example of the indirect anchorage approach is the Orthosystem implant placed in the palate. This mini-implant, once osseointegrated in approximately 10 weeks, is connected by means of a rigid palatal bar to the anchor teeth (usually the molars). However, it has been reported that even with a 0.032 by 0.032
transpalatal arch (TPA) used as a connector to the palatal implant, approximately 1mm of anchorage loss is evident in cases where maximum anterior retraction is desired. Thus, a more rigid bar can be casted that may provide less anchorage loss and comfort to the patient.

The fundamental concepts in biomechanics are more applicable to direct anchorage from TADs. Hence, a more adequate understanding of force systems is needed in order to properly plan for the system and placement site of the TAD. The line of action of the force and its direction, the point of force application, force vector addition, and Straumann, Waldenburg, Switzerland equivalent force systems are important concepts that the clinician should understand to optimize the use of skeletal anchorage.

The line of action of the force and its direction describe how a body (tooth or group of teeth) will move. The line of action and its direction need to be traced to the point of application in order to precisely describe the force vector. Moreover, the relationship between the line and point of force application to the center of resistance of the tooth or group of teeth, needs to be analyzed to predict the three dimensional movement of the body.

This relationship can be analyzed using equivalent force systems. Briefly, a force can be replaced from its point of force application by the same force plus its rotational moment produced around an arbitrary point in the same plane. To understand tooth movement, the selected arbitrary point is at center of resistance of the tooth or group of teeth. Force is applied buccal to the center of resistance of the tooth from a mini screw. From an occlusal view the center of resistance of the tooth is close to the central fossa. As the force is applied in the buccal, the equivalent force system at the center of resistance results in a mesial force and a rotational moment (mesial-in, lingual direction) in the lower right first molar. From a lateral view the line of force close to the center of resistance of the molar (generally found at the furcation area) and parallel to the occlusal plane. This force system results in a translatory movement of the
molar. However, the distance from the arm to the mini screw precludes achieving a good activation force. The extension arm bent distally to achieve more activation in the spring. As the arm is bent distally, it results in a point of force application that is more coronal. The line of force is slightly above the center of resistance and at an angle to the occlusal plane. A vertical component additional to the horizontal component of the force is generated which results in intrusion with the mesial movement of the molar. A line of force more occlusal to the center of resistance and a greater intrusive component. The equivalent force system at the center of resistance results in the same force in a mesial direction with an intrusive component and a moment of the force in a clockwise direction. The result of these force systems analyzed in the sagittal plane is a tooth that has tipped mesially and intruded from the occlusal plane.

Tooth movement relies on the application of forces. The laws of physics don’t change with skeletal anchorage, thus Newton’s third law for every action there is an equal and opposite reaction still applies. However, in this instance the reactive force is dissipated by the implant bone interface that does not remodel since the periodontal ligament is absent. Nonetheless, it has been reported that mini-screws have some mobility when loaded. Although this movement is minimal in magnitude, generally not exceeding one millimeter.\textsuperscript{20}

Force magnitude is an important factor in biomechanics, not only in relation to tooth movement, but also in regards to the stability of TADs. The maximum load that can be applied to the skeletal anchorage unit needs to be above the range of minimal forces required for the different tooth movements. Mini-screws have been shown to withstand up to 300 grams of force without compromising their stability.\textsuperscript{16,20} Among the different types of tooth movement, molar intrusion needs the greatest amount of force magnitude. It has been considered that approximately 200 grams of force is needed to achieve molar intrusion.\textsuperscript{8,21} This is well below the tolerance level of the mini-screw. However, some newer applications for skeletal anchorage may require a significant increase in the load resistance of the screw.
One of these applications is the delivery of orthopedic forces through TADs. A recent clinical report used a protraction headgear from mini-plates placed in the maxilla. Another application described consists in the use of intermaxillary bone-bone borne fixed functional appliances from the posterior region of the maxilla to the anterior region of the mandible. In this particular situation plates also need to be considered, since the forces generated are considerably higher.

The large variety of TAD types and brands currently in the market make the selection of the most appropriate system a difficult one. Important factors to consider are: simplicity in design and placement technique, stability, cost, time between placement and loading times, ability to be placed in many sites intraorally, and versatility in the attachment head to apply different force systems. The majority of the TADs available meet at least one of these requirements, and most of them possess a combination of these factors. Ultimately, the decision of the most adequate TAD for any clinical situation has to be driven by a force system approach, with the other factors being secondary.

When a TAD is considered as part of the patient’s treatment, the clinician must first define which type of dental movement is desired. For instance, a common use of TADs is molar intrusion. With this objective in mind, the clinician must decide what forces are needed to produce intrusion, and thereafter define the line of action and point of force application for a tooth or group of teeth. This information enables the selection of the TAD site, which can be determined by simply following the line of action of the force. Careful evaluation of the site is then needed to avoid damage to important anatomic structures such as the roots of teeth, maxillary sinus, nasal floor, nerves, etc. If one of these anatomical structures is located in the planned site, the clinician has to decide between changing slightly the line of force or using a system that allows the selection of the surgical site, reducing the risk of damaging any anatomic structures. A power
arm is then extended to conform precisely to the selected line of action of the force.

Another important consideration in the analysis of the site of placement is to evaluate the relationship of the TAD to the anticipated final location of the tooth. The clinician needs to ensure that the TAD does not interfere with the final desired position of the tooth being moved or the path followed by the tooth to that position. Thus, TADs that can be placed at a distance from the roots of the teeth, also offer the advantage of more significant amount of tooth movement in A-P or vertical direction without the need of TAD replacement.

The types of orthodontic tooth movement can be divided into seven broad categories: intrusion, extrusion, retraction, protraction, rotation, expansion and constriction. All of these movements are generally described in relation to the crown. However, these tooth movements can be further classified as translatory, tipping (controlled and uncontrolled), and root movement. The different TADs provide a mechanical advantage that can be more evident for certain types of orthodontic tooth movements than others. In the following paragraphs, the different types of tooth movements will be described in relationship to the applicability of the different TADs as aides to accomplish these movements. The most common force systems that can be delivered with a TAD will be described from a theoretical and technical aspect. In addition, the expected side effects and ways to control them.

Intrusion

Intrusion is the single type of tooth movement where TADs are most likely indicated, more specifically molar intrusion. Historically molar intrusion in orthodontics has been a type of tooth movement very difficult to achieve. The evidence of orthodontic molar intrusion previous to skeletal anchorage had been mostly based on case reports. This type of tooth movement has been primarily obtained from holding the molars against vertical growth. Clinical reports that have
attempted molar intrusion in adult patients show small amounts of molar movement, which is difficult to verify in the lateral cephalometric superimpositions. The clinical impression of intrusion in many instances has been the result of extrusion of the adjacent teeth.\textsuperscript{21}

\textbf{Molar Intrusion}

Many adult patients requiring multidisciplinary care are referred by the dentist/prosthodontist for the correction of altered occlusal planes and distribution of edentulous spaces pre-prosthetically. The correction of the occlusal plane in these patients usually requires intrusion of molars that have supra-erupted into an edentulous space in the opposing arch. A pure translatory intrusive force is usually necessary to achieve this correction. In order to accomplish this translatory movement, the line of force has to be perpendicular to the occlusal plane, in a gingival direction, and passing through the center of resistance of the molar. This type of force is better delivered through a direct instead of an indirect anchorage method. The TAD needs to be placed apical to the crown of the molar to be intruded in an effort to deliver an intrusive force from either the buccal or lingual side.

A problem is usually encountered when a mini-screw needs to be placed on the buccal aspect. Root divergence in the molar buccal roots and no interradicular space precludes in many instances, the placement of a miniscrew in the buccal mucosa. Therefore, if a mini screw is to be used, the force needs to be delivered from the palatal aspect due to this anatomical limitation.

Once the location of the TAD is selected, an attachment to the tooth’s crown can either be soldered to a band or bonded to the buccal or lingual side. Most often it should be attached on the same side of the TAD if direct anchorage is used. Regardless of the TAD type and attachment location (buccal or lingual), the line of action of the intrusive force will displace the crown gingivally. However, the moment of the intrusive force will tip the crown either buccally or
lingually. In most instances this moment is undesired, although it can be controlled in various ways.

Passive or active appliances can be used to control the moment of the intrusive force. The passive appliance that has been suggested is a large dimension stainless steel transpalatal arch.\textsuperscript{25,27} However, the moment of the intrusive force may be difficult to counteract albeit the rigidity of the TPA. Therefore, it may be better to place a soldered archwire of heavier dimensions such as it is done with a hyrax palatal expander. This expander can also actively control the side effects of buccal tipping if cemented with the screw open. Slow constriction of the screw when necessary may be able to counteract the buccal tipping. However, rigid cross arch splinting may inhibit the efficiency of molar intrusion in patients where this type of movement is desired unilaterally.

A second active solution to control the moment of the intrusive force is to place an additional TAD on the opposite side of the tooth. The intrusive force applied to the new TAD should be of equal magnitude to achieve a pure translatory movement of the molar. A third option to control the moment of the intrusive force, that does not require an additional bone anchor, but has to be used in conjunction with a TAD already placed on the buccal side, consists of a 0.036 by 0.036 TMA transpalatal arch. This arch will apply a buccal crown torque couple in the stationary molar while tying the other end of the arch occlusally or gingivally to the lingual attachment of the tooth to be moved. An intrusive lingual force will be generated that will counteract the moment of the intrusive force in the buccal. By not engaging the slot of the bracket, it is assured that a single force-one couple system is generated. Another option to prevent a couple in the active side is to round off the TPA on the intrusive force side and then engage it in the slot of the lingual bracket. Thus, a couple can’t be generated in the active side, and only the desired intrusive force will be acting in that molar from the lingual side. Finally, the same force system can be reversed with the couple side producing buccal root torque on the active tooth to intrude. With this method,
the lingual intrusive force can be lower in magnitude than the buccal force, since the buccal root moment is also acting to counteract the moment of the buccal force. The only side effect is the extrusive force at the other end of the TPA. However, if the intrusive force is maintained low, the resultant extrusive force will be the same in magnitude, and most possibly counteracted by the occlusal forces.

Overall, the best TADs for molar intrusion are the mini-plates and mini-screws. However, the mini-screw in many instances has anatomic limitations to achieve the exact line of action of the force needed for molar intrusion. The mini-plate can be placed directly on top of the furcation area of the molar. On the other hand, the mini-screw has to be either be placed mesially or distal to the center of resistance of the molar creating a tip back or tip forward movement on the molar when the force is applied. Although it could be technically possible to place a mini-screw in the furcation area, the amount of molar intrusion needed has to be taken into consideration. If extensive molar intrusion is needed, it would probably entail the placement of the mini-screw high in the buccal vestibule. A high placement of the TAD usually results in problems with soft tissue irritation. Therefore, a mini plate offers the possibility of a distant placement site (zygomatic buttress) without the soft tissue irritation, as the extension arm with the attachment head is placed in close proximity to the attached gingiva.

