European Journal of Molecular & Clinical Medicine
ISSN 2515-8260 Volume 07, Issue 2, 2020

Maxillo-Mandibular Distraction Osteogenesis – An Overview

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Abstract

Distraction Osteogenesis is a novel method of new bone formation that has reached various advances in recent years with its advantages of minimum invasiveness and formation of both bone and soft tissue. Though initially used in long bones, currently distraction osteogenesis is used widely in dentistry for correction of alveolar distraction, maxillo-mandibular deformities, cleft palate treatment and accelerated canine retraction. This review article gives an overview of distraction osteogenesis.

Keywords: Distraction osteogenesis, bone lengthening, mandibular distraction

Introduction

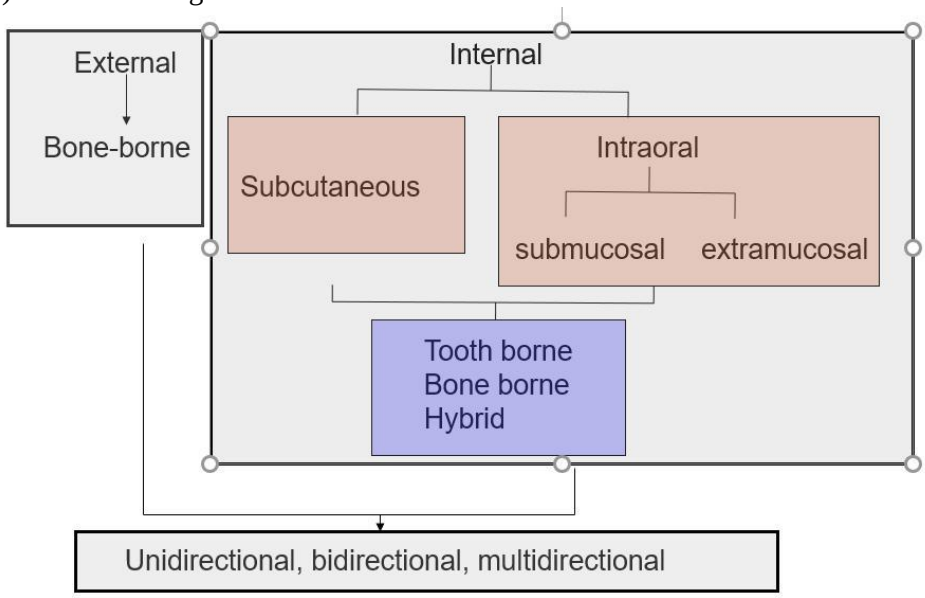
Distraction Osteogenesis (DO) is defined as a biological process of new bone formation between the surfaces of bone segments gradually separated by incremental traction. Distraction force applied on to bone creates tension in the surrounding soft tissue initiating a sequence of adaptive changes termed "Distraction histiogenesis".[1]In the days of yore, the deformities of the skeletal system was treated based on the potential of growth of the patient. Usually in growing children it is treated with myofunctional and orthopedic appliances and in the non-growing individual with surgery. The stretch of muscles and soft tissues is one of the limitations which brings about higher relapse rate. Distraction Osteogenesis is one such good alternative procedure to overcome some limitations of surgery.

History

In 1905, Alessandro Codivilla, introduced a crude method of distraction osteogenesis for lengthening of the lower limbs. Later in 1927 Abbott, improved the Codivilla method by incorporating pins instead of cast in the process of lengthening lower limbs. Around 1930's Rosenthal first performed this technique in the maxillofacial region by mandibular distraction followed by Kazanjian (1941) who performed mandibular distraction with a - L shaped osteotomy cut. Crawford (1948) and later Allan (1948) improvised the technique by incorporating a screw device to control the rate of distraction.

Distraction Device Classification[1]

(a) Based on design and location:



External Distractors: Rigid external distractor, Mandibular external distractor.

Internal distractors: Mandibular internal distractor, Modular internal distractor, Customised tooth borne distractor & Alveolar distractor. Distractors based on vectors: Unidirectional, bidirectional & multidirectional. Based on location: Manbibular, maxillary/midfacial, craniofacial, alveolar ridge, bone transport and dental distractors. Based on anchorage: Tooth borne, bone borne, hybrid. However, it was in 1951 that Gavril Ilzarov developed a unique technique for repairing complex fractures and non union of long bones and was hence responsible for the popularization and wide acceptance of this technique. McCarthy et al in 1989 was the first to clinically apply extraoral distraction osteogenesis in children with craniofacial anomalies. For the ease of communication an easy and a simple system of classification was published by Harikrishnan et al (2009), with some relevant parameters associated with distraction osteogenesis in the craniofacial region. Another comprehensive classification for distraction osteogenesis of maxilla and mandible was once again published by Harikrishnan et al[2] in the year 2019.

BIOLOGIC BASIS OF DISTRACTION OSTEOGENESIS

Subsequent to osteotomy cuts callus formation takes place and this callus is then placed under tension by the distractor device, which creates tension by stretching and helps in the formation of new bone at that particular site.

