Mandibular Distraction Osteogenesis: Bid adieu to major osteotomies – A Review

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Abstract

Majority of surgical experience with distraction technology has been in orthopaedics. Early results indicate the process to be equally effective in facial skeletal reconstruction. Distraction osteogenesis has proven to be a major advance for the treatment of several congenital and acquired mandibular deformities. A review of the literature dealing with distraction osteogenesis (DO) of the mandible is provided. The type of distraction, indications, contraindications, amount of lengthening, widening, distraction rates and rhythms, latency, relapse and the design of distraction device were analyzed. Treatment protocols and success criteria for mandibular distraction are suggested on the basis of these results. However, there is still, a lack of sufficient data which necessitates need for long term studies in the future.

Keywords

Mandibular distraction osteogenesis; Lengthening; Widening.

Introduction

It is not necessary to be around a surgical speciality to be a part of a revolution. Attempts to modify bone growth, both in terms of amount and direction have been made since antiquity. Intra oral and extra oral appliances are used to restrict growth of the maxilla in hopes of accentuating mandibular sagittal growth. For several decades, non-surgical distraction osteogenesis has been performed by our orthodontic colleagues in the form of rapid palatal expansion.

One of the recent techniques involving reconstruction of skeletal deformities is distraction osteogenesis. It involves gradual, controlled displacement of surgically created fractures which results in simultaneous expansion of soft tissues and bone volume. Thus distraction osteogenesis may be defined as a biologic process of new bone formation between the surfaces of bone segments that are gradually separated by incremental traction. A traction force is applied to the bone segments which continues as long as callus tissues are stretched, resulting in generation of tension within the tissues that connect the bone segments, which stimulates new bone formation parallel to the vector of distraction.

Apparently, distraction forces applied to the bone also create tension in the surrounding soft tissues initiating a sequence of adaptive changes termed distraction histiogenesis.

Distraction Heritage

A historical perspective is necessary to understand the genesis of the strengths as well as the weaknesses of distraction osteogenesis. Codvilla first introduced it in 1905, nearly a hundred years ago. The technique was
subsequently popularized by a Russian orthopaedic surgeon Ilizarov, who developed a single stage procedure to lengthen long bones without the use of a grafting material. In 1973, Snyder first described Ilizarov’s technique to lengthen a surgical osteotomy of the canine model. McCarthy et al. were among the pioneers who used the principles of DO in craniofacial skeleton i.e. lengthening the hypoplastic mandible. Polley and Figueroa used a rigid, external, adjustable distraction device to lengthen the entire maxilla in children with cleft problems.

PDL distraction was first reported by Liou and Huang in 1998 followed by several others. Haluk Iseri et al. described the dentoalveolar bone distraction.

**Biologic Basis of New Bone Formation**

Distraction osteogenesis is one of the most mysterious phenomena of bone biology. It commences with the development of reparative callus between the edges of two bones divided by an osteotomy. The initial formation of callus is followed by an application of distraction force which gradually pulls the bone segments apart. This places the callus under tension, aligning the intersegmentary gap tissue parallel to the direction of distraction. Tension stress generated in the gradually stretched tissues produces changes at both cellular and subcellular levels. This stimulates differentiation of mesenchymal cells into osteoblasts. The tension also enhances formation of capillaries.

Two mechanisms of bone formation have been demonstrated during DO:

a) Intramembranous ossification with direct formation of new bone at a rate of 1 mm/day.

b) Endochondral ossification, in which cartilage is formed and replaced by bone through vascular invasion of capillaries. At relatively slower distraction rate (0.5 mm/day) endochondral ossification predominates. Hypertrophic chondrocytes present in the distraction regenerate tissue respond directly to distraction forces by forming chondroid which in turn transforms into new bone.

The distraction force is discontinued once the desired amount of bone length is achieved. The newly formed bone (distraction regenerate) then undergoes maturation and remodeling until it becomes indistinguishable from the residual host bone.

