Distraction Osteogenesis- A review

Dr Jatin Gupta
MDS- Oral Medicine and Radiology,
Ph.D Research Scholar, Faculty of Dental Sciences, IMS, BHU, Varanasi.

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Abstract
Distraction osteogenesis (DO) is a biological process of new bone formation between surfaces of bone segments gradually separated by incremental traction. It is a combined surgical and orthodontic procedure; the orthodontist has a role in pre distraction assessment of the craniofacial skeleton and occlusal function in addition to planning both the pre distraction and post distraction orthodontic care. Both surgeon and orthodontist closely monitor the patient during the active distraction phase. Growth after mandibular distraction is variable and appears to be dependent on the genetic program of the native bone and the surrounding soft tissue matrix. In DO process, the surgeon and the orthodontist, gradually alters the magnitude and direction of craniofacial growth. DO has been widely used in the treatment of patients with great craniofacial bone deficiencies. Besides, it can eliminate the need for graft procedures and provide sufficient bone quality and quantity to allow implants and prosthesis to be placed and orthodontic movements to be performed. The present article is a literature review that aims to illustrate the orthodontic perspective before, during and after the treatment of DO.

Keywords: Distraction osteogenesis, craniofacial abnormalities; orthodontics; bone.

Introduction
Although orthognathic surgery has gained a generalized acceptance for craniofacial deformity correction, several limitations are associated with acute advancement of osteotomized bone segments. Furthermore, syndromic patients with large skeletal discrepancies, require such extensive bone movements that the surrounding soft tissues will not adapt to their new position, resulting in relapse or compromised function and esthetics. Of late, distraction osteogenesis, opens up new possibilities in the correction of craniofacial deformities by orthodontists and maxillofacial surgeons.1
Distraction osteogenesis (DO) is a surgical-orthodontic technique, described primarily in orthopedic surgery in order to promote long-bone lengthening. This technique results in new bone formation through the lengthening of the bone callus, consisting of a biological process which sets off the bone neoformation after the separation of two bone structures that used to be a single unit. The induced traction generates tension within the callus and stimulates the formation of new bone parallel to the distraction vector. This force also creates tension on the surrounding soft tissues, initiating a sequence of adaptive changes known as distraction...
histogenesis.2 Distraction osteogenesis has been widely used in the treatment of patients with great craniofacial bone deficiencies. Distraction osteogenesis has been used for some time to treat patients with Crouzon's disease, cleft palate, and other significant midface deficiencies. All too often, because of post treatment instability, patients have had to accept surgical compromises associated with esthetics and stability. Distraction osteogenesis treatment for cleft palate patients is inherently unstable because of the limitations posed by the scar tissue: not only does scarring cause tissue “rebound” and therefore relapse, but also the lack of elasticity in scar tissue limits the type and amount of surgical correction that can rendered.

**Origins and evolution**
The evolution of craniofacial DO was based on the development and improvement of dentofacial traction, craniofacial osteotomies, and skeletal fixation methods. Later, modifications of these techniques were merged into osteodistraction procedures that were finally improved based on experiences with distraction osteogenesis on long bones.3

**Dentofacial Traction**
From an orthodontic perspective, the application of tensile and compressive forces to bones of the craniofacial skeleton is not a new concept. As early as 1728, Fauchard4described the use of the expansion arch. However, this form of traction was limited to tooth movement only and had little effect on the shape of the bone. Goddard, 5 in 1893, further standardized the palatal expansion protocol. He activated the device twice a day for 3 weeks followed by a stabilization period to allow the deposition of “osseous material” in the created gap.

**Craniofacial Osteotomies**
Although orthodontic treatment provides a means of correcting maxillomandibular skeletal discrepancies, it is limited to actively growing children. In nongrowing individuals, surgical intervention has been implemented to circumvent this limitation. The first surgical procedure for the correction of a craniofacial deformity was reported in 1848, Hullihen6 successfully performed a partial osteoplastic resection of a prognathic mandible. Brown in 1918 and Bruhn-Linderman in 1921 each performed a vertical osteotomy of the mandibular body followed by acute advancement of the anterior segment.