Another alternative to achieve molar intrusion from a distant site using a direct anchorage force system can be obtained with a miniscrew or a mini implant in the palate. Although any of these two skeletal anchorage systems could be used for molar intrusion, an extension arm has to be fabricated in order to achieve a more vertical vector in the line of action of the force. In the Orthosystem, a casting from the mini implant extends in close proximity to the tissue along the palate ending gingival to the crown of the molar to be intruded. An active spring or elastic it then used from the free end of the casting to deliver a more vertical force vector.
Intrusion of a buccal segment

Patients with anterior open bite due to excess of the dentoalveolar posterior segments have been successfully treated with TADs. The anterior open bite is often found with the occlusal planes diverging anteriorly from the first premolars. Intrusion of the buccal segments not only corrects the occlusal problem but it also reduces the lower anterior facial height and facial convexity as the mandible auto-rotates anteriorly and superiorly in a counter-clockwise direction.

The intrusion of the buccal segment or occlusal plane can be either a level or canted intrusion. If the occlusal planes diverge from the molar anteriorly a canted intrusion is indicated and accomplished by differentially intruding a larger amount posteriorly. On the other hand, if the occlusal planes diverge anteriorly from the canine, a level intrusion may be indicated.

The force systems necessary to achieve a level intrusion or a canted intrusion are different. In the former, a force passing through the center of resistance of the buccal segment is necessary to produce translation. In the latter, a force passing distal to the center of resistance is needed to differentially intrude more the molar than the premolar. In general, the center of resistance of the buccal segment (first molar to first premolar) is estimated between the first molar and the second premolar.

Intrusion of a buccal segment can be easier accomplished with a plate system than with mini-screws; especially if a cant intrusion of the buccal segment is desired. A mini-screw could possibly interfere with the movement of the teeth. Additionally, the line of action of the force is more difficult to adjust once the tooth movement ensues. On the other hand, the plate system gives the clinician more versatility. The buccal segment can be moved in any direction without concerns of root damage to the teeth. Moreover, the line of action of the force can easily be altered by adding a power arm to a mini-plate system.

Mini-screws are a viable option if a level of the occlusal plane is to be corrected. However, since the interradicular space is limited, any force not passing through the estimated center of resistance will cause a moment that will tip the roots possibly into the mini-screw. In
order to prevent this, the mini-screw should be used initially to intrude the molar separately. Thereafter, the premolars can be intruded directly or indirectly after rigidly connecting the molar to the mini-screw. Another alternative is adding another mini-screw between the roots of the premolars. This would allow controlling the cant of the buccal segment, as the intrusive forces from the 2 adjacent mini-screws are applied.

Altogether, pure translatory intrusion of the buccal segment can be challenging. It has been clinically found that as the force is applied to the buccal segment a clockwise rotation of the segment is observed. In order to control this rotation some have proposed adding a mini-screw more anteriorly. However, the effect observed clinically is due to the line of action of the force. By altering this line, the cant can be controlled. An option is to apply the line of action closer to the center of resistance of the segment. Another option is to ligate one of the ends of the molar fixing the vertical distance to the TAD and applying a force to the other end of the buccal segment after extending an arm from the TAD.

**Technical aspects of buccal segment intrusion**

Intrusion of the buccal segments resembles a three-piece maxillary impaction. The upper anterior segment remains in the same vertically position. The objective is the intrusion of the buccal segment in order to close the anterior open bite through posterior intrusion instead of incisor extrusion. The upper arch is set up by placing a rigid 0.017 x 0.025 stainless steel wire segment bilaterally from the second molar to the first premolar. The anterior segment includes the upper incisors with the same wire dimensions. The canine is included either on the anterior or the posterior segment depending on the vertical relationship to the adjacent teeth and its estimated final vertical position. In many instances, it should not be connected to either of the segments initially, but connected to the archwire after the buccal segment has intruded. Connecting the canine to the buccal segment may cause extrusion of the canine if the intrusive force is applied to the first or second molar.
This effect is more clinically evident with a large buccal segment that extends from the second molar to the canine and is a result of the moment of the intrusive force applied at the molar level.

The same mechanics are applied to the lower arch if the occlusal plane diverges significantly anteriorly from the premolar. However, a severe divergence in the lower arch is uncommon; therefore, a continuous archwire can be placed from the beginning before placing the active intrusive force.

It should be noted that although significant intrusion can be accomplished in only one of the buccal segments, compensatory eruption of the antagonist teeth has been reported. Therefore, if intrusion of the dentoalveolar segments is only desired in one arch, TADs needs to be placed in the antagonist arch in order to hold the buccal segments from overerupting.

Once the treatment plan for buccal segment intrusion is defined, the plates can be placed. Although the leveling stage to a 0.017 x 0.025 stainless steel archwire would generally take significantly more time than the 2 weeks healing time after plate placement, the intrusive forces can be delivered during the buccal segment leveling stages.

Finally, the same buccal tipping side effect of molar intrusion is observed with the intrusion of the buccal segments. A rigid TPA is needed to prevent this tipping movement. As previously mentioned, the moment of the force may overcome the rigidity of the TPA. In this instance, a bonded acrylic expander not only helps with the rigidity, but also can be used to place the buccal attachment in the acrylic, increasing the distance to the TAD. Hence, a more constant force through a NiTi spring may be delivered. Furthermore, the acrylic plate may also aid in the vertical control, preventing the described compensatory eruption of the lower segment following the intrusion of the upper buccal segment.

Active applications may also be used to control for the tipping of the buccal segment. If significant upper premolar buccal tipping occurs, intrusion should be continued from the lingual by fixing the
molar to the TAD with a ligature wire and applying a force to the lingual of the premolar from a welded spur on the TPA.

**Incisor intrusion**

Temporary anchorage devices for intrusion of any of the teeth in the anterior segment can be considered impractical and unnecessary. Additionally, anatomical limitations for the placement of mini screws in the anterior region exist. The labial frenum can be easily irritated if a mini screw is placed in its proximity. Therefore, if mini screws are absolutely needed, 2 of them would need to be placed distal to the lateral incisor.

Numerous studies have shown the efficiency of incisor intrusion using a cantilever system.\(^{35-37}\) This force system can deliver the same incisor intrusive force as the one obtained from a mini-screw placed anteriorly. Furthermore, the cantilever offers the possibility to easily adjust the line of force. The inability of the cantilever to deliver a high force magnitude without significant side effects, as would be possible with a miniscrew may be the only difference between both systems. However, incisor intrusion does not require a great magnitude of force. Force values can be kept under 60 grams for the 4 incisors and 30 grams for each of the canines and still be effective in the objective of achieving incisor intrusion.\(^{38,39}\)

It has also been recommended, for en masse upper anterior retraction, to place a miniscrew in the anterior region in conjunction with TADs placed mesial to the molar.\(^{40}\) This additional miniscrew in the anterior region is intended to control the extrusive tendency of the incisors that results from the retraction force from a miniscrew placed in the molar region. However, the incisor extrusion observed as the anterior segment is retracted can be controlled with the same cantilever system provided by an intrusion arch or 2 cantilevers extended from the molars. Altogether, incisor intrusion with TADs is not cost-effective, as the mechanics described above can accomplish the same results.
However, there is one circumstance where TADs can be used to achieve incisor intrusion. Adult patients with a severe brachifacial pattern, convergent occlusal planes, and 100% impinging deepbites make the correction of the vertical problem of the malocclusion complex. The solution to this problem relies on either extruding the posterior buccal segments (very unstable orthodontic movement in adults)\textsuperscript{41,42} or intruding the anterior teeth. Additionally, many adults also present with minimal upper incisor display which leaves the solution of the vertical problem to be resolved solely by lower incisor intrusion. The convergence of the occlusal planes allows for possibly 2-3 mm of intrusion in the lower arch. In order to achieve more incisor intrusion, the lower occlusal plane needs to rotate in a clockwise direction around the crown of the lower first molars, thus intruding the premolars slightly. TADs could be used simultaneously with a lower intrusion arch as described above. The real use of TADs in this clinical situation would be to obtain the cant of the lower occlusal plane at the level of the premolars as the lower incisors are intruded by the cantilever system.

\textbf{A-P movements}

\textbf{Distalization}

The mechanics of molar distalization with TADs is generally accomplished by indirect anchorage. A TAD is placed anteriorly to the molar and 2 equal and opposite forces are applied between the first molar and the first or second premolars.\textsuperscript{43} The molar is thus distalized and the premolars remain stationary as it is fixed rigidly to the TAD. Once the molar is distalized, the TAD is fixed to the molars and the anterior segment is retracted. Any type of TAD can be used for this purpose; however, the Orthosystem (palatal mini implant) was one of the first systems to deliver this type of indirect anchorage.\textsuperscript{44}

Direct anchorage for molar distalization has been previously described from a mini-implant in the palate.\textsuperscript{7} This approach has a mechanical advantage as it offers the possibility of translatory movement of the molars. A similar approach has been described
using one or two screws placed in the same location in the palate from which a framework is connected and direct anchorage is provided.\textsuperscript{14,40,45}

This same mini implant or a mini screw can be used for direct anchorage for distalization in the lower arch if placed in the retromolar pad.\textsuperscript{46,47} However, a plate system offers a more hygienic alternative. Furthermore, the mini-plate may be more recommended for lower molar distalization as the placement site has an easier access for the surgeon. In addition, the more anterior location of the attachment head of the plate allows the orthodontist easier access to deliver the forces. The plate system can also be used for upper molar distalization with direct anchorage.\textsuperscript{48}

Although mini-screws placed in the buccal aspect can be used as direct anchorage for molar distalization, the greatest drawback is that these need to be placed initially between the roots of the premolars for molar distalization, to later be removed and replaced mesial or distal to the distalized molar in order to allow distal movement of the premolars and anterior teeth.\textsuperscript{40}

As the molars are distalized two common side effects are observed depending on the location of the line of action of the force. When the line of action of the force, analyzed from a sagittal aspect, does not cross through the center of resistance, the molar will tip mesially or distally. Most frequently, the line of force passes below the center of resistance and since the force is distal, the molar will tip distally. Since the point of application of the force from the TAD is usually from the alveolar bone, a greater translatory movement tendency with direct anchorage should be observed compared to traditional distalizing tooth-borne appliances using indirect anchorage. From the occlusal aspect, the molar will rotate mesial-out or distal-in depending on the location of the distalizing force i.e. buccal side for the former, lingual side for the latter. Preventing this rotational tendency is usually more difficult in the first order than in the second order due to anatomical constraints. A rigid transpalatal arch may help prevent this rotational tendency.
Overall, distalization with TADs can be considered an adequate alternative when the incisors need to be slightly to moderately retracted or maintained in the same A-P position, and/or posterior segments need to be moved posteriorly approximately 3 – 4mm. Additionally these systems can be used to correct midlines by differentially distalizing one of the buccal segments. Research studies of upper and lower molar distalization with miniplate systems have shown an average of 3 mm of distalization at the coronal and 2 mm at the apical level. 48,49

**Mesialization**

Temporary anchorage devices have made “mesialization” a popular term. One of the major indications for TADs is the mesial movement of teeth in the buccal segments in patients with missing molars or premolars. It is a very cost effective procedure since it saves the patient from dental procedures such as fixed partial dentures or implants. Additionally, if implants placement is considered, grafting procedures, which may be necessary to reconstruct atrophic ridges, are obviated. Space closure through mesial movement of the posterior teeth can generate new bone in the defect and spare the patient from costly dental procedures. 50

The mesialization of the posterior segment is usually indicated for one missing molar or premolars. Using a screw to mesialize teeth posterior through a large edentulous space is usually not recommended as the amount of time to protract more than the mesiodistal width of a molar may be significant. 47,51 Mesial movement of the posterior segments is another indication in patients with congenitally missing laterals teeth and a class I molar occlusion. Although it is usually recommended to place a bridge or implants in place of the missing laterals in these patients, limited finances is often a reason that canine substitution may be chosen. In order to completely move the buccal segments anteriorly in these types of patients, TADs are highly indicated.
The different TADs and force systems necessary for mesialization are very similar to the ones described for distalization. Direct, as well as indirect anchorage are possible mechanisms of force delivery. Generally, a pull-type force system is indicated, which makes the insertion of the TAD easier as the placement site would be more anterior. Although push systems can be applied, the TADs and the appliances to deliver such forces need to be placed in areas that not only have difficult access for placement, but are also uncomfortable and difficult to maintain clean for the patient i.e. ramus of the mandible.