Clinically distraction osteogenesis consists of five sequential steps:

1. **Osteotomy**: The bone is divided into two segments creating a loss of continuity and mechanical integrity. This is also referred to as ‘fracture’. The osteotomy for mandibular lengthening is dictated by the anatomic region to be lengthened (angle, ramus, corpus) (fig. 1) and by the desired vector of lengthening which depends upon the orientation of the distraction device.

![Fig. 1A: Ramus osteotomy; B: Angular osteotomy; C: Corpus osteotomy.](image)

- Ramus osteotomy is indicated for vertical mandibular ramus distraction.
- Angular osteotomy is performed when downward and forward lengthening is required.
- Corpus osteotomy is performed for forward and horizontal distraction of the mandible.

2. **Latency Period**: This is the period from bone division to the onset of traction.

3. **Distraction Period**: The distraction period is characterized by the application of traction forces to the osteotomized bone segments. The bone segments are gradually pulled apart, resulting in the formation of new bony tissues with the progressively increasing intersegmentary gap.

4. **Consolidation Period**: This is the time between the removal of traction force and removal of the distraction device. It represents the time required for complete mineralization of the distraction regenerate.

5. **Remodelling Period**: This represents the interval between the application of full functional loading and complete remodeling of the newly formed bone.
Techniques of Distraction Osteogenesis

The technique can be classified according to the site of application of tensional stress, as depicted in (Fig. 2).

Callotasis: Distraction of the reparative callus formed around bone segments interrupted by osteotomy or fracture.\(^{18}\)

Physal distraction: Distraction of the bone growth plate.\(^{19}\)

a) Distraction epiphyseolysis: This technique involves separation of the epiphysis from the metaphysis at a rate of 1.0 – 1.5 mm/day.

b) Chondrodistalasis: This technique utilizes slow rate of bone segment separation (less than 0.5mm/day) and allows stretching of the growth plate without fracture.

Distraction Histiogenesis

Lengthening of the soft tissues is an important part of distraction osteogenesis. Under the influence of tensional stresses, a cascade of adaptive changes occur in the soft tissues. Thus distraction histiogenesis may be defined as the biologic process of soft tissue adaptation to gradual stretching.\(^ {1}\)

The sequence of adaptive changes in various tissues following mandibular osteodistraction is as follows:-

a) Effect on Skeletal Muscle:

Guerrissi et al\(^ {10}\) performed bilateral mandibular lengthening in rabbits and histologically evaluated the surrounding soft tissues. Although no alterations in the muscle tissue were found during distraction, an increase in the metabolic and synthetic activities of the muscles was observed. Fisher et al\(^ {21}\) reported that muscles oriented in a plane parallel to the distraction force adapted with compensatory regeneration, whereas muscles aligned in a plane perpendicular to the distraction force showed decreased protein synthesis and persistent evidence of atrophy.

Analyzing the effects of distraction rate on muscles Simpson et al\(^ {22}\) confirmed that slower rate of distraction provides better muscle accommodation to limb lengthening. On the other hand rapid rates of distraction are associated with gross changes such as disorganization of muscle structure, necrosis and significant accumulation of connective tissue in the interstitium. With regard to rhythm of distraction, a more fractionated rhythm appears to provide better results\(^ {23}\) i.e. increases in the increments of distraction lead to more effective myogenesis.

b) Effect on Nerves:

The information regarding the effect of gradual distraction on Inferior Alveolar Nerve (IAN) function is limited and controversial. Karp et al\(^ {24}\) reported the absence of myelinated fibres in the IAN of five dogs after 12 mm of mandibular distraction. The authors concluded that these abnormalities developed either due to the osteotomy or subsequent distraction. In contrast Michaeli et al\(^ {25}\) found no observable histologic alterations in the IAN fibre after 5 mm and 15 mm mandibular lengthening in the same animal model. Block\(^ {26}\) and colleagues observed mild degenerative changes after 7mm of mandibular distraction in dogs. However, these observations were limited to structural alterations only.