Clinically, distraction osteogenesis consists of 5 sequential steps:

1. Osteotomy phase
2. Latency phase
3. Distraction phase
4. Consolidation phase
5. Remodeling phase

OSTEOTOMY PHASE

The process of surgical sectioning of the bone is called as "OSTEOTOMY"., During osteotomy, maximum care should be taken to preserve the periosteum and endosteum to aid in maintaining the good venous flow & blood supply as also to maintain the viability of the cells in order to perpetuate and initiate the distraction osteogenesis process. After this phase, angiogenesis, osteogenesis and fibrogenesis commences.

LATENCY PHASE

This phase lasts from around 5-7 days and is the time period from the osteotomy cut till the traction force is commenced. The healing process of fracture and the latency phase in distraction osteogenesis exhibits similar histologic features. During the latency phase adequate time is required for the process of callus maturation. Decreased bone formation is seen if the distraction force is given too early while on the other hand further separation of bone becomes very difficult if the distraction force is delayed. Skipping the period of latency and distracting the mandible rapidly is acceptable only in pediatric patients. Hence, pediatric patients experience overall reduction in the treatment process.[3]

DISTRACTION PHASE

The period of distraction phase ranges from 2- 3 weeks. It is characterized by the application of traction forces to the osteotomized bone segments. This is the actual phase when the distraction device is activated. During the first week, capillaries grow into fibrous tissue and their terminals actively invade the fibrous tissue, supplying them with less differentiated cells that differentiate into fibroblasts, chondroblasts, or osteoblasts. During 2^{nd} week, primary trabeculae begin to form. Osteogenesis is initiated at the existing bone walls & progresses towards the centre of distraction gap and by the end of 2^{nd} week, the osteoid bone begins to mineralize. Rate and rhythm are the two important variables which are essential during the activation /distraction phase. If the rate of distraction is very small, it increases the risk of premature consolidation. If it is too great, it may cause undue stress and force on the soft callus resulting in reduced quality of the bone formed. With regards the rhythm of distraction, various authors have suggested various protocols. Ilizarov suggested increments of 0.25mm, 4 times a day whereas Mc Carthy (1989) advised distraction should be 0.5 mm per day, twice daily and Mollina and Ortiz (1995) recommended 1 mm per day, once per day.[4]

CONSOLIDATION PHASE

It is the time period between the termination of traction force and the removal of the distraction device. This phase aids in maturation. As a rule of thumb, the larger the distance between the distractions, longer is the overall duration of consolidation phase. In the maxillofacial region, 4-8 weeks consolidation phase is usually suggested.

REMODELLING PHASE

It is the period from the application of full functional loading to the complete remodeling of the newly formed bone. This phase usually takes a year or more and it is only after this phase can the newly formed bone be compared to the pre-exisiting bones around the area. The newly generated bone has low radiodensity and mineral content compared to the pre-existing surrounding bones.

The difference between distraction osteogenesis in long bones and facial bones is that in facial bones:

- The requirements for movement of the bony segments are more complex and requires complex three-dimensional movements.
- There are complex soft tissue and muscle attachments in the facial region.
- Mobilization of the maxilla involves separation at several sutures as well as osteotomy across skeletal buttresses and new bone formation must occur along the thin cortical plates.

- Facial aesthetic issues due to scarring of devices.
- Smaller devices often with multidirectional vectors of force makes usage difficult to advocate.

ROLE OF ORTHODONTIST IN DISTRACTION

OSTEOGENESIS Treatment planning in distraction osteogenesis:

Basic treatment planning in distraction osteogenesis involves complete extraoral & intraoral examination and collection of records and data. Extraoral examination includes examination of angle of the mandible, orbit, forehead, zygoma and chin for any other skeletal defects. Intraorally, the occlusion of teeth and the occlusal plane is examined. Functional movements like maximum interincisal opening, mandibular deflection or deviation are also noted. The temporomandibular joint is examined and any sensory nerve loss in the facial region is noted. Orthopantomograph, lateral cephalogram, PA cephalogram and photographs, are all recorded and in certain cases, cone beam computed tomography and stereolithographic models are also recommended.

Pre-distraction orthodontics

Before distraction osteogenesis the arches are prepared by leveling, alignment, decompensation and correction of the curve of Spee. In order to avoid compromise in the ideal maxillomandibular relationships the teeth should be ideally positioned relative to the basal bone. Future growth prediction should be kept in mind while treating children and adolescents and therefore necessary overcorrections should be recommended. If there is a need for engaging elastics post distraction the necessary auxiliary attachments for engaging elastics should be planned and given by the orthodontist. Good communication between surgeon and orthodontist regarding the vector of distraction and the type and extent of tooth movement is highly mandatory.