**Space closure with TAD’s**

Orthodontics has always been in search of obtaining perfect anchorage. This perfect anchorage has been usually described in the A-P dimension and more commonly as the resistance of the molars to anterior movement as the anterior teeth are retracted after premolar extractions. TADs have been suggested as the replacements of headgear.\textsuperscript{12,17} Although the intention of maintaining perfect anchorage may be the goal, a slight anchorage loss of 1 to 2 mm (Group A anchorage) can be obtained without TAD’s. Moreover, if these 2 mm result in 2 mm of less incisor retraction, the question to be asked is how would this impact on the patient esthetics?

In general, anteroposterior lip changes to incisor movement have been considered unpredictable; no perfect algorithm exits. Furthermore, the relationship of upper lip response to incisor retraction is usually less than 50%. If this assumption were correct, would a 1 mm or less difference (50% of 2 mm) in antero posterior position of the upper lip be noticeable? Unpublished data suggest there is no significant difference in the final incisor edge position using Tweed mechanics compared to retraction with mini implants in patients undergoing premolar extractions.\textsuperscript{52}

The biomechanics in space closure involved with direct anchorage is different than indirect anchorage. Indirect anchorage is delivered through regular conventional mechanics where the mesial force to
the molar is negated by the connection to the TAD. In direct anchorage, the force is usually delivered from the TAD in an occlusal direction. Therefore, the distal force also has an intrusive component with direct anchorage. If the canine is being retracted separately along the archwire, the normal force in the second order is increased. Therefore depending on the stiffness of the wire, the deflection is going to generate 2 side effects: extrusion of the incisors and friction.

To control for the extrusion side effect during retraction, it has been recommended to place a miniscrew anteriorly in the maxilla. As aforementioned this extrusion can easily be controlled with a cantilever system such as the intrusion arch. The other side effect, additional friction, can possibly reduce the efficiency in canine retraction. To reduce this effect, an extension arm can be attached to the canine. Hence, a more translatory movement of the canine can be obtained, thus less friction. The wire may still serve for rotational control in the first order. Another alternative is to use a frictionless system (loops) for anterior retraction, extending a force from the TAD to the loop system. Although, this last option describes more an indirect anchorage approach since the force delivered from the miniscrew is not driving the appliance.

When en masse retraction is planned, the line of the force applied from the TAD may have a predominant horizontal component by attaching it to the lateral incisors. However, in this instance friction is still an issue. Additionally, the extrusion of the incisors would also occur, although to a lesser extent than just with canine retraction, as the moment of the retraction force is reduced.

Mini-screws in the upper anterior region have been advocated with en masse retraction to control vertical incisor position. Instead, the same cantilever system that has been mentioned before in numerous occasions should be added. Another alternative is to add a loop system that would deliver a moment and an intrusive force from the TAD. However, the loop system may be more adequate for indirect anchorage since it would probably impinge on the soft tissues if it is delivered from a TAD.
Transverse Expansion

Mini-screws have been described as an aid in the correction of a transverse discrepancy.\(^3\) From a force system perspective, this is the least of the indications for TADs. Expansion can be easily obtained from a force system exerting equal and opposite forces, delivered by an orthopedic device ie. palatal expander, or by conventional orthodontic force delivered through an expanded arch wire. Placement of a TAD would only be indicated in a patient with unilateral crossbite, in conjunction with an open bite tendency. This is due to the extrusive component usually encountered by traditional dental cross bite mechanics consisting of a cross elastic. However, even in those patients, other alternatives to obtain unilateral expansion without an extrusive force have been described.\(^{53,54}\) Briefly, the side where no expansion is desired, a TPA with a moment is added with buccal root torque direction. Concurrently, an equal and opposite force is delivered through a TPA with an expansion force.

One Couple systems with direct Anchorage

Skeletal anchorage can be used to produce one and two couple force systems for tooth movement. One couple systems provide the advantage of having high predictability in the type of tooth movement.\(^{55,56}\) The classic example of a one couple system is the cantilever. This is a versatile system having two discernable units with two different effects. On one end of the system, there is only a directional force in that plane of space to be applied at a single point. On the other end, there is a force of the exact magnitude and in the opposite direction in the same plane of space. Additionally, this side has a moment or couple produced by the spring engaging a tube or a bracket. Since this system is in equilibrium, the sum of the forces and moments is equal to zero. By having this type of force system, tooth movement can be predicted. This force system can be nicely applied to the biomechanics of TADs. Either side of the force system can be
used (force and moment side or single force side) to achieve desired tooth movements with TADs.

There is a big advantage in using the single force delivered from a cantilever spring, more so when TADs are used for direct anchorage. This force can be applied almost in any direction and along the entire longitudinal axis of the tooth or group of teeth to be moved, the only limitation being soft tissue comfort. Additionally, the force can be delivered from a distant point offering the advantage of more constant force delivery. Furthermore, the single force provided by a cantilever system can even described in terms of cost effectiveness when using TADs as less amount of these will need to be placed.

Two important technical elements need to be considered when a one couple system is going to be applied from a TAD. If the second order couple side of the wire is going to be attached to a TAD, a slot for the wire needs to be present in the attachment head in order to create the couple. However, most mini-screw systems available don’t have this feature in the attachment head. Some systems may have a slot, but it is usually round and in some instances with a large dimension up to .045 inches in diameter. Although a round wire can be used to apply a single force with a cantilever system, the intraoral stability of such in the couple side can be compromised especially if the cantilever system is unilateral instead of bilateral ( intrusion arch). Furthermore, a large dimension slot needs a wire with a similar dimension to ensure stability, which would probably deliver unnecessary high force values and discomfort to the patient.

The direction of the force of the cantilever may create another potential problem in TADs with a round slot in the attachment head. For instance, if the TAD is placed on the ridge parallel to the long axes of the adjacent teeth and the slot is perpendicular to the screw in bucco-lingual direction, an intrusive or extrusive force cannot be delivered due to the absence of a second order couple in a round wire.

However, there are solutions to solve this clinical problem. The first one is to bond the wire to the head of the screw using flowable
composite in order to create a rigid junction between the TAD and the wire, thus being able to produce a second order couple in the TAD. This rigid union will generate the intrusive or extrusive force needed. The second option is to bond a bracket to the attachment head of the TAD, also with flowable composite, although the adhesive strength to the screw head might be questionable. A rectangular sectional wire also needs to be used with this option to assure the stability of the cantilever system. Thirdly, an acrylic coping can be cemented on top of the screw head with a wire extension. Thus, the couple can be resisted by the height of the screw head. To use the latter option, the head has to have sufficient resistance form in order to prevent the cemented acrylic coping from loosening or becoming dislodged. The arm is connected to the teeth by a force delivered through a coil spring or an elastic chain or thread. In this instance the dimensions of the extension wire should be high enough to resist deformation from the force. The extension wire with a bracket spot welded to it which serves the purpose of an attachment to the force-producing mechanism and also allows the possibility of delivering a two couple system if needed.

Most of the mini-plate systems offer the alternative of bonding a tube to the plate, or have a locking mechanism to attach a wire. It has a locking mechanism that acts as rigid junction. Additionally, in this particular situation, the applied force and the slot of the attachment head are in the same plane. In this instance, although the slot in attachment head is round the locking mechanism provides a rigid junction and the second order couple is resisted by the width of the slot in the attachement head. Moreover, when the force and the couple are in the same plane the intraoral stability of the sectional wire is not compromised, provided a tight fit between the slot of the attachment head and the wire.

The second important consideration when using a one couple system is the magnitude of the force. The higher the magnitude of the force, the bigger moment is going to be generated in the couple side, which has been described to this point at the mini screw level.
The magnitude of this moment is not a problem when it is resisted by the longitudinal axis of the tooth. However, the magnitude can become an issue when the moment generated by the force is in a plane perpendicular to the longitudinal axis of the screw. In this instance, the moment will act as torque to the screw head in a clockwise or counter clockwise rotation, depending on the direction of the force.

It has been reported that mini-screws can withstand an average removal torque of 11,000 gm/mm. This means that for an average distance of 30 mm for a given cantilever, the force delivered can be up to 366 gm/mm. This force level is well above the force levels of 200 grams needed to intrude a molar. However, the results of the study have to be evaluated with caution as these showed a great variation in the removal torque values with a range between 200 gm/mm and 22000gm/mm.

This same clinical scenario can be encountered when a TAD is placed on top of the ridge. When an A-P force is applied, a rotational moment on the TAD in a clockwise or counterclockwise direction is generated. However, since the limitation of the soft tissue is evident, the moment arm will generally be small. Thus, a very significant force well above 1000 grams needs to be applied to generate a moment of 11,000 gm/mm.

One couple systems can also be used in such a way that the couple acts on the teeth to be moved and the force is applied to the TAD. Clinical scenarios where this force system can be useful are in molar uprighting and correction of root inclinations. The most important aspect when using this type of force system is to keep in mind that the same magnitude of force being applied to the TAD is going to be acting on the tooth in the opposite direction. Thus, if a lower molar is being uprighted and a high force magnitude is delivered to the TAD, the tooth will tend to supraerupt and possibly cause traumatic occlusion.

**Troubleshooting**

In some instances the TAD is placed in a less than ideal position. When this occurs the clinician must seriously consider the possibility
of replacing the device. The other alternative is to design an appliance that will benefit the most from the TAD before its removal. One of these instances where the TAD was placed improperly in the edentulous area where the mandibular molar was supposed to be moved. Ideally, the molar should be bodily translated to contact distal to the lower right second premolar. However this translatory movement would be interrupted half way during the space closure effort. In order to maximize the use of the mini screw it was decided to use the TAD to accomplish the most difficult type of movement, root movement. To accomplish this, the line of force was directed from the mini screw to an arm almost to the full depth of the buccal sulcus, promoting translation of the molar. In order to obtain root movement, a cantilever was added to the molar to root correct the molar until it almost contacts the mini implant. The mini-screw would then be removed and a crown tipping movement is obtained with conventional mechanics. A similar problem is observed when the implant was place distal to the canine but was place too far distal in an effort to prevent root damage. In this patient the mini-screw was placed too close to the apical third of the premolar to be moved anteriorly. In this instance the TAD can be used to tip the second premolar and first molar mesially almost completely through the edentulous space and then removed to thereafter correct the root inclination of the buccal segment.