Makarov and co-investigators\(^ {27}\) concentrated on IAN function during DO in dogs. They attributed the incidence of acute IAN injury to be related to device construction and osteotomy technique. If acute nerve injury is avoided at surgery, DO with 10 mm of mandibular lengthening appears to produce minimal deleterious effects on the IAN function. In a separate study on goats, Hu et al\(^ {28}\) showed that degenerative changes in the IAN were more severe and more likely to be permanent in animals distracted 2mm/day versus 1mm/day. Whitesides et al\(^ {29}\) concluded that stable mandibular advancements of 10mm or greater can be successfully accomplished by distraction osteogenesis without producing significant damage to the IAN.
c) Effect on blood vessels:

Recruitment of blood supply is critical for successful bone induction and fracture healing. Mandibular DO is associated with an intense vascular response during the early stages of distraction. The number of blood vessels in the distraction regenerate decreases significantly during later distraction. Also, a lower blood vessel density is found in patients with a distraction rate of 1 mm/day as compared to patients with 0.5 mm/day.

d) Effect on Gingival Tissue:

The gingival tissue responds to injury depending on the degree of trauma. If the insult is minimal, only inflammatory reactive changes occur, such as hyperkeratinization of gingiva. If the injury is sufficient to elicit an inflammatory reaction, a healing response is evoked, resulting in either complete restoration of tissue architecture (regeneration) or restoration of tissue continuity with scarring and distortion of normal tissue architecture (repair). The gingiva responds favourably to gradual stretching during osteodistraction. It undergoes regeneration as opposed to repair as suggested by an inflammatory response, without any breakdown in the gingival continuity.

e) Effect on Periodontal Ligament:

The sequence of adaptive changes in the PDL is affected by the placement of distraction forces. Whether placed directly to the bone segment or to the teeth. The mechanism of PDL adaptation to gradual incremental traction during craniofacial distraction osteogenesis is similar to that of orthodontic tooth movement, where tension/compression effect on teeth and associated PDL structures lead to bone resorption, osteogenesis and cementogenesis.

Block and colleagues demonstrated greater bone segment movement after 10 mm of maxillary advancement in dogs with an implant supported bone borne distractor. However, the separated teeth moved back towards each other after completion of distraction due to elastic traction of PDL transepical fibres. They also reported that craniofacial distraction with tooth borne devices result in greater tooth movements than skeletal devices.

Molecular Biology of Distraction Osteogenesis

Distraction osteogenesis has augmented our armamentarium for reconstructive procedures. Therefore deciphering the molecular mechanisms that mediate mandibular distraction osteogenesis is of primary importance.

Mehrara et al have demonstrated that TGF-(beta)1 mRNA (transforming growth factor b-1), a major regulator of osteogenesis during endochondral bone formation and protein production, coincides with osteoblast migration, differentiation and extracellular matrix synthesis. They have also shown that TGF (b)1 production to be an important regulator of vasculogenesis during mandibular distraction osteogenesis.

Osteocalcin is a non-collagenous extracellular protein. Warran et al confirmed its marked elevation along with collagen I during the consolidation period of gradual distraction with acute lengthening. In addition, the expression of an inhibitor of extracellular matrix turnover, tissue inhibitor of metalloproteinase, was also elevated. This suggested that gradual distraction osteogenesis promotes successful osseous bone repair by regulating the expression of bone specific extracellular matrix molecules. However, an insight into the molecular mechanisms involved in distraction osteogenesis is further required since it may enable targeted therapeutic manipulations designed to accelerate osseous regeneration.

Distraction Devices

Selection of a proper distraction device is an important consideration prior to surgery. In general, the devices can be broadly classified as follows (Fig.3):

a) Tooth borne: The tooth borne distraction devices are fabricated according to the location, direction and amount of distraction. They are directly attached to the teeth, thereby transmitting distraction forces from the teeth to the bone via the PDL. The bone element is a standard 7, 9, 11 or 13 mm Hyrax screw. The distal arms are soldered to the lingual surfaces of the molar bands and the mesial arms to the lingual surfaces of the premolar bands. The screw should be located as anterior as possible at an angle of 45 to the occlusal plane without contacting the lingual surface of mandibular anterior teeth. This angle
Fig. 3: (From Samchucov ML, Cope JB, Cherkashin AM: Craniofacial Distraction Osteogenesis; St. Louis Mo: Mosby; 2001).