**Initial Mandibular Distraction Techniques**
According to Wassmund,7 in 1927 Rosenthal performed the first mandibular osteodistraction procedure by using an intraoral tooth borne appliance that was gradually activated over a period of 1 month. In 1937, Kazanjian8 also performed mandibular osteodistraction by using gradual incremental traction instead of acute advancement. Crawford9 in 1948, applied gradual incremental traction to the fracture callus of the mandible.
Ilizarov Method

Subsequently, Ilizarov10-12 introduced his distraction osteogenesis technique for limb lengthening. The procedure was initiated by surgical bone division with maximum preservation of periosteum and endosteum - a technique that he called a corticotomy. Specifically, Ilizarov divided two thirds of the bony cortex with a narrow osteotome followed by the completion of bone separation with rotational osteoclasis.

Current techniques

The first report demonstrating the application of Ilizarov’s principles to the mandible appeared in 1973. In order to simulate a mandibular deformity, Snyder et al.13 resected a unilateral 15 mm bone segment from a canine mandible, thereby creating a crossbite. Ten weeks later, the shortened mandible was osteotomized and an extra-oral distraction appliance was placed. After a 7 day latency period, the device was activated at a rate of 1 mm per day for 14 days, at which time the occlusion was restored. Michieli and Miotti14 demonstrated the feasibility of intraoral mandibular lengthening. Implementing a device cemented to the teeth, they lengthened the mandibles of two dogs—one by 5 mm, the other by 15 mm—after a bilateral reverse-step osteotomy. Histologic examination revealed new bone formation originating from the parallel ordered collagenous fibers, which subsequently remodeled to form lamellar bone.

Indications of distraction osteogenesis in craniofacial region:
The technique of distraction osteogenesis has been applied to patients with unilateral craniofacial microsomia, bilateral craniofacial microsomia, developmental micrognathia, Treacher Collins syndrome, and Nager’s syndrome. Distraction has also been used for the correction of midface hypoplasia (craniofacial synostosis syndromes).15,16 Transport distraction has been shown to be a useful technique for the regeneration (newly forming bone) of the mandibular condyle.17 Distraction techniques, no doubt, will be used to correct mild skeletal Class II deformities and, in some cases, to expand the mandibular symphysis to skeletally correct lower anterior crowding.18

Advantages of Distraction Osteogenesis19

The process of distraction osteogenesis has a number of advantages over the conventional orthognathic surgery procedures. Length of hospitalization and operating time is drastically reduced. It can even be performed on an outpatient’s basis. Blood transfusions are generally not required during the placement or removal of the devices. There is no need for autogenous bone grafting.

It can be applied to correct deformities in the very young child as early as 2 years of age. Compared to traditional orthognathic surgery procedures, there is minimal relapse in distraction osteogenesis. This is because, during distraction osteogenesis there is gradual distraction and lengthening of the soft tissue (skin, subcutaneous tissues and muscle) and the functional matrix surrounding the bony skeleton along with the bony lengthening.
Orthognathic surgeries only permit acute changes in the position of bone with limited possibilities of new bone growth. It does not allow complete bone sculpting i.e. changing the shape and form of bone to maximize the three dimensional structural, functional and esthetic needs of the patient.

**Disadvantages and limitations:**
Distraction osteogenesis cannot be useful in dysplasias due to excessive growth. It is treatment modality for deficiency problems only. It is highly dependent on patient compliance. The use of bulky extraoral appliances is psychosocially not very well accepted. Scarring can occur if extraoral approach is used. Risk of infection. The intraoral approach for the osteotomy and pin insertion has evolved as the approach of choice in certain cases in order to eliminate the scar.19

**Phases of distraction osteogenesis**
I. Osteotomy Phase Ilizarov recommended a green stick fracture after corticotomy for distraction of limbs. A complete osteotomy is more reliable for distraction of the jaws.