Orthodontic management during distraction and consolidation

Active orthodontics continues throughout the phase of distraction with the use of bands, brackets, elastics, headgear, acrylic guiding appliance, etc. The vector of distraction in all the three planes of space such as transverse, antero-posterior and vertical is influenced by the interarch elastic traction applied during distraction. In order to prevent laterognathism in unilateral distraction of mandible, elastic traction is commonly used.

Post distraction orthodontics

Orthodontic treatment is further continued after the removal of the distractor appliance for good post-operative results and stability. Post distraction orthodontics depends upon the type and the manner in which the distraction has occurred. Midline corrections, correction of maxillo-mandibular relationship and occlusal plane correction are the most common post orthodontic management in unilateral distraction of the mandible. Sometimes, as a consequence of distraction. an open bite may be created (e.g. unilateral distraction). In such cases, special orthodontic care should be taken to bring about ideal occlusion.

APPLICATIONS OF DISTRACTION OSTEOGENESIS

(A) MANDIBULAR DISTRACTION

In cases of conventional surgery and subsequent ramus lengthening the adaptation of musculature such as the pterygomandibular sling does not adapt so well. This however is overcome in distraction osteogenesis.

Syndromic patients such as Pierre Robin syndrome or Nagers syndrome who are at a higher risk due to hypoplasia of the mandible definitely benefit by this method. Patients with asymmetry such as in hemifacial microsomia or anklylosed TMJ also benefit when distraction is done at an younger age. Mandibular distraction has been proved to be helpful in cases of sleep apnea patients with a short mandibular ramus and body.

(B) MAXILLARY/MID FACE DISTRACTION

Rigid external distractors are usually used in order to advance the midface in cases of syndromic cleft lip and palate cases. These are usually external distractors and activation is done with keys extraorally.

(C) ALVEOLAR DISTRACTORS[5]

These type of distractions are usually used in an edentulous dental arch which is prepared for the placement of implants. Other needs for alveolar distraction includes developmental anomalies (cleft palate & congenital tooth absence), vertical alveolar bone loss, periodontal disease and maxillofacial trauma. Alveolar distraction can be done vertically or horizontally in order to increase the length or width of the arch respectively. These procedures have gained more interest because of simultaneous augmentation of soft tissue and bone segments. In case of transport distraction the segment which includes implants or teeth is transported to the necessary location aiding in correction of prosthetic and occlusal defects.

(D) RAPID CANINE DISTRACTION

It is a modification of distraction osteogenesis technique, wherein the interdental bone is undermined after tooth extraction but prior to tooth retraction.[6] It is based on the principles of bifocal bone transport used in case of long bones. After the extraction of the premolar and undermining of the interdental septa, distraction devices are used to retract the canine by rapidly stretching the PDL on the mesial side of the tooth.[7] The vitality of the teeth involved in the distraction process is not compromised even after 6 months.[8] Hence, DO can be considered as one of the safe methods for rapid canine retraction.

(E) MANAGEMENT OF ANKYLOSED TEETH

In cases of infraerupted ankylosed teeth, the use of miniature distraction device has been successfully used.

(F) EXPANSION OF MANDIBLE AND MAXILLA

Distraction devices are used to increase the transverse dimension of maxilla and mandible in the form of mid-palatal sutural expansion and mid symphyseal expansion. Bone borne, tooth borne or hybrid appliances are used for this purpose.

COMPLICATIONS OF DISTRACTION OSTEOGENESIS

Intraoperative complications of distraction osteogenesis include improper osteotomy cut, bleeding complications, damage to nerves and improper device placement. Intraoperative distraction complications also include pin infections, pin loosening, device loosening & dislodgement, pin tract formation with subsequent scarring, inappropriate distraction vector, paresthesia, trismus, premature consolidation and cyst formation. Master et al [9] quoted that with regards to mandibular distraction the complications include relapse (64.8%), tooth injury (22.5%), scaring(15.6%), nerve injury(11.4%), infection(9.5%), inappropriate distraction vector(8.8%), device failure(7.9%) and TMJ injury(0.7%).

RECENT ADVANCEMENTS IN DISTRACTION DEVICES

The technique of new bone generation has made tremendous advancement in the past few years some of which include resorbable distractors, automated continuous distraction devices and completely implanted battery operated devices. Resorbable distraction devices which has been used in mandibular distraction avoids the need for second surgery for the device removal.[10]

Automatic continuous distraction osteogenesis (ACDO) has gained popularity since it is less painful as also enhances and improves the quality of the newly generated bone tissue.[11] Though ACDO has shown promising results its success in humans is still under speculation. To be used in humans further research to improve the reliability of the device, portability, safety and size should be considered.[12]

Conclusion

An enormous regenerative capacity is possessed by the human body and distraction osteogenesis transforms this capacity into a treatment process to regenerate bone, blood vessels, nerves and mucosa around the distracted region. Though it has its limitations it can still be considered as an excellent option in the treatment of craniofacial abnormalities and various other dental conditions. This technique mandates an interdisciplinary approach and when coordinated with good clinical care would definitely pave the path for successful clinical outcome in the deserving patients.

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