is important since it determines the ease with which the patient activates the appliance.41

b) Bone borne:- These devices are indicated when a tooth borne appliance becomes dislodged or breaks intraoperatively.42 They are also used in cases where a tooth borne distractor does not fit within the confines of the mandibular arch.39
c) External distraction devices:- These are placed using transcutionary pins,7,43-46 are easy to place and remove during distraction, if necessary, and offer excellent control of bone segment movement especially if a multidirectional device is used.47 However, they may be poorly accepted by the patients,48,49 and may also have other disadvantages, such as skin scarring48,49, and difficulties in eating, speech, sleep, recreational activities. School attendance may also be affected.50 Therefore patient motivation and full understanding of the family is mandatory for successful completion of the treatment.50
d) Internal distraction devices:- The internal distraction devices are placed either submucosally (buried) or extra mucosally (intraoral).32,39,44,45,46-54 They may be tooth borne,53 bone borne or hybrid,53 and offer the following advantages:

1) Internal devices neither produce scarring nor have a negative psychosocial impact.49
2) The stability of internal distractors is excellent; infection and dehiscence are rare and they are less prone to trauma.55 However, a small external incision is necessary for accessing the activation arm which, if planned carefully, can be positioned esthetically.48

The internal devices are not free of disadvantages, some of which are listed below:

1. High risk of injury to the nerve and other anatomic structures (e.g. ducts, tooth buds).48
2. Difficult to place when a vertical orientation of the device is required.48
3. A second surgical procedure is often necessary to remove the device following completion of consolidation.51
4. Lack of multidirection capability.48
e) Unilateral distraction devices:- These are placed when structures on one side of the face are affected.36,57
f) Bilateral distraction devices:- These are placed when there is a bilateral deficiency of the mandible, e.g. patients having micrognathia with bilateral mandibular hypoplasia.54,56,57
g) Unidirectional devices:- Such devices allow mandibular lengthening in one direction only.53,58 This direction is determined by the angle between the Frankfort horizontal plane and the distraction device.59

One of the important limitations of unidirectional devices is that they cannot be adjusted after insertion to alter the direction of lengthening.59 Therefore the device has to be accurately placed at the time of surgery. This, however, may not always be possible because of anatomic considerations in the hypoplastic mandible such as developing tooth buds, the location of mandibular nerve and the overlying soft tissue.59

h) Bidirectional and multidirectional devices:- They allow distraction in two directions.59 The essential components of the device are an angular joint and two geared rods of variable lengths.59 In the bidirectional device the middle joint is a simple hinge whereas in a multidirectional device it is a multifunctional double ball joint.59 These devices can thus be adapted according to individual anatomic situations and the components can be used to move bony segments in almost any direction during distraction.47,59
i) Resorbable distraction devices:- Though the internal metallic distraction devices offer several advantages, they can sometimes be difficult to remove.60 Burstein et al.61 reported the use of internal, resorbable bone distraction devices for craniofacial applications. The resorbable devices allow a single operative procedure for device
placement, eliminating the need for a second procedure for hardware removal.62

**Biomechanical Parameters of Osteodistraction**

Success of distraction osteogenesis technique is dependent upon various biologic and biomechanical factors. Orientation of the distraction device relative to the anatomic axis of bone segment, occlusal plane, desired direction of distraction and the resulting distraction vector must be considered.

Samchukov et al63 evaluated the biomechanical effects of distractors placed parallel to the body of the mandible or parallel to the axis of distraction. The former results in a lateral displacement of the posterior component of the distraction device and a reduction of the midline distraction gap during mandibular lengthening (Fig. 4).

These were eliminated when the device was oriented parallel to the axis of distraction (Fig. 5).

