

DISTRACTION OSTEOGENESIS - A REVIEW

<sup>1</sup> Venkata Naidu Bavikati

<sup>2</sup> Gowri Sankar Singaraju

<sup>3</sup> Prasad Mandava

<sup>4</sup> Vivek Reddy Ganugapanta

<sup>1</sup> Postgraduate student

<sup>2</sup> Professor

<sup>3</sup> Professor and Head

<sup>4</sup> Senior lecturer

<sup>1-4</sup> Department of Orthodontics, Narayana Dental College, Nellore, Andhra Pradesh, India.

**ABSTRACT:** Distraction osteogenesis (DO) one of the recent and most successful treatment option for various skeletal deformities. Initially it was mainly used for correction of axial skeleton, but its introduction to the craniofacial skeleton has revolutionized the mode of treatment of craniofacial deformities and congenital syndromes. Currently DO in dentistry have a wide range application starting from, rapid canine retraction, alveolar distraction, treatment of cleft palate, and correction of many mandibular disorders.

**KEYWORDS:** canine retraction, congenital syndromes, craniofacial, Distraction osteogenesis, Orthodontics.

INTRODUCTION

Malformations are common abnormalities in humans they may be congenital, acquired or due to mutations. Craniofacial region is not an exemption for these malformations. Jaw malformations can cause mastication difficulties, altered speech and early loss of teeth, disfigurement and dysfunction of the jaws. Maxillomandibular hypoplasia, facial asymmetry, and congenital micrognathia are common abnormalities in the craniofacial complex.<sup>1</sup>

Traditionally, the skeletal deformities were treated based on growth potential of the patient. In growing patient they can be treated using growth modification using functional appliance and orthopedic appliances. While in non-growing patients they are addressed via orthognathic surgery.<sup>1</sup> One of the limitations is the excessive stretch of soft tissue and muscles finally ending with higher risk of relapse. Many congenital deformities require such large musculoskeletal movements, which will not be accommodated by the soft tissues, leading to compromised function, and esthetics unless soft tissue procedures are performed.<sup>2</sup>

To overcome relapse from surgery many alternatives were developed like auto and allografts, guided bone and tissue regeneration and regenerative medicine. Distraction is one of the alternatives providing excellent outcomes.<sup>3</sup>

Distraction osteogenesis (DO) or callotasis (stretching of callus), is defined as a process of new bone formation between the vascularised surfaces of bone segments gradually separated by incremental traction. The main advantage of DO is not only the bone has grown but the

adjoining soft tissue, nerves and blood vessels growth thus avoiding the soft tissue relapse.<sup>4</sup> DO has become widely accepted as treatment modality in orthopedics for treating skeletal deformities and severe bony defects. Recently it has been broadly applied for treatment of skeletal defect and severe bony defect in craniofacial complex.<sup>5</sup>

HISTORICAL ASPECTS

Fauchard<sup>6</sup> in 1728 applied compressive and tensile forces to the craniofacial skeleton for expansion of arch. Wescott<sup>7</sup> (1859) first reported the application of mechanical forces on maxilla bones for correction of a crossbite. First clinical distraction was done by Codvilla<sup>8</sup> in 1905 to correct the limb length discrepancy. Ilizarov<sup>9</sup> (1988) conducted many studies and introduced technique for limb lengthening. It is initiated with corticotomy, and then distraction was started after 5 to 7 day latency period and bone segments separated at rate of 1mm per day. After completion of distraction consolidation was done until new bone was formed between the bone segments.

According to Wassmund,<sup>10</sup> Rosenthal (1927) using intra oral tooth borne appliance performed the first mandibular osteodistraction. The first clinical extra oral distraction was done by McCarthy<sup>11</sup> and colleagues (1989) using Hoffman Mini Lengthener in children with hemifacial microsomia and Nager's syndrome. Guerrero (1990)<sup>12</sup> developed midsymphysal mandibular widening using an intraoral tooth-borne hyrax-type device. Molina

and Ortiz- Monasterio<sup>13</sup> were the first to use bidirectional device for osteodistraction of the mandible.

Ortiz Monasterio and Molina <sup>14</sup>(1999) introduced a technique for synchronized mandibular and maxillary distraction using mandibular devices alone. In 1995, Cohen et al<sup>15</sup> performed first multidirectional midface distraction, using buried Lefort III midface advancement in 2 children with cleft lip and palate. Both cases had transverse expansion performed simultaneously with sagittal distraction.

### BIOLOGIC BASIS OF NEW BONE FORMATION

Novel bone formation begins with formation of reparative callus between the two bony segments divided by corticotomy. After the callus has initially formed, a distraction force is applied to these bone segments that periodically separates them leading to tension in callus, resulting in alignment of callus tissue parallel to force. After the desired amount of bone length is achieved, the distraction force is discontinued and consolidated to allow the new bone undergo maturation and remodeling. Distraction can be divided into 5 clinical stages<sup>16</sup>:

- (1) Osteotomy – surgical cut.
- (2) Latency – the duration from bone division to the onset of traction.
- (3) Distraction – the time period when incremental forces are applied.
- (4) Remodeling – time period for maturation and remodeling of new bone.

1. **Osteotomy:** An osteotomy is a procedure that divides the bone into two segments i.e., intentional fracturing of bone. Fracture triggers the healing process, which includes conscription of osteoprogenitor cells, followed by osteoinduction and osteoconduction. As a consequence reparative callus is formed between the fractured bone segments.

