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DISTRACTION OSTEOGENESIS IN ORTHODONTICS

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INTRODUCTION:

In humans, malformations are common abnormality which may result from congenital, acquired or even due to mutations. Malformations in craniofacial region such asmaxillomandibular hypoplasia facial asymmetry etc., can cause difficulty in speech, mastication, abnormal and dysfunction of the jaws. While treatment is carried out in suchpatient, the main limitation in a non-growing patient is the risk of relapse where the muscles and soft tissues are excessively stretched. Many alternatives were developed to overcome relapse from surgery. Distraction osteogenesis is one such alternative with excellent outcome. [1]

'Distraction osteogenesis is a biological process where new bone is formed between the bone segment that are separated gradually by incremental tension' . It was 1st done is femur bone to correct length defect by Codivilla in 1905[2]. There were complications in the procedures including oedema, infection, skin necrosis,delayed ossification and deviation of expanded segments[3]. Several studies reported that the incidence of complication reduced by performing corticotomy without disrupting periosteum and endosteum [4-8]. In Distraction ontogenesis bone grafting is not needed and itrequires minimal invasion to correct the deformities [9]. The striking function of distraction osteogenesis compared to the conventional technique is the potential to accomplish larger bony movements with simultaneous expansion of surrounding neurovascular structures and soft tissues thus increasing the potential for greater stability[10].

HISTORY:

The history begins with Hippocrates who used a technique of repositioning and stabilizing fractured bones, which was observed in a novel by Sam chukkov, Cope and Cherkashin in 1999 [11]. In 1728, Fauchard applied compressive and tensile forces for expansion of arch in craniofacial skeleton [12]. Wescott in 1859 used mechanical forces on maxilla for correction of cross bite [13]. Codivilla was the 1st person to implement the procedure clinically in 1905, where he used this method to lengthen lower limbs [14]. Codivilla'smethod was improved by Abbott in 1927 ,where he incorporated pins instead of casts [15]. In craniofacial region, bone lengthening of mandible was done in micrognathic patient by Rosenthal in 1927 [17] and advancement of maxilla was done in a patient having maxillary hypoplasia by Wassmund in 1926 [16]. In 1930, Rosenthal was the 1st one to perform this procedure in maxillofacial region which was then backed up by Kazanjian in 1941 [18] and Crawford in 1948 [19]. A screw device was incorporated by Allan in 1948 to regulate the distraction rate[20]. Gavril Ilizarov in 1969 developed a technique where he used DO in repairing complex fracture. His technique was based on the capability of surrounding soft tissues to regenerate under tension [21]. McCarthy and his colleagues in 1989 were 1st to do extraoral distraction clinically in mandible [22]. Guerrero in 1990 used an intraoral tooth borne device in widening the midsymphysisof mandible [23]. Cohen et al in 1995 was the 1st one to perform multifunctonal distraction of midface [24]. Ortiz Monasterio& Molina in 1999 introduced a technique of distraction in both maxilla and mandible by using mandibular devices alone [25]. Liou et al in 2001was the 1st one to apply this concept of distraction in orthodontic tooth movement and used in rapid retraction of canine [26].

Biology :

The main difference between osteotomy/corticotomy in DO and traumatic fracture is the healing process. As there is slow expansion and controlled microtrauma in DO membranous ossification occurs in the gap produced by distraction rather than endochondral ossification [27,28]. Distraction force is applied to the bony segments only after the callus has started to form. As the bones are separated periodically, it will create tension in the callus which results in alignment of callus tissue parallel to force. After achieving the desired bone length the distraction force is discontinued and the new bone formed is permitted to undergo maturation and remodelling [1].

The distraction process can be done in 5 phases [29]

a) Osteotomy
b) Latency

c) Distraction
d) Consolidation
e) Remodelling

a) Osteotomy:
In this procedure the bone is intentionally divided into 2 segments. This triggers the process of healing. Consequently, a reparative callus is formed between the fractured segments [1].
b) Latency period:
This is the period from osteotomy to application of traction forces. This period allows the formation of callus. The events that occur in this period is similar to fracture healing [1]. It may range from 5 to 7 days. For older individual with poor vascular supply 7 days are recommended [30-32].

c) Distraction period:
In this period the device is activated gradually ie. the tractional forces are applied to the bony segments. As a result of this new bone is formed parallel to the force of distraction [33]. The ossification between the fractured segments and expansion of surrounding tissues are influenced by rate of activation of the distraction device [34]. Rate of distraction for younger individual 1.5 to 2 mm /day and adult 1 mm /day [35]. In case of bifocal DO 1 mm of distraction force in applied on 2 sites ie 2 mm / day [1].
d) Consolidation period:

Once the desired bone length is achieved, the tractional forces are stopped. Once the ossification between the distracted bony segments are complete then the distraction device is removed. This time period ie 'from cessasion of traction force to removal of the distraction device' is the consolidation period [1]. This period may vary from 4-12 weeks [33,36].

e) Remodelling period:
It is the time between the application of functional loading and remodelling of newly formed bone. Intramembranous ossification takes place and it bridges the gap between the fractured bony segments [25].