A common clinical problem is not being able to deliver the desired line of force from the TAD. This usually occurs due to the placement of the TAD close to the free gingival margin. This placement site is often necessary to prevent burying of the TAD, mainly seen when placed in un-attached gingiva. The options to achieve the desired line of force are to extend an arm from the TAD or to extend an arm from the tooth to be moved. This is usually difficult to achieve in the second molar region due to the soft tissue limitation, as the depth of the sulcus decreases in this area. Additionally, the appliances may impair access to hygiene, a critical factor to mini-screw attachment head clearance.
A problem related to the line of force is encountered when the TAD and the tooth to be moved are in close proximity. The solution to this problem is to extend arms along the line of force from the TAD or the attachment of the tooth to be moved. The arm was placed from the distal in order to increase the distance. Since the tissue was growing around the TAD, no arm could be extended from it. Thus, the distance was further increased by bending the arm distally instead, almost maintaining the same line of force.

Troubleshooting with TADs is not infrequent, especially in the initial phases of familiarization phase of the systems. Understanding biomechanics allows the clinician to be creative and find solutions to the side effects and possible complications still found with TADs. In some instances the TADs need to be removed and the desired tooth movements reassessed in order to select a new TAD site and/or skeletal anchorage system.

**Summary**

Temporary anchorage devices have become very popular and most orthodontists are incorporating them into their armamentarium of their daily practices. As any other device in orthodontics, TADs remain as a tool to achieve a treatment objective. The clinician should always consider if these devices are the most cost effective way to achieve the desired objectives. Overall, TADs expand the range of tooth movements achievable with orthodontic movement. This is usually can be observed in two types of tooth movements that previously were very difficult to obtain: molar intrusion and significant tooth displacements in the A-P direction. Other applications such as anchorage control and incisor intrusion may be obtained by other methods that don’t necessarily rely on patient’s compliance.

A good amount of literature has been published in case reports and the technical aspects of TADs placement. This chapter describes the biomechanic possibilities with TAD’s which, in general, apply the same principles that govern traditional orthodontic tooth movement.
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Statement of problem. The success of implant restorations can depend on treatment planning implant positions and the subsequent transfer of planned implant positions through the surgical placement. Stereolithographic surgical templates have been introduced in an effort to improve accuracy of implant placement. Although use of this type of surgical template can be considered a reliable method to guide surgical implant placement, evaluation of its use and affect on accuracy is lacking in the literature.

Objectives: The aim of this pilot study is to propose a method for evaluating implant placement accuracy using the Coordinate Measure Machine (CMM) and to evaluate how accurate implant point of entrance and angulations can be transferred when using a stereolithographic surgical template.

Material & Methods: Entrance points, angulations of 40 implants placed in six edentulous jaws using stereolithographic surgical template were evaluated. The angulations were noted in both mesio-distally and bucco-lingually. The central axis of each treatment planned implant was determined using the CMM by locating three points along the hollow channel of the drill guide stainless steel tube
of the stereolithographic surgical template and the central axis of the actual implant, evaluated post-surgically, were determined. Three points along the guide pins were noted after mounted to the implant fixture analogs on the working cast. The difference between the proposed and actual implant point of entrance and angulations were calculated and the data was analyzed using the paired t-test.

**Results:** The difference of the entrance points between the planned positions and the actual implants was within 0.2 “b 0.72 mm; the mean angle deviation mesio-distally between the planned and actual implants was 0.7”a “b 5.02”a, and the mean angle deviation bucco-lingually was 0.46”a “b 4.43”a. No significant difference was found between the planned and the actual implant points of entrance and angulations.

**Conclusion:** When measured using the CMM, the stereolithographic surgical template was sufficiently accurate in transferring the planned implant position to the surgical field relative to the implant point of entrance and angulations. Further clinical studies using a greater number of patients are needed to confirm the results of this study.

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Dental Implant Distractor

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Objective: To study the application of fibular flap combined with Dental Implant Distracter (DID) in mandibular functional reconstruction. Materials and Methods: We designed a new device named DID (Dental Implant Distractor), which including the permanent dental implant and the temporary distracter in itself. It’s specially designed for fibula wider distraction in mandible reconstruction. 53 sets of DID devices were used in 17 patients (9 males and 8 female) during operations from 2000 to 2006. 7 patients suffered from ameloblastoma of mandible, 6 from benign tumor of mandible and the other 4 from malignant tumor of mandible. After one week’s latency, the fibular flap was distracted 0.7mm per day till it reached a seasonable height for denture reconstruction.

Results: All the fibular flap were survival with acceptable mandibular contour during postoperative 4-25 months follow up. 10 sets of 34 DID which were placed during the first two year were lost because of inflammation. 24 sets were clinical successful with X-ray film showed normal density of reconstructed mandible and the osteointegration of the implants was solid enough to load the denture force. The other 19 sets of improved DID used in the last two years
gained a successful rate of 100% with normal osteointegration. In all 17 cases, 9 had successfully worn the fixed dental prosthesis. The outcomes were satisfactory. Conclusion DID device, which specially designed for mandibular reconstruction with fibula flap, can help us to simplify convenient procedures to a single surgery.

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Neonatal Mandibular Distraction with a Resorbable Device in Pierre Robin Sequence

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Purpose: Neonatal mandibular distraction has a well documented role in the management of airway obstruction in babies with the Pierre Robin Sequence. Computer aided surgical planning allows for a more precise osteotomy at surgery. The use of a mandibular distractor incorporating resorbable footplates avoids the need for a second procedure to remove hardware.

Material/Methods: Between May 2005 and April 2006 three babies at Princess Margaret Hospital, had airway problems such that they were not able to be managed conservatively. One patient presented with a tracheostomy and the other two patients were to undergo tracheostomy unless the airway could be managed in another fashion. All patients were assessed by an ear, nose and throat surgeon to exclude lower airway problems. Pre-operative CT scans were obtained and virtual reality surgical planning was undertaken. A 3 dimensional model of the mandible was built, to be used for transfer of the surgical plan to the operative site. Bilateral mandibular osteotomies were performed, at an average of 3 months of age, via an extra oral approach. Resorbable distractors were inserted (W. Lorenz Lactosorb Resorbable Distraction System) with the activation port
behind the earlobe. Once the mandible was exposed the lactosorb footplates were heated and conformed to the 3 dimensional model, then fixed in position. Distraction commenced the day after surgery at a rate of 2mm per day for 10 days giving an advancement of the mandible of 20mm. The distractor pin remained in position for 3-4 weeks and was simply removed with no pain in the Outpatient Clinic.

**Results/Discussion:** All patients had a significant improvement in airway function and the tracheostomised patient was able to be decannulated. Neither of the other two patients needed to proceed to tracheostomy. The submandibular scars settled well and there were no other associated morbidities.

**Conclusion:** Mandibular distraction in the neonate with airway problems related to Pierre Robin Sequence may avoid the need for tracheostomy. Computer aided surgical planning and use of a 3 dimensional model improves the accuracy of transfer of the surgical plan to the operative site and leads to predictable results.
Advanced tip plasty technique

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What happens after the cut? A question that every surgeon should be aware of during rhinoplasty procedure. The healing process is slow and long, it involves variable degree of fibrosis, scaring and contracture. In particular, the nose is a hollow delicate and thin organ which makes imperfect healing more obvious. Therefore, there are no perfect rhinoplasty results.

The Joseph rhinoplasty, on long term, has many unpleasant effects, the dropped tip, Pollybeak, asymmetry, alar collapsed, hanging columella and wider nares, that is because tip supportive means were not considered. The Goldman’s tip has also ended in problems such as pinching, notching, retraction, asymmetry, alar collapse and pointed tip, these were mainly related to the unsecured, unstable and weak lateral crus flap which been delivered and to be sutured back to alar rim composing a weak alar Sidewall Support. We highly recommend the technique of new dome creation [double dome] through scoring, suture fixation, columella strut and tip grafts. It has the most predictable results, because of the preservation of the continuity of the lateral crus [strong alar sidewall support] and obtaining a strong tripod of conjoined lateral to medial crura supported
by columella and tip grafts, but, because of the lateral crus exposure, whether using delivery or external approach, there may be unavoidable healing problems due to scarring, fibrosis and contracture along the alar sidewalls such as notching, retraction, collapse, pinching, dimpling and even deviation. These undesirable problems are worse in Mediterranean and Middle Eastern patients, since their skin is relatively thicker and has more fibroblast cells, which produce more fibrin and later on more fibrosis and scarring. In order to reduce these healing problems, the author has been using a modified technique which is largely based on the Goldman’s tip and the I-beam of medial crura but without lateral crus marginal incision and delivery, that is in order to keep an intact alar rim, and reduce the healing process along the alar rim, alar sidewalls and supra alar region, in turn, reduce the forementioned healing problems. The author has been applying this technique for the last 6 years. He has performed over 2500 cases using this technique. Our preoperative assessment, step by step technique and 6 years postoperative results with comparison will be discussed with photographs and illustrations.
The correction of the crooked nose is undoubtedly, the most difficult and challenging clinical situation in cosmetic and functional nasal surgery. In crooked nose, there is deviation, collapse of cartilagenous and bony compartments, airway obstruction and occasional hump. It is quite obvious that the correction of these deformities requires outstanding and distinguished surgical skills. The surgeon should always aim to achieve well projected, profound, oriented, strong, straight, symmetrical supported bony and cartilaginous compartments with patent airways. The use of intermediate and transverse osteotomies, together with the recent advances of tip surgery and dorsum augmentation, have certainly upgraded and promoted our end results. The transverse and intermediate osteotomies have achieved more mobilization and accurate repositioning of the nasal bones, spreader grafts have obtained a straight cartilagenous dorsum and improved tip support techniques have accomplished more tip symmetry, elevation and projection. The operative technique of these key manouevres and the postoperative results will be fully discussed with timetables, photographs and illustrations.

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Reappraisal of orthognathic Surgery in Facial Aesthetics

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The dento-facial skeleton anomalies e.g. malocclusion, open anterior bite, asymmetric face, deviated jaw, long face, gummy smile etc. need surgical correction to restore the proper anatomic and functional relationship in patients. The dento-facial deformities are much more pronounced in CL + P patients. Eighty-six patients who had undergone orthognathic surgery at Al Babtain Centre for Plastic Surgery and Burns, Kuwait, over a period of 10 years from January 1997 to January 2007 are included in the study. There were 25 males and 61 females with a mean age of 22 years (range 16 to 31).