II. Latency Phase: this phase is important for adequate maturation of the callus. If distraction is started too early, the result is decreased bone formation often with cartilaginous elements present and decreased mechanical strength of the newly created bone. If the latency period is too long (i.e., if hard callus formation has begun), the distraction device may be unable to further separate the bony segments. The soft callus phase of fracture healing begins 3-7 days after the injury and lasts 2-3 weeks; this time frame sets the boundaries of the latency period. Healing occurs more quickly in children. So in majority of cases, ideal latency period is selected as 5 to 7 days after the surgical injury.

III Distraction Phase: After the appropriate latency period, tension is placed on the body segments by activating the appliance. There are two important variables in the activation:
   a) Rate or the amount of distraction per day
   b) Rhythm or how frequently the device is activated.

Rate – If the rate of distraction is too small, there is a risk of premature consolidation. On the other hand, too great a rate of distraction may place induce stress on the soft callus, resulting in thinning of all dimensions in the mid portion of the regenerate distraction is found to be 1 mm per day.

Rhythm – Ilizarov recommended 0.25 mm four times day activation. The most common protocol for maxillofacial patients is 0.5mm increments twice daily. It can be changes to 0.25 mm four times daily, in some patients, in whom pain occurs on 0.5mm twice daily activation.
IV Consolidation phase: Once adequate distraction has been obtained, the distraction device is left in place while the regenerate bone matures and remodels. Most authors have recommended 6-8 weeks as a consolidation period following Distraction osteogenesis. Histologic specimens from human subjects shows that at 60 days the new bone in a distracted area is likely to still be relatively immature (women bone) in contrast to the well-organized mature bone present at 120 days. Crago, Ruiz and profit recommends a consolidation period of 120 days. The acceptability of the distraction device over a long consolidation phase should be considered in planning for the procedure.

Preoperative Clinical Evaluation
The preoperative clinical examination is similar to the examination carried out in preparation for orthognathic or craniofacial surgery. The patient should be examined with the head in an upright position, one should note forehead, orbital, zygomatic, and external ear position and relationships by also viewing the patient from the "bird's eye" and submental vertex positions. The position and contour of the chin, inferior border, and angle of the mandible are recorded. The external ear is graded according to one of several classification protocols. The intraoral examination documents the status of the occlusion. The occlusal plane or transverse cant should be related to the transorbital plane, adetermination later facilitated by examination of the posteroanterior cephalogram. The functional clinical examination should include mandibular excursions, maximum inter-incisal opening. The function of the temporomandibular joint before distraction is documented.

Diagnostic Records
Craniofacial pathology and asymmetry should be documented by standard medical photographs (frontal, lateral, oblique, submental, and intraoral). In addition, 3D computed tomographic (CT) scan, lateral and postero-anterior cephalograms, panoramic roentgenogram (panorex), and dental study models are made. In patients with unilateral craniofacial microsomia and microtia, head should be placed in the correct vertical or midsagittal plane while obtaining the cephalograms.

Orthodontic intervention;
The orthodontist has an extremely important role to play right from diagnosis and treatment planning till the end of the treatment of the patient. Orthodontic management can be divided into 3 stages, Pre-distraction orthodontics, and orthodontics during distraction and consolidation.

Pre-distraction orthodontics:
This begins with a careful appraisal of the dentition and how it relates to the projected skeletal changes. Orthodontic appliances are selected and treatment initiated that is consistent with the overall goals of the distraction treatment plan. This involves the following procedures:
Removal of dental compensations:
The teeth should be moved to ideal positions relative to the basal bone so that an ideal maxilla-mandibular relationship is not compromised by existing dental malrelations.

Preliminary alignment:
All dental mal-relationships that would mechanically interfere with the movement of teeth bearing segment during distraction should be eliminated. For example retruded or extruded maxillary incisors, correction of occlusal plane disharmony and crowding. If these interferences are not orthodontically eliminated, they may be overcome using bite plane or bite block appliances.