<u>Types of devices used in DO</u> [9]:

1) BASED ON THE TYPE OF DISTRACTOR USED
A) External
Unidirectional
Bidirectional
Multidirectional
B) Internal
Subcutaneous
Intraoral
-Submucosal
-Extramucosal
Tooth bourne
Bone bourne
Hybrid
2) BASED ON THE SITE OF DISTRACTOR PLACED
A) Mandibular distractor
B) Maxillary and midface distractor
C) Alveolar ridge distractor
Tooth bourne
Bone bourne
Hybrid
D) Periodontal ligament distractor
E) Cranial distractor

3)BASED ON THE PLANE WHERE DEVICES WOKS

A)Uniplanar distractor

B)Biplanar distractor

C)Multiplanar distractor

<u>Bone Biomechanics:</u>

The regeneration of new bony tissue in distraction osteogenesis is a highly complexand dynamic process [37]. There are certain physical and biological parameter which affects the success of DO. It includes

1. Anatomy of bone in macroscopic andmicroscopic level.
2. Amount and direction of the forces applied.

3. Capacity of the involved tissues to regenerate.

Force transduction through joints, ligaments, muscles & soft tissues produces stresswithin the callus which will influence the regeneration of tissue withinthe bony fragments[9].

There are 3 types of stresses namely tension, compression and shear which are used in combination in DO [37].

Clinical consideration [37]:

The clinical application of DO depends upon the factors related to devices used and the tissues involved.

Device related factors includelength, number,rigidity of the distractor fixation, diameter of fixation pins; orientation of distractor ; material properties of device; relation of resulting distraction vector to anatomical axis of distracted bony segments; joint position and occlusal plane.

All these factor are important and should be considered and these might have effect on the clinical outcome of the distraction procedure.

Tissue related factors include geometric shape, density of the distracted bony segments, cross sectional area, length of distraction gap and tension of soft tissue envelop.

There factors might affect the quality of the distraction tissue to be generated. It is essential to consider dental aspect in DO involving craniofacial and alveolar region.

It includes predistraction orthodontics, osteotomy design, location and selection of distractior,use of distraction splints, orientation of distraction vector,functional loading of the generated bone andpost distraction orthodontics.

DO in mandible transmits force to TMJ , structural alternations in joint anatomy and overlying soft tissue might occur. Effects of DO on joints should also be considered during treatment planning.

Preoperative Clinical Evaluation [9]:

The following examination should be performedthoroughly for a proper treatment planning and should be documented.

Extraoral clinical examination should include examination of forehead, orbit, zygomatic region, external ear position.

This is performed with patients head in upright position from bird's eye view and submentovertexview.

Position of oral comminute and its distance from external auditory canal should be recorded.

Location of chin contour, lower border and angle of mandible should be registered

Intraoral Examination includes

Occlusion should be examined

Intraoral pathology should be related to extra oral Skelton and soft tissue abnormalities.

Relation of occlusal plane to the trans orbital plane.

Transmeatal, transgonial, Mid sagittal plane should be assessed.

Function clinical Examination:

Maximum mouth opening

Lateral and forward excursions of mandible

TMJ functions should be documented.

Motor and sensory nerve functions also should be recorded.

Diagnostic Records [9]:

Along with the clinical examination diagnostic data base should be created with study models, photographs including frontal, lateral, oblique ,submental and intraoral view.

3D CT scan, lateral ceph, PA ceph,

OPG

Computer assisted tools helps to determine the osteotomy line.

As an additional tool, stereolithography model can be used.

Vectors of DO:

Combination of various factors determines the type of distractor to be used and its position on Maxillaand Mandible. The mechanical and biological forces act as key elements to determine the position of the appliance [38].

During active distraction , the force vector should be selected and controlled properly to achieve desired shape and function of Maxilla/ Mandible.

The morphology of the regenerating bone is influenced by biological factors, whicharises from the supporting neuromuscular envelope.

The mechanical forces under the clinician's control derives from their particular orientation towards skeletal anatomy, the application of intermaxillary elastics during the active distraction process, the activation of distraction devices and the intercuspation of dentition [2].