Ten patients had unilateral and seven bilateral CL + P, where as 69 patients were non-clefted. All patients had mandatory orthodontic treatment. Fifty-five patients underwent bimax surgery, and 31 patients had one jaw surgery. The maxillary impaction ranged form 1-9 mm and the mean jaw movement in maxilla was 6 mm (range 1-12.5mm) and in mandible it was 7 mm (range 2.5-15mm). Malar agumention in 8 and genioplasty in 3 patients were simultaneous surgeries along with jaw surgery. The numbness of lower lip in 3% of the cases, haemorrhage in 3.2% of the cases and bite problem in 4 patients were the main complications needed re-doing to achieve good
results. In-spite of some difficulties in surgical manipulation amongst cleft patients the over all satisfaction was more or less same. The results were viewed as good except three patients who were subjectively unsatisfied but objectively they were rated good. Orthognathic surgery improved facial aesthetic and corrected the soft tissue deformities.
Mandibular war trauma-microvascular reconstruction

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War wounds of the lower third of the face is frequently associated with extensive soft tissue and bone defects. During the civil war in former Yugoslavia a great number of wounded with injuries of the lower third of the face were treated in our hospital. About one third of them required reconstruction of larger or smaller mandibular defects and defects of the adjacent soft tissues. From 1993, we began to use free composite flaps in reconstruction of extensive defects of the lower third of the face: scapular, radial forearm and fibular. We report our experiences in the treatment of 45 patients who underwent microsurgical free osteocutaneous flap reconstruction. Scapular flaps were applied in 14, radial forearm composite flaps in 11 and fibular bone and composite flaps in 20 wounded. All of them were males aged 29 years on the average. Average time after the former surgery was 25 weeks. Length of the mandibular defects varied from 5-16 cm. The flaps were designed and raised in the usual manner according to the dimensions and shape of the defect. Due to modeling of bone portion of the flap, one or two infracture were made with preservation of the periosteum. The bones were fixed by wire, miniplates or external fixation. Intermaxillary immobilisation
was made, too. The skin parts of the flaps were used in reconstruction of lower lip, chin and/or cheek, respectively. Vascular pedicles of the flaps were microsutured to either the superior thyroid, facial or external maxillary vessels. Follow up included clinical, radiological and scintigraphic examinations. All patients underwent functional prosthetic rehabilitation. Our results support the use of this reconstructive method in war and in peace time pathology, as well.

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Microvascular Reconstruction of the Head and Neck

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The head and neck region’s defects always presents a great challenge for reconstructive surgeons. We report our experiences in the treatment of 54 patients who underwent microvascular osteocutaneous flap reconstruction on the head and neck region (in 15 patients after tumor resection, in 2 patients with burns, in one for correction of postburned neck’s contracture, and in 36 patients after war wounds). There were 53 males and one female, aged 34 years on the average.

After resection of the tumor in the floor of the mouth, mandibular, maxilar or after egzenteration of the orbital region we applied free flaps in 15 patients (six fibular, four scapular, three radial forearm, one dorsalis pedis and one latissimus dorsi free flaps). Fibular and radial forearm flap were used for reconstruction of the mandibular bone, while scapular, dorsalis pedis and latissimus dorsi flaps were used for covering and plombing the defects of the mouth floor, orbital or maxilar region.

We used scapular free flap for covering the burn of the face, scapular and parascapular flap for the covering of the neck and exposed mandibular bone and preexpanded scapular and parascapular flap for correction of the neck’s postburn contracture.
War trauma of the face is frequently associated with extensive soft tissue and bone defects especially of the lower third of the face. From 1993, we began to use free composite flaps in reconstruction of extensive defects of the lower third of the face. Seven of them were treated with scapular, nine with radial forearm composite flaps and twenty with fibular flaps. Length of the mandibular defects varied from 5-16 cm. Due to the modeling of bone portion of the flap, one or two infracture were made with preservation of the periosteum. The bones were fixed by wire, miniplates or external fixation. Intermaxillary immobilisation was made, too. The skin parts of the flaps were used in reconstruction of lower lip, chin and/or cheek, respectively. Vascular pedicles of the flaps were microsutured to either the superior thyroid, facial or external maxillary and carotid vessels. Average duration of operation was 6.5 hours.

Our experiences and results in microvascular reconstruction in the head and neck region support the use of this reconstructive method in peace-time pathology and in the treatment of wounded during the war, as well.

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Surgical Correction of Microtia

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In the period from January 1989 till December 1997 at Clinic of Plastic Surgery in Military Medical Academy we treated 127 patients with congenital auricular deformity. Microtio was present in 22 cases (17.32%). Male patients were present in 66.92% cases, and female in 33.07%, aging between 5 and 26 years. Unilateral deformity had 41.73%, and bilateral deformity 58.26% patients. We performed the operative treatment in two or three stages in patients with microtio. In 90% cases we have used Converse two-stage method with rib cartilage graft and in 10% Cronin method with silastic prosthesis. When Converse method were used the size of new auriculae was good, but the shape was very poor after the second act of reconstruction. When using the silastic prosthesis method (Cronin) the size and shape were very good, but in 50% of the cases the prosthesis was not accepted and finally had to be removed.
Transferred free flaps some biological characteristics

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Summary: At the Clinic for plastic surgery and burns of the MMA, we examined 33 patients with transferred 5 cutaneous, 18 miocutaneous and 10 osteocutaneous free flaps out of which 10 were done on foot, 13 on the lower leg, and 10 on the face. We analyzed the blood circulation (patency of arterial micro anastomosis and perfusion) of transferred free flaps, recovery of sensitivity, functioning of the sebaceous and sweat glands as well as histomorphologic changes in the skin of the transferred free flaps during the period of 6 up to 36 months after the free flap transfer and compared with the same characteristics of the skin and tissue of the surrounding area of the recipient region.

Key words: free flaps, micro anastomosis, microcirculation, reinervation, histological changes.

Introduction: Microvascular transfer of tissues provides a single act of a flap transfer to any part of the body by applying microvascular anastomosis. Anatomic, morphological, histological, physiological and other characteristics of the donor region are biological values of a free flap which differs from the same characteristics of the surrounding area of the recipient region. During the microvascular...
tissue transfer, the free flap tissue is exposed to various pathophysiological processes; temporary ischemia, anaerobic metabolism, inflammation, denervation and processes of reinervation which significantly affect above mentioned characteristics of the transferred free flap tissue. Wide spectrum of indications for applying free flaps assumes various aims of the microvascular reconstruction. The need for a good perfusion of a local tissue in the complex fracture of the limb long bones or sensitivity in flaps transferred to feet, palms, the face, breasts, genitals, etc, require a reconstructive microsurgeon’s optimal choice of a free flap. The main task of our research was to evaluate biological values of various free flaps transferred onto different regions in regards with the biological value of a tissue in the surrounding area of the recipient region.

**Methods:** At the Clinic for plastic surgery and burns of the Military Medical Academy, we examined 33 patients with transferred 5 cutaneous, 18 miocutaneous and 10 osteocutaneous free flaps out of which 10 on foot, 13 on the lower leg, and 10 on the face. We analyzed the blood circulation (1-3), recovery of sensitivity, functioning of the sebaceous and sweat glands as well as histomorphological changes in the skin of the transferred free flaps during the period of 6 up to 36 months after the free flap transfer.

By using Seldinger’s arteriography, we evaluated patency of the arterial microvascular anastomosis. A femoral catheter was placed selectively in the arterial vessel, from which the recipient artery with microvascular anastomosis was arising and gave contrast. After getting the arteriographic picture, we analysed the microvascular arterial patency of the recipient vessel, microvascular anastomosis and different flap vessel.

Perfusion in the transferred flap tissue was evaluated by the Tc-99m (2mCi, MAA HAS or 2 mCi pertechnetat) radionuclear arteriography. The perfusion quantification of the transplanted free flap was done by a counting number of impulse in time measurement in both the flap and the surrounding recipient site. To be independent from the size of the region, that number was standardised by a picture.
element, piksel, what means the standardization by the volumen measurement of a flap and a recipient site. To get independence of the detected impulse number of the above flap from an injected dose and radiopharmac biodistribution alone, the number of impulses from the flap region is shared with the number of impulses from the recipient region. This ratio is the quantity measurement for perfusion of a transplanted free flap, compared to the recipient region. Ratio is independent from all measurement conditions, a patient state, the size of a transplanted flap and is depending only on perfusion of that region.

The recovery of touch sensitivity was tested by Von Frey test; hot and cold sensitivity was tested by termoestziometre with water +10 or water + 40°C degrees (4-6). Pain sensitivity was evaluated by using Bernard’s diadynamic current of 100 MHz frequency and of 1-15 mA intensity.

The quality of the established sensitivity was tested by the two-point discrimination test (7).

The sensibility examination of transplanted free flaps in all examined patients was done under same microclimatic conditions of temperature and humidity and carried out by the same examiner in order to get the most objective result possible. Prior to the examination, the patient was given the thorough explanation what was an important precondition for a good patient co-operation. During the tests, the patient’s look was excluded by turning his/her head, what was good for getting objective results as much as possible. The sensibility examination began 6 months after the free flap transplantation in intervals of 6 months to 3 years.

The functioning of the sebaceous glands was tested by Herman-Prose’s test while ninhidrinic test was used for testing the functioning of sweat glands.

Histopathologic changes in the skin of transferred free flaps were evaluated by the light microscopy and application of various histochemical and imunochemical dyeing methods (PAS,PAS-diastasis, Masson trichrom, Elastin,Van Geison, Wolcker, S-100
protein). We analyzed the elements of the skin of both the transferred flap and the surrounding area of the recipient site: epiderm (normal structure, hypothrophic, hypertrophic and hyperkeratotic), collagen fibres (normal structure, hyaline degeneration), skin adnexa (normal structure, hypertrophic), blood vessels (normal structure, with thicker wall, with lymphocyte infiltration, existing of PAS positive matherias), nerve elements (normal structure, some fibres of normal structure and some degenerated, degenerated fibres).

Results: Arterial anastomosis were patent in all transferred flaps after 15,24 months (in average) of the free tissue transfer, while arteriography revealed signs of stenosis of microanastomosis in 2 patients.

Concentrations of the radiopharmacs in the tissue of the transferred free flaps were 2,3 times higher than in the surrounding area of the recipient region according to radionuclear arteriography.

Sensibility tests showed that, after the transplantation, the touch sense was first detected 6 months later and established 30 months after the procedure. Hot sensitivity was first detected 18 months and established 36 months after the transplantation; the sense of cold was first detected 6 months and established 36 months after the operation. Pain sensitivity was first detected 12 months after the operation with the diadynamic current of 10,11mA intensity.

The two-point discrimination test performed 36 months after the transplantation showed the distance of 46 mm at which two separate touches are perceived in 37.5% patients.

The functioning of sebaceous glands in a free flap stands at 98% of the sebaceous glands functioning in the surrounding of the recipient region or 99% in relation with their functioning in the surrounding of the donor region.