The effect of device orientation has been also evaluated in the sagittal plane by placing the device parallel to the inferior border of the mandible (Fig. 6) or parallel to the maxillary occlusal plane (Fig. 7). Distractors placed parallel to the inferior border of the mandible resulted in an increase in the lower anterior facial height during lengthening.64

The shape of the neomandible is also influenced by the vector of placement of the distraction device.65 Ramal elongation occurs when the device is placed vertically (Fig. 8). Ramal and body elongation with preservation of the gonial angle is seen with oblique placement (Fig. 9), whereas anterior projection of the mandibular body takes place with horizontal placement of the device (Fig. 10).

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Fig. 4A: Bilateral mandibular corpus lengthening with distractors placed parallel to the body of the mandible. B: Note lateral displacement of the posterior component resulting in an increase in the intercondylar width during lengthening (arrows) compared with the predistraction mandible (faint line). DV, Distraction vector.

Fig. 5A: Bilateral mandibular corpus lengthening with distractors placed parallel to the axis or direction of distraction. B: There is no increase in intercondylar width during lengthening. DV, Distraction vector.

Fig. 6A: Distractors placed parallel to the inferior border of the mandible. B: Note the inferior translation of the distal segment resulting in an increase of the lower anterior facial height during lengthening. OPmx, Maxillary occlusal plane; DV, Distraction vector.
Fig 7 A: Distractors placed parallel to the maxillary occlusal plane. B: There is no increase in lower anterior facial height during lengthening. OPmx, Maxillary occlusal plane; DV, distraction vector.

Fig. 8: Vertical orientation of the distraction device.

Fig 9: Oblique orientation of the distraction device.

Fig 10: Horizontal orientation of the distraction device.

**Indications**

Osteogenic distraction is advocated in a plethora of conditions because of its unique capabilities in treating deformities of the craniofacial skeleton. The indications of mandibular distraction osteogenesis are:- Hemifacial microsomia.7,43,49,66-89 (Facial asymmetry, hypoplasia of mandible/ maxillary region, hypoplasia of the facial musculature); Segmental bone defect (Trauma, Tumour).35,67-100; Class II. 52,58,101-105; Acquired micrognathia (Trauma, temporomandibular ankylosis).67,71,72,73,75,106-112 (Retrusion of the chin or steep mandibular angle and abnormal development of condyles); Transverse discrepancy – for relieving mandibular anterior crowding.40,41,52,53,57,104,105,113-121; Craniofacial microsomia.50,82,108,110,122-127 (Retrusion of the mandible, chin, steep mandibular angle); Treacher Collins syndrome.43,50,72,73,75,106,110,126-131 (Hypoplasia of the mandible, skeletal deformities and deficiency of eye
lashes); Congenital micrognathia, Obstructive sleep apnea syndrome (Receding jaw, small chin, loud snoring and disrupted sleep); Alveolar deficiency; Nagers syndrome; Pierre Robin syndrome; Goldenhar syndrome; (Cleft palate, hypoplasia of mandible, glossophtosis); Goldenhar syndrome (Hemifacial microsomia associated with ocular and vertebral involvement); Arthrogryposis (Muscular hypotonia and severe joint contractures); Hypoglossia – Hypodactyl syndromes (Micrognathia, retrognathia of the mandible); Hanhart Syndrome (Hypoglosia, hypodontia, micrognathia of the mandible); Post irradiation therapy (Limited mouth opening, fixation of the jaw, glossoptosis); Goldenhar syndrome (Mask syndrome) (Facial asymmetry, growth retardation, micrognathia, high forehead that tapers to a small jaw); Bilateral dysostosis mandibularis (Micrognathia, ear defects with zygomatic arch involvement); Plagiocephaly (An unsymmetrical and twisted condition of the head, due to irregular closure of the cranial suture); Morpheaform scleroderma (Limited mouth opening, fixation of the jaws due to the involvement of peritemporomandibular joint tissue); Ammonband syndrome.

Contraindications

No absolute contraindications to treatment exist. However the relative contraindications are as follows:

1. Patients who are unwilling to comply with the distraction schedule are not ideal candidates for this procedure.
2. Mandibular distraction osteogenesis has been performed on infants as young as 6 months but more difficulty is encountered when dealing with small fragile bones in the placement of distraction device.
3. Distraction osteogenesis of the mandible may be used in post radiation patients. However this procedure must be performed with caution due to delay in wound healing.