Vertical Device Placement:

This type of device rises theramus of the mandible in vertical dimension while activation changes occurin the direction of the device due to neuromusculature's nonlinear moulding effect on regeneration as it is formed. As a result of this the mandible rotates in anticlockwise direction and lower anterior occupy advanced position. The ramus that has undergone vertical distraction most often causes posterior open bite.Vertical lengthening of the mandibular ramus bilaterally causes anticlockwise uprighting of the symphysis . The increased prominence of the lower third of the face becomes evident when vertical distraction is combined with sagittal advancement of mandibular body. In association with vertical lengthening of mandibular ramus unilaterally, it also corrects chin position in transverse plane and cant correction of occlusal planein mandible[9, 39].

Horizontal Device Placement:

Horizontal device placement of the distractor is effective to attain the saggital projection of the body of mandible. The body of mandible is likely to rotate in clockwise direction, resulting in open bite in horizontal distraction.[40]. The reason behind open bite might be due to the role of suprahyoid musculature and distraction device. It was reported that the sagittal advancement of mandible can improve the tongue positionand patency of oropharyngeal airway[41]. In neonates, distraction of the mandible can be performed only when the child has life threatening airway problems .

Oblique Device Placement:

The horizontal and vertical dimensions of the mandibular body and ramus are increased by this form of positioning. This combines the effect of both horizontal and vertical device placement [9, 39].

Predistraction orthodontic Management:

It may involve correction of disharmonic occlusal plane,crowding and elimination of dental compensation and arch width coordination.Fixed orthodontic appliances are used for correction and once achieved, surgical hooks and passive rectangular arch wires are mounted to direct intermaxillary elastics during active distraction stage. Occusal splints might be needed in treating young child [9, 42].

Intermaxillay elastic during Active distraction:

These are utilized for altering the path of skeletal alteration and to adjust the effect of distraction on occlusal outcome.This elastic can be used in buccolingual or class III or II distraction during the active distraction process. The molding response of the regenerating new bone to the intermaxillary elastic occurs as the bones on either side of the regenerate has the ability to rotate around the pins of the distractor. After the period of consolidation (8 Weeks), following which active elastics and mechanical distraction are performed. In cases where the open bite is closed then elastics are worn during consolidation period [9].

Occlusion:

Rapid changes in occlusion are evident during the active mandibular distraction process. Occlusal interferences must be eliminated as it has an impact on intensity and path of distraction [43]. Neutral occlusal bite plate may be inserted to overcome the effects of occlusal prematurities.

The Distraction progress is monitored in relation to chin's position, oral commissure, level of occlusal plane, maxillary and mandibular dentition.

Over correction of the deforming might be required. The amount of over correction required depends on the estimated sum of post distraction growth that remains in the cranio facial skeleton[44].

After activation is completed the device is left in position until there is evidence of mineralization of the regenerating bone or cortical border is seen radiographically.

Post distraction orthodontics:

In case of unilateral distraction, the posterior open bite can be treated using bite plate. Transpalatal arch, lingual arches, intermaxillary cross elastics and palatal expansion device can be used to correct cross bite on contralateral side. It is also important to focus on preventing the relapse of correction of mandibular occlusal plane [9].

Indication:

Unilateral and Bilateral craniofacial microsomia

Developmental micrognathia

Treacher Collin's syndrome

Nager's syndrome

Craniofacial synostosis syndromes

Mid skeletal classII deformities

Skeletal correction of lower anterior crowding

Rapid canine expansion

Distraction ankylosed teeth

Contraindication:

Systemic condition or poor nutrition affecting normal morphology of bone.
Bone irradiaton.
Osteoporosis
Geriatric person with insufficient bone matrix and lack of soft tissue.

Advantages:

Safe and effective technique

Operating time and length of hospitalization is reduced.

Technique can be applied at younger age.

Reduced chances of relapse

Disadvantages:

Residual cutaneous scarring

Need for 2nd operation to remove the device

Complication:

Technical failure of distraction process

Injury to vital structure

Failure to guide the distraction process along the appropriate vector.

Infection.

Conclusion:

As one of the key therapies for the correction of several clinical conditions, distraction osteogenesis has developed. Distraction osteogenesis involving the cranial and facial skeleton has opened up considerable fresh recovery opportunitiesof extreme and moderate skeletal deformities. The function of orthodontist while planning the treatment in distraction osteogenesis is to consider the surgical and dental concerns. The technical developments have made the device smaller and more advanced than previous models.

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