Coordination of arch widths:
The patient with severe mandibular retrognathia will have transverse maxillary deficiency also. It is appropriate to expand the maxilla either before or during distraction to accommodate the width of the advancing mandible.

Fabrication and use of distraction stabilization appliances:
These are used in patients who do not require specific tooth movement before distraction, are not in full orthodontic bands and brackets, and are very young, have limited compliance, may have limited teeth present, or may require maximum segment anchorage. These appliances facilitate vector control during and after distraction by maintaining mediolateral dental arch relationships. As the interarch transverse relationship is maintained during distraction, the tooth-bearing segment cannot be displaced laterally and all the length introduced by distraction is maintained in a vertical and/or anterior direction. The distraction stabilization appliances consist of a banded maxillary expansion appliance and a mandibular lingual holding arch attached to 2 bands on each side. All 8 bands on these appliances have symmetrically placed buccal and lingual ball hooks. These allow the use the interarch elastics to control mandibular position during the distraction, consolidation and post consolidation phases. Distraction stabilization appliances and Intermaxillary elastics may be helpful in the reduction of an anterior open bite and may be used transversely to correct crossbite or lateral shift of the mandible during active distraction.

Surgical Hooks:
If fully banded appliances are already in place for preliminary orthodontics after finishing the predistraction orthodontic treatment passive rectangular archwires and surgical hooks are placed for use of intermaxillary guiding elastics during the active stage of distraction.

Orthodontics during distraction and consolidation
Active orthodontics or orthopedics continues throughout the distraction and consolidation phases and may include the use of bands, brackets, distraction stabilization appliances.
Maxillary expansion appliance, functional appliances etc are used to direct the tooth bearing segment towards its planned post distraction position.

**Orthodontics after distraction and consolidation**

After consolidation and removal of the device orthodontics aims to accomplish the original treatment goals. In bilateral distraction to correct sagittal discrepancies in growing individual patients, over correction with creation of an anterior cross bite is a temporary treatment objective. Eruption guidance and dental alignment over basal bone is done. If the patient may require further distraction or surgery after growth, orthodontic treatment at this time aims to ready the occlusion for the future procedures.

In adults minimal correction is done during distraction and orthodontic finishing is accomplished after consolidation.

The unilateral distraction patient generally has a canted occlusal plane. After vertical ramus distraction on the affected site, the mandibular occlusal plane is corrected while the maxillary occlusal plane remains canted resulting in a posterior open bite on the affected side. Its correction involves the maintenance of the corrected mandibular occlusal plane while the affected maxillary teeth and dentoalveolar process are allowed to descend downwards.

This can be done by a unilateral posterior bite plane is placed and reduced one tooth at a time to allow for serial eruption of maxillary posterior dentition.

If patient has laterognathism, a functional appliance with lingual shields can be used to control the mandibular position and a bite plane incorporated in it for passive eruption of the maxillary posteriors on the affected side.

Adding elastic traction to these appliances may do active correction of maxillary occlusal plane.

Unilateral distraction patients also have a tendency for laterognathism as discussed previously, which creates posterior cross bites. This may be corrected by a combination of transpalatal arches, lingual arches, intermaxillary cross elastics and palatal expansion appliances as required.

**Intermaxillary Elastics during Active Distraction**

The vectors of distraction may be further modified by the use of intermaxillary elastics during the active distraction phase. Intermaxillary elastics at this point have been shown clinically to alter skeletal and dental relationships. It is believed that the observed occlusal response to elastic forces is secondary to molding of the regenerate and dentoalveolar remodeling. Thus, intermaxillary elastics can be used to modify the direction of skeletal change and fine tune the occlusal outcome of distraction. Intermaxillary elastics may be worn in Class II, III, vertical, or transverse (buccolingual) directions during the active phase of distraction. Anterior vertical intermaxillary elastics may be helpful in the reduction of an anterior open bite and may be used transversely to correct crossbite. Thus, the authors have observed skeletal response to intermaxillary elastics used during the active phase of
distraction. Active elastic and mechanical distraction is followed by an 8-week period of consolidation.