Orthodontics and Mandibular Distraction Osteogenesis

Mandibular deficiency is one of the most common dentofacial deformities which can present itself in all the three dimensions viz, anteroposterior, vertical and transverse. In the past, these problems were treated by orthodontics alone (dental compensation) or by an orthodontic-surgical approach.

More recently, distraction osteogenesis has been successfully employed in these conditions. The orthodontist, often the first person to identify the deficient mandible and the need for bony distraction, participates in all stages of its treatment as a member of the multidisciplinary team.

He or she introduces the technique to the patient and the parents. Since an orthodontist plays an important role in presurgical orthodontics, he or she has an intimate understanding of the patient's occlusal relationship and finally finishes the occlusion after distraction.

Diagnosis and Treatment Planning

Mandibular distraction osteogenesis – Transverse dimension: Contasti et al. have suggested the following clinical indications for successful mandibular expansion.

- V-shaped mandible
- Severe mandibular crowding with well aligned maxillary teeth
- Brody's syndrome (scissor bite) – unilateral or bilateral
- Impacted anterior mandibular teeth with no alveolar space.
- Maxillo mandibular transverse deficiency (crocodile bite) or tunnel smile.
- Retreatment with crowding (with or without extractions)

Aids used for diagnosis of transverse mandibular deficiency are clinical examination, cephalometric analysis, burstone soft tissue analysis, Ricketts frontal cephalometric analysis to determine whether the transverse problems are due to tooth inclinations or skeletal deficiencies. Dental Cast Analysis includes direct measurement and occlusogram gram analysis.
Pre-distraction orthodontics: Contasti et al. suggested that the maxillary arch should be aligned and levelled to its final desired position once the decision to surgically expand the mandible has been reached. This usually takes 6-10 months and is important since the mandible will be expanded to fit within the confines of the maxillary arch.39

Separators are placed mesial and distal to the mandibular teeth that will support the distractor.41 (Usually the 1st molar and 1st premolar). After one week, bands are fitted and an impression is taken. The bands are carefully removed from the teeth and set into the impression and a working cast is poured. The appliance is then fabricated and the screw is cemented in place, but not activated. The surgery is then scheduled one to two days later.41

Post-distraction orthodontics: Following are the most important post-surgical orthodontic considerations:41

- Waiting for 7 days before activation of the device to ensure good collagen fibre formation at the distraction site.
- After the latency period of 7-10 days, the distractor is activated 1mm/day and the patient is seen regularly until the desired mandibular expansion has been achieved.
- Since an anterior diastema is produced by expansion in the osteotomy area, a plastic pontic with bonded bracket can be placed to maintain arch length, prevent premature mesial drifting of teeth, preserve periodontal health and provide optimal esthetics. The expansion appliance should be stabilized by covering the screw with acrylic.
- Application of a force system to co-ordinate both arches into a class I relationship.
- After consolidation (8-10 weeks), most of the swelling and tenderness are resolved and the device is removed and replaced with new bands or brackets. A heavy round arch wire is placed. At the same appointment the denture tooth is reduced in size and an elastic chain is placed to move the teeth slowly into the distraction gap. As the space gets smaller the plastic tooth is eliminated and the residual space is closed.
- Correction of the axial inclination of the teeth in the buccal segment is done with cross elastics. Once mandibular teeth alignment and levelling is complete, a rectangular arch wire is placed for tooth torquing and stabilization of the new arch form.
- 0.36" stainless steel lingual arch is recommended to retain the expansion. Retention of the mandibular arch width is not a major concern, since it is a result of basal bone width increase as opposed to orthodontic expansion.

Histologic studies by Duran et al. have suggested that the bone exposed to stretching undergoes new bone formation and the newly formed bone is membraneous, also known as woven type. This neo formation is generally parallel to the axis of the stretching force. Consequently it is possible to mould the newly formed bone into the required shape.