The functioning of sweat glands was detected 12 months after the transplantation but even 36 months later they still did not reach the functioning level of the glands in the surrounding of the recipient region.
Histo-morphological results showed a significant difference in the texture of a free flap skin characterized by the hypotrophy and hyperkeratosis of epidermis. The epidermis of transplanted free flaps, significantly differed (p+,0,05) from the epidermis of the immediate surrounding area of the recipient region. The adnexa of the transplanted micro-vascular flap skin were mainly hypotrophic and significantly differed (p<0,01) from the adnexa of the region surrounding the recipient region. Collagenous fibrae of the transplanted micro-vascular flaps significantly differed (p<0,01) from the collagenous fibrae of the region surrounding the recipient area. They were mainly edematous, of rifted texture or hyalinously degenerated. Blood vessels in transferred free flaps showed signs of “lymphocyte vacuities”. There was no significant difference between the blood vessels in the transplanted micro-vascular flaps and the blood vessels in the region surrounding the recipient area. Nerves, detected in the material taken by biopsy from the edge of transplanted micro-vascular flaps, significantly differ (p<0.01) from the nerves in the immediate surrounding area of the recipient cite. Degenerated nerves were detected in 58,06% patients fig.23. In 16,12% of those patients nerves with degenerative changes only were detected while, in 41,49% of our patients, nerves with both degenerated and preserved texture were found.fig.24 In 41,49% of patients, we detected nerves with preserved texture.fig.25 Considering that material obtained by biopsy was taken only once (not several times in equal intervals) when the surgery was medically justified, the histological results were assessed in the context of the time elapsed from the transplantation to the moment the biopsy was performed. The correlation was obtained and indicated that the more time elapsed, the less degenerated nerves were detected.

**Discussion:** Patency of micro-vascular anastomosis in the transplanted micro-vascular flaps and the dilemma whether these vessels obliterate after a certain period or not, has been the subject of interest of many reconstructive micro surgeons (3,10,11,12,13). The arterial micro-anastomosis in our study was patent with all our
patients. With two of them (6.06%) angiographic signs of arterial micro-vascular stenosis were registered. Angiographic signs of micro-vascular stenosis were registered with two transplanted micro-cutaneous free flaps where autologous venous grafts were used to extend vascular pedicles of the flaps. Angiographic signs of arterial micro-vascular stenosis reported with our patients, resulted from the different lumens of the free flaps¢ arterial blood vessels and the autologous venous micro-vascular grafts. Our results, obtained by arteriographic testing of arterial micro-vascular anastomosis¢ patency carried out on 33 patients in the 6 to 36 months period after the transplantation (15.24 months in the average), were in full concord with the results of Machens and all (10) who publicized the results of ultra-sound tests carried out on the transplanted free flaps. They reported that arterial micro-vascular anastomosis were patent even 10 years after the micro-vascular transplantation of the tissue was performed. Arteriographic finding in the flap vascular system, the presence of the autonomous vascular net in transplanted free flaps three years after the transplantation, as well as the latest data on the ten years long patency of the free flap vascular stem, publicized in scientific literature (10), have proved that the autonomous vascular net of transplanted flaps was preserved.

Arteriographic examinations may provide necessary data on pato-anatomic status of blood vessels for the need of vascular or micro-vascular surgery. Data on the perfusion of the areal capillary status may be obtained by intra-arterial usage of macro-agents marked with radio-pharmaceuticals (14). In clinical practice, the intra-arterial administration of macro-agents is performed during the examination of a tissue perfusion in people with macro or micro-angiopathia, trophycal ulcers or with fibrous displazia of bones. In the available literature we did not encounter scientific papers referring to administration of macro-agents marked with Tc 99 in the process of examining perfusion of transplanted free flaps. The blood flow in the skin vessels, based on the Tc99 pertehnet clearance, was examined by Waterhause (15). While examining the
re-vascularization of a bone graft in muscular and cutaneous pedicle flaps, Fischer found that the perfusion in muscular flaps was three times better than in the cutaneous ones. Our examinations showed that the average radio-activity detected in the area of transplanted micro-vascular flaps (503.57 impulses/s/pixel) in the AP projection was higher that the radio-activity in the region surrounding the recipient cite (270.9 impulses/s/pixel). Although the number of impulses/s/pixel is directly dependent on the number of macro-agent particles which caused embolism in both the flap and the region surrounding the recipient cite micro-circulations, the status of the perfusion in the flap micro-circulation cannot be assessed on the basis of the flap radio-activity. The number of relevant impulses/s/pixel in the area is dependent on the activity performed and its bio-distribution, which is individual for each of our patients, as well as on the conditions under which measuring took place. With the aim of avoiding the influence of the activities (and their bio-distribution) to which the patients were exposed, we introduced a relative ratio between the radio-activity in the flap area and the region surrounding the recipient cite. The ratio was aimed at counting the detected number of impulses/s/pixel. The ratio does not depend on the above mentioned activities and is one of the reliable factors in tissue perfusion analysis. The perfusion of the micro-circulation in the tissue of transplanted micro-vascular flaps is better than the perfusion of the micro-circulation in the region surrounding the recipient cite and amounts to 232% of the recipient cite perfusion.

The restoration of sensation. The free micro-vascular transplantation procedure implies that free micro-vascular flaps are completely separated from the donor cite prior to the transplantation to the recipient cite. It makes the flap completely denervated. During the transplantation, the skin of a free flap loses its sensitivity which does not exist even shortly after the transplantation. Healing of the wound and ingrowth of the connective tissue create new blood vessels and, as the time passes, nerves also start ingrowing into flap tissue from the region surrounding the recipient cite. In such a way,
sensitivity of transplanted flaps is recovered. Examinations of the recovery of the transplanted micro-vascular flaps’ sensitivity (re-inervation) began in the second half of the eighties and the beginning of nineties. In the first period, few scientific statements were publicized (5,6,16,17). These statements were contradictory. They examined only some types of sensitivity or only muscular free flaps sensitivity (16).

Simple and complex flaps containing skin component were examined by other authors (5,6) the outcomes of which resulted in opposite conclusions. The works of the above mentioned authors indicate that the sensitivity in the transplanted micro-vascular flaps recovered. The differences in their conclusions related to the quality of the recovered sensitivity or the time needed for various types of sensitivity to recover.

**In our investigations we find out that the detection time of various types of sensitivity was as follows:**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Detection Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch</td>
<td>6 months</td>
</tr>
<tr>
<td>Pain</td>
<td>12 months</td>
</tr>
<tr>
<td>Warm</td>
<td>18 months</td>
</tr>
<tr>
<td>Cold</td>
<td>6 months</td>
</tr>
</tbody>
</table>

Data obtained from the available literature (5) said that the pain and touch sensitivities were detected in the average of 7 months after that transplantation of the flap was performed. In assessing the restoration of the touch, warm and cold sensitivities, we were guided by the number of positive responds to certain stimuli which had to be higher than 50%. For the pain sensitivity, we considered it recovered once it is detected. Accordingly, the pain sensitivity was the first to restore (12 months after the transplantation). The second to restore was the touch sensitivity (30 months after the transplantation) while the cold and warm sensitivities were restored 36 months after the transplantation of micro-vascular flaps.

**Restoration time of various types of sensitivity**

<table>
<thead>
<tr>
<th>Sensitivity</th>
<th>Restoration Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Touch</td>
<td>30 months</td>
</tr>
<tr>
<td>Pain</td>
<td>12 months</td>
</tr>
<tr>
<td>Warm</td>
<td>36 months</td>
</tr>
<tr>
<td>Cold</td>
<td>36 months</td>
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</tbody>
</table>
The results of our examinations showed that the touch sensitivity was detected 6 months after the transplantation while the pain sensitivity was detected 12 months after the transplantation. The warm and cold sensitivities were detected in the flaps 18 months after the transplantation. According to our results, the pain sensitivity was first to restore (12 months), the touch sensitivity was the second (30 months) and the latest were the warm and cold sensitivities (36 months after the transplantation). The results obtained on a sequence of the sensitivity detection are in concord with results publicized in the available literature (5). The cold sensitivity although being detected before the warm sensitivity, restored more slowly.

The functioning of sweat glands in transplanted micro-vascular flaps implies the existence of sweat on the skin surface. There were no information in the available literature on the recovery of the sweat glands functioning in the transplanted micro-vascular flaps. Ponten (18) maintained the recovery of the sweat glands functioning in the full-thickness skin transplants as well as in conventional flaps. Skin transplants and flaps with no sensitivity cannot have sweat gland function either. The sweat glands in skin transplants and flaps with no sensitivity can not function either. Our examinations indicated that the functioning of sweat glands in the transplanted micro-vascular flaps was recovered and in co-relation with the recovery of the touch sensitivity. On the basis of our examinations, we learned that the degree of the recovered functioning of sweat glands in transplanted micro-vascular flaps did not reach the functioning level of the sweat glands in the region surrounding the recipient cite.

So far, the functioning of sebaceous glands in transplanted micro-vascular flaps did not drew so much of scientists attention as the condition of the circulation or recovery of sensitivity did. For that reason, we did not find data on the examinations related to the recovery of the functioning of sebaceous glands in transplanted micro-vascular flaps. Ponten examined the functioning of sebaceous glands in the skin transplants of partial thickness and flaps. He detected functional sebaceous glands in the skin transplants of partial
thickness and his opinion is that their function neither depends on the reinervation of the transplanted skin nor on the functioning of the pilomotor muscles. This opinion is contrary to the up to then belief that the re-inervation was a precondition inevitable for the functioning of sebaceous glands. Our measurements of the dry residue of the skin substance in transplanted micro-vascular flaps, showed values which were slightly lower than those of the skin substance dry residue in the regions surrounding the recipient and the donor cites. The difference in the weight of the dry residue in the aether-soluble materials was insignificant. Our examinations indicated that the functioning of sebaceous glands in the transplanted micro-vascular flaps was insignificantly poorer than the functioning of the sebaceous glands in the donor areas. This was probably the consequence of ischemia and denervative processes which occur during and after the transplantation of a tissue to sebaceous glands.

Histo-Pathologic Examinations

There were several articles in the available literature related to the recovery of the sensibility in the skin transplants or in the pedicle flaps. They deal with physiological aspect of the issue with no histological analyses of the re-inervation and their co-relation (18,19) Histologic analyses of the ingrowth of nerve particles into skin transplants and flaps was carried out by various techniques. Adeymo and Wyburn (1952) as well as Fitzerald (1967) used the heavy metal submersion technique. (20) Fitzerald and Waris used histo-chemical techniques (choline-esterasis). Both techniques are non-specific. (8,20,21). The histological examinations were aimed at identifying the way in which nerve endings were ingrowing into skin transplants, the process that might be carried out through the Schwann's hollow outlines or bypassing them. In case the ingrowth went through the Schwann's hollow outlines, the nature of the recovered sensitivity was similar to the sensitivity of the donor area (20). In case nerve endings penetrated into the skin transplant using their own ways, the sensitivity recovered was similar to the sensitivity of the recipient area (18,19). In his works, Santoni Rugiu (19) demonstrated the complete degeneration of the full thickness skin
transplants¢ nerve structure within 30 days after the transplantation. Later on, by ingrowing through the Schwan¢s hollow outlines, nerves could create nerve endings. Unlike Rugiu, Waris and associates detected free nerve endings but failed to detect nerve ending corpuscles. (8).Kadanoff (1977) showed that patients, in whose material (obtained by biopsy from the skin transplants or flaps) no terminal nerve corpuscles were detected, might feel pain, touch, hot or cold. Histopathological examinations carried out with our patients, indicated the existence of the significant difference in the histo-pathological skin structure of the transplanted micro-vascular flap in relation to the skin structure of the region surrounding the recipient cite. The histo-pathological changes in the skin structure of the transplanted micro-vascular flaps resulted from patho-physiologic processes occurring during the transplantation of free flaps. While comparing histo-pathologic results, we noticed a positive co-relation between the preservation of the nerve texture and the recovery of sensitivity. Histo-pathologic findings of degenerated nerves of a mixture of preserved and degenerative nerves and that of preserved nerves exclusively, co-relate with the number of positive responds reported while testing touch, hot and cold sensitivities as well as with the number of mA while testing the pain sensitivity within the period when the biopsy was carried out.