**Occlusion**

Occlusion undergoes rapid change throughout the active phase of mandibular distraction osteogenesis. Premature occlusal contacts may result in functional shifts of the mandible and inaccurate appraisal of the actual skeletal change. Occlusal interferences may have an effect on the force and direction of distraction with a resulting net skeletal change. Equilibration of occlusal prematurities or the insertion of a neutral occlusal bite plate may eliminate this effect on the vectors of distraction. In general, and especially in the growing child, activation of the device continues until the deformity is overcorrected. The amount of overcorrection is influenced by the amount of expected post distraction growth remaining in the craniofacial skeleton. After completion of activation, the device is maintained in position for approximately 8 weeks (consolidation phase).

**Post distraction Orthodontic Management**

In the unilateral distraction cases, the orthodontist is often confronted with a posterior open bite on the distracted side and a crossbite on the contralateral side. The open bite may be managed with gradual adjustment of a bite plate. The crossbite resulting from mandibular shift across the mid sagittal plane may be corrected by a combination of transpalatal arches, lingual arches, intermaxillary cross elastics, and a palatal expansion device.

**Long-Term Post distraction Change and Growth**

In a longitudinal study, 10 patients with unilateral craniofacial microsomia and bilateral micrognathia who underwent correction of their mandibular deformities by distraction osteogenesis were evaluated by clinical and cephalometric examination. The period of post distraction follow-up ranged from 12 to 70 months. Five patients underwent unilateral mandibular distraction and five patients underwent bilateral distraction with an extraoral device. Cephalograms (panoramic, posteroanterior, and lateral) were obtained at the following time points: preoperative, posttreatment, and annual follow-up. In the period of observation after distraction, the 10 mandibles showed cephalometric and clinical evidence of growth. In the five unilateral cases, the unoperated side grew in a pattern as would be expected for the unaffected side of a mandible with unilateral craniofacial microsomia. The distracted side, however, grew with a variable response. The growth response of the operated side was variable and appeared to be dependent on the genetic program of the native bone and the surrounding soft tissue matrix.

**Role of the Functional Matrix**

A surprising finding is the multidimensional changes in mandibular skeletal form achieved with a unidirectional distraction device. For example, increases in the transverse or bigonial
distance and in the vertical dimension of the coronoid process have been observed. It appears that the masticatory muscles work on the bony regenerate and thus significantly modify changes in mandibular form. Bony remodeling occurs predominantly during and after distraction while the patient is functioning with deglutition, mastication, and speech. Gradual distraction or lengthening, not only of the skeleton, but also the muscular and cutaneous tissues, probably accounts for the absence of relapse previously apparent after bone grafting of the ramus in unilateral craniofacial microsomia and orthognathic surgical advancement for the correction of severe mandibular micrognathia.

Conclusion
The role of the orthodontist in distraction osteogenesis is one of close collaboration and planning with the treatment team. The traditional role of the orthodontist has been and continues to be one of documentation and evaluation of growth, description of the presenting deformity, growth prediction, and evaluation of occlusion, facial proportions, and esthetics. Through careful assessment of the clinical, radiographic, and photographic records, the orthodontist and surgeon will plan the magnitude and direction of the desired change. A treatment plan will emerge after collaboration and discussion with selected members of the treatment team. Distraction osteogenesis of the craniofacial skeleton has opened up significant new possibilities for the treatment of severe, as well as mild, skeletal deformities. Thus, the surgeon and orthodontist have become collaborators in a process that gradually alters the direction and magnitude of craniofacial growth.

References:


Corresponding Author:-
Dr Jatin Gupta,
MDS- Oral Medicine and Radiology,
PhD Research Scholar,
Faculty of Dental Sciences, IMS, BHU, Varanasi- 221005.
Email-id: drjatin18@gmail.com