Mandibular distraction osteogenesis - Sagittal dimension: Contasti et al. have suggested the following indications for sagittal mandibular distraction osteogenesis.

- Mandibular advancements over 7mm
- Presurgical temporomandibular joint degeneration
- Sleep apnea
- Inadequate mandibular anatomy

Pre-distraction orthodontics

The maxillary arch is levelled, aligned and coordinated to an ideal arch form. The mandibular arch is carefully analysed to determine the need for expansion, extractions, curve of spee levelling and in precise, the amount of bone formation required at the distraction site.39 If there is no need for expansion or extraction, fixed orthodontic appliances are bonded to the mandibular teeth to obtain a perfect arch form presurgically.

Contasti et al. have suggested the following records to be taken:-

1. Dental casts
2. Lateral, posteroanterior, submentovertex and panoramic radiographs

The pre-surgical orthodontic treatment usually lasts for 6-10 months.

Post-distraction orthodontics: The surgical procedure is followed by the activation of the device. The distractors are stabilized after the final mandibular position is obtained.162 Radiographic examination is performed to monitor the consolidation of the new bone.162
Contasti et al. have recommended that Class II elastics (4-6 oz/side) be worn 24 hours/day during distraction and consolidation to counteract soft tissue forces at the time of bone healing, otherwise reciprocal forces will act against temporomandibular joint, causing detrimental arthritic changes in the condyle, disk and glenoid fossa. This might cause pain and discomfort to the patient. Unloading of the joints with elastics during consolidation avoids class II relapse and minimizes patient discomfort. After consolidation is complete, the arches are coordinated and orthodontic finishing procedures are initiated, which last for an additional 6 months.

Tooth movement through distracted bone

Movement of teeth through regenerate bone is a topic of current interest. Contasti et al. believe tooth movement should not begin until radiographic evidence of consolidation is observed after the distraction period. Closure of the interdental space should be delayed until the bone is observed. In the mean time mesial migration of teeth should be prevented by placing an acrylic denture in the distraction space. These recommendations are based on the assumption that allowing the teeth to move into the gap early can lead to periodontal defects and potential loss of teeth.

Other reports however, suggest that a tooth can be moved into the regenerate bone after the distraction period. Moderate to severe alveolar bone loss was noted in the fourth premolars moved simultaneously with distraction. Initiating orthodontics at the end of the distraction period preserves periodontal support. Liou et al. observed that orthodontic tooth movement into the newly distracted bone two weeks after the cessation of the distraction period accelerates the maturation process of the bone. They suggested that orthodontic tooth movement in a newly distracted bone is possible and the new alveolar bone thus created is mature, compact and indistinguishable from the original mandibular bone.

Nakamoto et al. evaluated the influence of tooth movement on tooth roots and periodontal tissues, when the teeth were moved into mature, well-organized and mineralized regenerate created after DO compared with less mineralized, immature, fibrous bone. They concluded that heavy forces (80-100 gms) and orthodontic tooth movement through regenerate bone after DO are not recommended to avoid tipping and severe root resorption. Early tooth movement has no effects on bone maturation. Waiting for 12 weeks after distraction to initiate tooth movement resulted in a lower rate of tooth movement and lesser root resorption.

Fate of developing teeth in mandibular distraction osteogenesis

Knowledge of the development of teeth lying within the distraction area is important since mandibular lengthening and widening is often used in young children. Hagins et al. reported that although the root apices closed, the shape of the roots became irregular. In addition, deformation of the proximal root has been noticed more on the side of distraction. The tooth buds in the line of mandibular fracture erupt normally but 18% exhibit either delayed eruption or non-eruption with resorption of the tooth bud.

Thus the developing tooth can erupt and root formation can continue in the distraction area even when the surgical procedure has influenced the tooth. These findings suggest that the existence of tooth buds does not restrict the type of surgical intervention, if some effort is made to preserve the dental follicle during operation. However pre-operative evaluation of tooth buds using radiographs is advised.