Conclusion: The micro-vascular tissue transplantation is a standard surgery procedure in the current reconstructive surgery. The transplanted tissue passes through a number of circulatory, biochemical and patho-physiological processes which govern its biologic value. It is of great significance to the transplanted flap to preserve biological values of the donor area in order to suit the recipient area. The autonomy of its vascular network is one of the main biological qualities of micro-vascular flaps circulation, which is obtained through its arterial micro anastomosis which stay patent for several years. The vascular network of flaps provides 2,3 times better perfusion than the perfusion in the surrounding of the recipient region. This biological characteristic of free flaps is widely used in
clinical treatment of osteo-myelitis and difficult circulatory damages on extremities. Our examinations of the biological values of the free flaps transplanted by the micro-vascular technique showed that such flaps had better vascular and circular characteristics than the regions surrounding the recipient and the donor areas. The skin sensitivity of transplanted flaps is necessary in the reconstructive surgery on a palm, foot, the face, breasts, penis and other areas requiring sensitivity. The functioning of the skin adnexa and the existence of sebaceous and sweat glands secretion in the skin of transplanted flaps, are of great significance when assessing the biological value of free flaps and the functioning of sweat glands is in correlation with the skin reinervation process initiated by nerves spreading out from the surrounding tissue. Neurological characteristics of the transplanted free flaps, besides their restoration, were poorer than those of the regions surrounding the recipient and the donor areas, because the tests conducted showed that all senses (touch, pain, hot, cold) were partially recovered but even 36 months later they could not reach the level or the quality of the surrounding of the recipient region. Histopathologic changes in the free flap skin have probably resulted from denervation and inflammatory processes that occurred during the micro vascular tissue transfer which was proved by histological examined texture of the nerves in the transplanted micro-vascular flaps.

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Soft Tissue Corrections

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Abstract: Congenital or acquired soft and bony tissue loss or excess causes facial contour deformities. Today, for correction of such deformities can be repaired by dermofat grafts, autogenous and alloplastic materials, bone and cartilage grafts, distraction and flaps. In this study we aimed to present our patients with contour restorations, between March 2003-April 2006. There were 23 patients operated for contour restorations. The average age was 27 (2-60) years old and average follow up period was 12 (3-24) months. The etiology of the patients were: gunshot injuries in 4 patients, encephalocele in 3 patients, frontal sinus fracture in 4 patients, secondary deformities after facial fractures in 6 patients and hemifacial microsomia in 5 patients. In 10 patients alloplastic implants were used. Bone grafts were used in 3 patients, free flaps were used in two patients. Open reduction and internal fixation is performed in 4 patients. And distraction osteogenesis is performed in 4 patients. In all cases aesthetically acceptable results were obtained. In cases where alloplastic implants were used, neither infection nor exposition were encountered. In most of the cases, alloplastic implants were used and no complications according to alloplastic implants were encountered. If alloplastic implants are used carefully, they are extremely useful for facial contour restorations.

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Resection and Reconstruction of Giant Cell Lesion of Bone in Skull Base-Temporomandibular Joint Region

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PURPOSE: To explore the resection features and reconstruction principles of giant cell lesion of bone in the skull base-temporomandibular joint region.

Methods: From 03/94~06/06, patients with giant cell lesions of bone in the skull base-temporomandibular joint regions were collected. There were 16 patients in total, nine males and seven females, 15~47 of age averaging 34.3 years old. Courses of disease ranged from one month to 15 years. The 16 patients underwent surgical resection under general anesthesia; six patients used coronal incision while 10 patients used (semi-)coronal incision + parotid-“S” incisions. All patients temporarily dissected the facial nerves and zygomatic arch; seven patients dissected the parotid superficial lobe, three patients temporarily dissected facial nerve trunk, and the rest of the 13 patients did not. One subject removed the facial nerve temporal branch. Tumors of 10 patients were discovered breaching large portions of the skull base; collaboration with the neurosurgery was necessary to properly dissect the skull. After adequately exposing the extra-cranial tumor, the tumor was completely removed along the tumor border. Those whose skull base was attached to the cerebral dura mater were
carefully separated along the surface of the cerebral dura mater. Radical resections were done in 13 patients and subtotal resections in three patients, and all 16 patients had unharmed cerebral dura mater. As for local defects from the surgery, eight patients applied temporal musculofascial flap to reconstruct, two patients applied temporal muscle flap and sternocleidomastoid muscle flap to reconstruct, four patients applied temporal muscle flap and Ti-plate and(or) Ti-mesh to reconstruct, and lastly, two patients reconstructed temporomandibular joint. Postoperative radiotherapy was conducted in three subtotal resection patients.

RESULT: All 16 patients had no complications after the operation, and the contour were satisfying. Four patients’ appearances were symmetrical, which were reconstructed with temporal muscle flap + titanium plate and (or) titanium mesh. After the operation all tumor-induced pain and headache disappeared in 16 patients, and 11 patients with limited mouth opening improved in varying degrees; nine patients with malocclusion and divergence had their occlusions restored (two of the nine patients reconstructed temporomandibular joint). One patient with declined eyesight had his eyesight improved. Two patients with declined hearing with tinnitus had their hearing restored and tinnitus vanished. During the post-operation period of five months to 10 years, recurrences were not found in 14 patients; however two patients never followed up for verification.

CONCLUSION: For giant cell lesion of bone in the skull base-temporomandibular joint region, radical resection should be ideal. Soft-tissue defect could be reconstructed with temporal muscle flap and the sternocleidomastoid muscle flap, while reconstruction of bone defect in the cranio-maxillo-facial region with Ti-plate and(or) Ti-mesh for optimal facial contour.

[Keyword] Giant cell lesion of bone, surgery, reconstruction 
Other Authors: Shenyi Lijun
Functional Reconstruction of Mandibular Defect with Double Barrel Fibular Graft and Condylar Prosthesis

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PURPOSE: Using free fibular flap graft to reconstruct various types of mandibular defects has currently become one of the most ideal mandibular reconstruction methods. However, the limited width of the fibular often causes the mandible to lack the height to allow osseointegrated dental implants, which also causes external disfigurement due to regional structural collapse. In order to solve this shortcoming, we used double barrel fibular grafts along with condylar prostheses to reconstruct the mandibular defect.

METHODS: From 2003-2006, 13 patients underwent reconstruction of segmental mandibular defects with the double barrel fibular graft. The three modes of reconstruction were the double barrel fibular graft in the mandibular body, the partial double barrel fibular graft, and the double barrel fibular graft in mandibular body with condylar prosthesis.

RESULT: Fibular graft of all patients survived; no significant complications occurred in the donor site of the lower extremities. The contour of the face was ample and symmetrical. The height of the reconstructed mandible was inferior to the normal side within 4.77±4.49MmMm(P=0.0024). Occlusion was normal and speech was...
comprehensible. Panoramic radiograph and the three-dimensional CT scan revealed that the location and height of the fibular bone was in accordance pre- and post-reconstruction. The condylar prosthesis was located within the glenoid fossa.

**CONCLUSION**: The double barrel fibular graft techniques provided a relatively simple and effective technique to reconstruct large-scale mandibular defects. The length of fibulas could be used most efficiently to provide optimal function and contour of the reconstructed mandibles, because the double barrel fibular grafts could be applied to both the mandibular body and the chin region, which were the functional region and where artificial prostheses were applied to the ramus of the mandible. Therefore individual functional reconstruction of the mandible should be utilized flexibly according to the location and extent of the mandibular defect and the length and width of the fibula.

[**Keyword**] mandibular reconstruction, free fibular flap, double barrel graft.

**Other Authors**: Shenyi Lijun
The principal difficulty in treating maxillary median diastemas is the relapse after complete closure. The purpose of the present study is to evaluate in a long term follow-up a surgically assisted orthodontic approach for closure of maxillary median diastemas. Twelve patients presenting with diastemas ranging from 2.5 mm to 6.0 mm participated in this study. Buccal and palatal midline maxillary corticotomies were performed in the twelve patients. Concomitantly, orthodontic treatment for diastema closure was done by edgewise technique. No relapse was detected in any of our cases after a follow-up period of seven years. The stability in the midline could be attributed to rapid accelerated phenomenon as a result of compression osteogenesis. In conclusion, our technique for closure of maxillary median diastemas could be considered as a valid, reliable and less invasive one.

Other Authors: Tarek H. Marei
Comparison of allelogenous and autogenous bone graft for alveolar reconstructions in patients with cleft lip and palate

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Oral Presentation, Federal University of Santa Catarina, Brazil

Abstract: Purpose: To compare allogenous bone grafts associated with platelet-rich plasma (PRP) to autogenous bone grafts for alveolar reconstructions in patients with cleft lip and palate (CLP).

Material and methods: Thirty of forty-six patients reviewed fulfilled the entry criteria, and were operated on by a single surgeon from October 2000 through December 2001. The minimum follow-up was of 6 months. The entry criteria included the age (8-12 years old), and type of fissure (Pre or transforamen unilateral fissures). Reconstructive surgery of the alveolar cleft was performed. A scoring system was used to grade the anatomical severity of the cleft and the results obtained after the surgical procedure. Postoperative radiological measures were conducted and the degrees of CLP closure were analyzed. After 6 months, surgical results were registered by means of digital periapical x-ray device. Radiological measures were made concerning height of the alveolar bone of the adjacent teeth. Results: There was statistically significant (p < 0.05) bone height in the test group (66.6%) compared to the control group (73.3%).

Discussion: The allogenous bone grafting procedures show promising results. The results obtained from this investigation are in

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accordance with the reviewed literature. Conclusions: Allogeneous bone grafts combined with platelet-rich plasma are recommended as a successful treatment modality, reducing the necessity of an additional bone grafting surgical site. Further, this technique reduces morbidity and length of hospital stay.

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Complications during mandibular midline distraction - the first 120 cases

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**Aim:** To analyse the number and type of complications during mandibular midline distraction. Subjects and Methods: The records of the first 120 patients who underwent mandibular midline distraction were evaluated. If complications occurred during treatment, these were recorded.