Advantages of Osteodistraction

Distraction osteogenesis is a boon and has several advantages. Several authors have emphasized the benefits of the technique as listed below:-

1. Minimally invasive
2. Short operating time
3. Elimination of the need for bone grafts thereby avoiding donor site morbidity
4. Larger magnitudes of skeletal expansion is possible when compared to other standard techniques.
5. Less chances for relapse because of gradual expansion of the surrounding tissues which decreases soft tissue resistance.
6. Widening of the mandible which is difficult to do with traditional osteotomies.
7. Obviation of the need of tracheostomy in newborns with micrognathia and airway obstruction.
8. When used for rapid canine retraction, there is minimal loss of anchorage, rapid distalization of canine with minimal patient discomfort.
Disadvantages of Osteodistraction:

The technique may have some drawbacks.\(^{173}\)
- Dependence on patient compliance
- Pin track scars with external devices
- Long duration of treatment

Potential complications:
- Non compliant patient with treatment failure
- Development of anterior open bite
- Infection that may hinder osteogenesis
- Scarring of the skin with external devices
- Inferior alveolar nerve paresthesia

Need for overcorrection

Ideally, the mandibular advancement should be performed in a single stage. However, due to growth abnormalities, the deficiency may recur in time. Therefore, in order to compensate for growth disturbances overcorrection must be performed.\(^{56}\) The amount of overcorrection is calculated based on the percentage of growth deficiency, 1.2mm of yearly mandibular growth and the duration of the remaining growth until 16 years of age.\(^{56}\)

Potential for Relapse

If relapse after orthognathic surgery is caused by resilient soft tissue envelope and/or lack of sufficient bone contact, distraction osteogenesis might prevent this relapse by gradual distraction of the soft tissue envelope, resulting in a bone bridge of the same consistency and diameter as the original mandibular bone.\(^{174}\) Cope and coworkers\(^{175}\) have suggested that adaptive changes in the soft tissues during slower distraction procedure may minimize the potential relapse seen during acute orthopedic corrections. In support of this Fisher and colleagues\(^{21}\) found that the soft tissues do not tolerate stretching greater than 2mm/ day. However a study conducted by Strijen et el\(^{176}\) showed that high-angle patients are still at risk of relapsing and that distraction osteogenesis cannot prevent relapse in cases with high mandibular plane angle. But in patients with low-angle it is a safe and a predictable procedure.

Patient’s Response to Distraction Osteogenesis

The assessment of the psychological effects and the quality of life led by the patient during the course of distraction osteogenesis is of utmost importance. Analysing from the patients perspective, it was found that majority of the patients with both intra oral and extra oral devices were satisfied with the treatment, would undergo the same again if required would and recommend it to others in their situation.\(^{177}\) But a major disadvantage which they felt with extra oral devices was scarring, which did not improve with time.\(^{177}\) Patient’s suggestions on how the intra oral devices could be improved centered around making the device less obstructive within the oral cavity, particularly by reducing the length of the activation rods.\(^{177}\)

Majority of the patients who experienced problems during treatment, were able to cope with the difficulties.\(^{50}\) Patient’s motivation and the full understanding of the family for this type of intervention is mandatory.\(^{50}\)

Future

Distraction osteogenesis is developing into an important treatment modality and has become a common place procedure with the flexibility to address a wide variety of mandibular defects. As with many new treatment concepts and techniques, the learning curve regarding distraction osteogenesis was steep and is still continuing. What we now need to assess after almost 10 yrs of experience with distraction is:-

- Its long term stability
- future growth potential of a pathologic mandible after distraction
- better understanding of vectors of distraction to achieve three dimensional changes
- improve the design of the distraction devices to be more functional, surgeon friendly and affordable.

Purposeful research, accurate recording of clinical data and critical analysis of distraction results will enable us to further refine this science into a treatment method to achieve predictable, functional, aesthetic and stable outcomes.

Conclusion

Although orthognathic surgery is a strong competitor for distraction, the latter is a promising technique for treating various craniofacial defects. By combining our creativity, imagination, orthodontic skill and surgical experience with this basic science, new and exciting applications can be developed.
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