**Results:** 14 patients had complications during the distraction. In 4 cases the screw of the appliance rotated back between the activations. In 4 cases the osteotomy had to be repeated because the symphysis did not open, two cases developed scar strictures, in another two a lower incisor fractured. One case developed an abscess, one a mandibular swelling and one a large gingival recession.

**Conclusion:** Since both the development of scar strictures (2%) and instable screws (4%) can be considered mild complications, 9 patients remained with serious complications. Most of these could be corrected, but three patients remained with an irreversible damage: two with a fractured tooth and one with a gingival recession.

**Others Authors:** Prof. Dr. S. Ruf University Giessen, Dr. Dr. W.M. Kater, Bad Homburg, Dr. J. von Bremen, University Giessen
Aim: We aimed in this paper to study the result of an early fronto-orbital advancement procedure for trigonocephaly.

Patients and Methods: 36 patients suffering from trigonocephaly were operated on for their malformations at age of 2 to 5 months. A fronto-orbital remodelling was performed. The fronto-orbital bandage was fixed rigidly at the midline and kept floating laterally. This early procedure was decided when early signs of brain atrophy were seen. The follow-up period was varies from 3 to 5 years.

Results: 26(72%) developed a pneumatisation of the frontal sinus. Residual, mild contour abnormalities of the temporal regions were found in 6 patients. To date, no gross disturbances in craniofacial growth related to our method of (rigid fixation/floating) have been observed and the aesthetic results were excellent.

Conclusions: Early fronto-orbital remodelling can be performed without any additional complications, the pneumatisation of the frontal sinus is possible and the aesthetics is satisfactory.

Others Authors: Alhakam A Mawla

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Anthropometric study of the normal ears in Egyptian children with study of the constricted ear deformity and its management

Hussein Abulhassan

Background: Ear reconstruction is one of the most challenging operations that reconstructive surgeon can perform. The aim of any procedure is to restore the auricular structure to as near normal shape and position as possible. Quantitative parameters to date are the most valid way to assess a result of any operation or experiment. For this reason many reconstructive surgeons devised and started to use certain anthropometric measurements and indices. However; most if not all these measurements have been applied to North American, Caucasian and Asian races. Therefore the dimensions and geography of the Egyptian ears (with mixed roots) were not quantified so far.

Objective: to describe the normal contour of the Egyptian ears in healthy children aged from seven to ten years, as well as standardization of nomenclature, classification and management of the spectrum of constricted ear deformity.

Patients and methods: the patients were divided into 2 groups (group 1: 50 patients and 10 patients in group 2). An anthropometric study was conducted on group 1 to define the normal contour of normal ear in the Egyptian children. The patients in group 2 were suffering from congenital constricted ear deformity and required
corrective otoplasty. Patients in group 1 were subjected to the following procedures: visual examination, surface measurements and ear position judgment. Patients in group 2 were subjected to the following procedures: personal sheet, visual examination, anthropometric measurements, photography, a plan of management, retesting of the reconstructed ear using the standard anthropometric measurements in addition to Horlock and Grobbelaar clinical evaluation system to evaluate the procedure used for correction and finally photography of the reconstructed ear immediately post-operatively and follow up for six months.

Results: the mean ear length was 5.86 ± 0.36 cm in males and 5.81 ± 0.33 cm in females with no significant difference between both sexes (P=0.553). The mean ear width was 3.21 ± 0.20 cm in males and 3.17 ± 0.19 cm in females with no significant difference between both sexes (P=0.223). The mean ear inclination was 16.69 ± 5.29 in males and 5.04 ± 5.83 in females with no significant difference between both sexes (P=0.141). The mean ear protrusion was 23.21 ± 2.95 in males and 22.65 ± 3.57 in females with no significant difference between both sexes (P=0.389). The mean ear tragus to subnasal was 12.13 ± 0.49 in males and 1.99 ± 0.67 in females with no significant difference between both sexes (P=0.250). The mean ear tragus to chin was 12.80 ± 0.45 in males and 12.44 ± 0.30 in females with no significant difference between both sexes (P=0.142).

Conclusion: Although statistically significant difference between males and females was not obtained as regard ear length, width, protrusion and inclination; the overall examination revealed that the male ear is longer than the female ear, while they obtained the same width. Inclination and protrusion angles also were more in males than females. The Egyptian ear measurements were slightly smaller in all dimensions in comparison with North American and Caucasian population. The constricted ear diagnosis entails the presence of the following four corner stones partly or totally: lidding, protrusion, small ear size and low ear position. Cosman classification proved to be the most practical to deal with spectrum of constricted ear deformity; as
it categorize the different grades of the deformity according to the amount of tissue defect using the standard anthropometric measurements. In the management of the constricted ear deformity we tried to reach affixed algorithm either by: simple excision, tumble concha flap, anterior scoring, Musgrave’s technique or subtotal ear reconstruction using carved costal cartilage. The following adjunctive techniques were used in almost all cases despite of their grade: chonco-mastoid suture, mastoid stitch and V-Y mobilization of the helical root.
Clinical applications of autologous cryoplatelet gel for the reconstruction of the maxillary sinus - A new approach for the treatment of chronic oro-sinusal fistula

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The authors report their clinical experience regarding an original method of surgical repair of oro-sinusal communications. From September 1999 to December 2003, 13 patients (7 males and 6 female patients; mean age: 52 years, range: 24-68 years) underwent surgical repair of an oro-antral fistula by means of cryoplatelet gel: in three patients, it was mixed with bioglass granules; in two, it was mixed with BiossTM; in three, it was mixed with particulate bone extracted by means of bone grafter from the oral cavity close to the operative site, with addition of demineralised bovine bone; in three, it was used together with porose hydroxiapatite, and in two patients the cryoplatelet gel was only used. No postoperative complication was reported; primary wound healing was achieved within seven to nine days. A bony orthopantoscintigraphy was performed a few months following the operative procedure, showing an active osteogenic process. In eight patients, a CT was performed after 8 to 12 months from the operation, showing a normal pneumatization with reconstruction of the floor of the maxillary sinus. Although preliminary, these findings seem to suggest that the use of bioengineered materials coupled with growth factors and osteoprogenitor cells may represent a valuable alternative to autologous bone transplantation for the reconstruction of the maxillary sinus.

Others Authors: P.Strada;P.Mereu;G.Margarino and F. Cafiero
Cranial transport DO - a study

Muzaffer Durmus

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**Introduction:** The surgical techniques applied to the reconstruction of the calvarial defects have high morbidity and complication rates. The reconstruction of these defects is technically difficult, and their long-term results are not satisfactory. Hence, it is necessary to carry on the search for less invasive techniques that have low morbidity rates.

**Aim:** The aim is to apply bifocal transport distraction osteogenesis to a three-dimensional reconstruction of the cranium and to have optimal cosmetic consequences as well as minimum morbidity.

**Method:** This research was carried out in GATA Research Centre on 8 Akkaraman sheep (48-64 kg), each of which was 2 years old. The sheep were divided into two groups, namely control (N: 3) and experimental groups (N: 5). Osteotomies were applied to the craniums of all the sheep in order to create a 40x50 mm-bone defect. The control group was not subject to any reconstructive method. On the other hand, in the experimental group, a 20x40 mm-transport bone segment was received from the posterior region. After a five-day latency period following the distraction procedure, 2x0.5 mm forward-horizontal and 0.25 mmx2 upward-vertical distraction task was commenced.
and carried out everyday. A downward-vertical distraction procedure was commenced twenty days after that task. Activation period was planned to be 40 days, while consolidation period was estimated to be 30 days. The research results were examined via 4 major parameters, namely conventional radiography, gross analysis, quantitative computer-assisted tomography and histopathological.

**Findings:** No major complications were observed during anaesthesia, surgical procedures and postoperative follow-up. The subjects well tolerated the procedure and no biomechanical problem occurred during the active distraction period. The radiological examination carried out following the consolidation period showed that the bone defect was not reconstructed in the control group, whereas the experimental group experienced the reconstruction of the bone defect as a result of bifocal distraction. The macroscopic and histopathological examinations indicated that there occurred inductive bone regeneration and mature bone structure in the gap field. The three-dimensional tomography yielded the images of the preoperative and postoperative cranial volumes. A reasonable increase was observed in the cranial volume.

**Result:** Cranial transport distraction osteogenesis is an efficient and reliable technique that can be applied to the three-dimensional reconstruction of the hardly treatable and complicated cranial defects and deformities. This technique further yields optimal cosmetic results.

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Distraction Osteogenesis in management of Craniofacial bone stock deficiency

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Abstract: Craniofacial anomalies have a profound influence on the developing skeleton and can cause deleterious effects on it leading to a bone stock deficiency in that region. Orthognathic surgery has been the workhorse in the surgical correction of craniofacial deformities till the recent past. The advent of distraction and its application in craniofacial surgery has revolutionised the management of craniofacial bone stock deficiency negating the multifarious drawbacks of conventional orthognathic surgery.

Midface deficiencies have been managed using conventional osteotomies and distraction in a number of cases. The paper discusses the management of midface craniofacial deformities with special emphasis on principles, protocol and indications of distraction osteogenesis. The versatality of distraction in these cases and the integrated approach incorporating orthodontics remains the key to good results.

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Distraction Osteogenesis in Hand-foot anomalies with craniofacyal syndromes

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INTRODUCTION: In syndromes like Apert, Pfeiffer, heavy craniofacial abnormalities accompany with serious foot problems. In the literature, there are no treatment methods or their results which are proposed and approved, aimed at foot problems in these syndromes. After correction of the craniofacial region abnormalities by important and violent operations, the functional and esthetic problems that can be concealed with shoes were neglected. The patients who have extremely progressing deformities, who are complaining of heel-foot pain, who can not use ready-made shoes and who have walking pattern disorders were selected and included in our treatment group and surgical treatment were performed.

MATERÝAL AND METHOD: Both feet of the five patients, whose ages were ranging from four to eight, were operated at the same time. Correction and lengthening operation were performed in one patient’s hand thumb deformity. The basic foot problems in all patients were short first metatars, metatarsus elevatus and foot inversion in varying degrees. No operation was performed aiming at syndactily of the foot fingers. First metatars lengthening osteotomy was performed in totally ten fingers of five patients. Also, synostosis
excision and tensor fasia lata interposition were performed for the synostosis between the first and second metatarses of the four fingers of two patients. The special made distracters and the Orthofix (M 400 series) were put into place with the use of scopy. After seven days of waiting period, distraction osteogenesis was performed by 0.5mm/ day advancing.

**RESULTS:** During the distraction, walking by pressing the heel, after six weeks of waiting period, simple walking with the take out of the distractors were permitted. In By performing midtarsal osteotomy procedure, inversion and metatarsus adductus deformity were also corrected in two patients. Two patients were reoperated because of early consolidation. After the treatment, with the local wound care and oral antibiotics, no additional problem was observed except the recovering nail base infection. All of the patients were able to wear normal shoes at the and of the treatment. In spite of the difficulty in the surgical intervention and the long period after the surgical procedure, esthetic and functional results were found positive and sufficient.

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