2. **Latency period :** The latency period is the period from bone division and application of traction forces. It represents the time endorsed for formation of reparative callus. The sequence of events occurring during the latency period is similar to that seen during fracture healing.

3. **Distraction period;** The distraction period is characterized by application of traction forces to the bone segments that has undergone osteotomy. Bone segments are gradually pulled apart, resulting in formation of new bony tissues within the progressively increasing inter segment gap.

4. **Consolidation period :** The consolidation period is the time between cessation of traction forces

and removal of the distraction device. This period represents the time required for complete mineralization of the distraction regenerate. After distraction ceases, the fibrous interzone gradually ossifies and one distinct zone of fiber bone completely bridges the gap.

5. **Remodeling period :** The period from the application of full functional loading to the complete remodeling of the newly formed bone. Both the cortical bone and marrow cavity are restored. Harvesian remodeling, representing the last stage of cortical reconstruction, normalizes the bone structure.<sup>14</sup> It takes a year or more before the structure of newly formed bony tissue is comparable to that of the preexisting bone.

**Factors affecting distraction osteogenesis:** The factors that determine the local mechanical environment at the distraction site include

**Type of osteotomy (corticotomy versus osteotomy) :** Both periosteal and endosteal structures are important for bone healing. Hence, corticotomy with preservation of intramedullary blood vessels is preferred. A comparison of different corticotomy techniques in distraction osteogenesis of canine tibia done by Paley (1990)<sup>17</sup> showed no significant differences between a true corticotomy technique and an osteotomy performed by multiple drill holes and osteotome.

**Timing of distraction (immediate distraction versus delayed distraction):** To optimize the response of osteogenic tissue to distraction, a latency period has been suggested for early callus formation. Different latency periods, ranging from 5 to 21 days, have been reported in clinical trials and animal experiments. On an average, a 5-day latency period whereas for younger patients, 2-day latency period is adequate. For older patients with poor vascular supply or bone quality, or when there is excessive intraoperative trauma to the periosteum, the latency period of 7 days is recommended.

**Rate and rhythm of distraction:** A rate of 1.0mm per day of distraction force is appropriate in most cases. In younger children, the rate is increased to 1.5 to 2.0mm per day. If bifocal DO is performed then the soft tissue can only support 1.0mm of distraction force applied to two sites, for a total of 2mm per day.

**Stability of fixation:** Stable fixation is important for adequate formation of microcolumns of bone during DO. Bending or shear forces seem to induce fractures of the microcolumns with local hemorrhage and resultant histologic cartilage interposition. Stable fixation which allows controlled axial compression or distraction is optimal (Paley et al 1990).<sup>17</sup>

**Indications**

Indications of DO Current usage falls into 3 broad groups as follows<sup>18</sup>:

**1. Lower face (mandible)**

- Unilateral distraction of the ramus, angle, or posterior body for hemifacialmicrosomia
- Bilateral advancement of the body for severe micrognathia, particularly in infants and children with airway obstruction as observed in the Pierre Robin syndrome
- Vertical distraction of alveolar segments to correct an uneven occlusal plane or to facilitate implantation into edentulous zones
- Horizontal distraction across the midline to correct crossbite deformities or to improve arch form

**2. Mid face (maxilla, orbits)**

- Advance the lower maxilla at the LeFort I level
- Complete midfacial advancement at the LeFort III level
- Closure of alveolar bony gaps associated with cleft lip and palate deformities
- Upper face (fronto-orbital, cranial vault)
- Advancement of the fronto-orbital bandeau, alone or in combination with the mid face as a monobloc or facial bipartition
- New use of distraction as a means of cranial vault remodeling by gradual separation across resected stenotic sutures

**3. Established indications for craniofacial DO include the following:****I. Congenital indications**

- Nonsyndromic Craniofacial Syndrome - Coronal (bilateral or unilateral) or sagittal
- Syndromic Craniofacial Syndrome (Apert, Crouzon, and Pfeiffer syndromes)
- Facial clefts, cleft lip and palate
- Patients with severe sleep apnea
- Hemifacialmicrosomia
- Severe retrognathia associated with a syndrome (eg, Pierre Robin syndrome, Treacher Collins syndrome, Goldenhar syndrome, Brodie Syndrome), especially in infants and children who are not candidates for traditional osteotomies
- Bimaxillary crowding with anterior-posterior deformity
- Bimaxillary deficiencies
- Asymmetry
- Mandibular hypoplasia due to trauma and/or ankylosis of the temporomandibular joint

**II. Acquired indications**

- Reconstruction of posttraumatic deformities
- Insufficient alveolar height and/or width

- Reconstruction of oncologic and/or aggressive cystic jaws defects
- Previously failed bone graft sites
- Insufficient soft tissue coverage
- Patient is not a candidate for a bone graft.

**MANDIBULAR DISTRACTION**

**Mandibular distraction can be unidirectional, bidirectional or multi directional.** McCarthy<sup>2</sup>(1989) was the first to clinically apply an external fixation Hoffman Uniplanar Device for mandibular lengthening. Molina and Ortiz-Monasteri<sup>13</sup> were the first to use bi-directional osteodistraction in the mandible.

**The Frankfurt Modular Distraction System:** It is a bi directional appliance consists of two limbs connected to an angulation joint. The angulation piece allows controlled rotation of the two limbs from 180° to 90° positions. Radial grooves on the inner surface of the angulation joint apply slight friction, thereby avoiding uncontrolled angular changes between the two limbs.

**MD-DOS device:** Mandibular Distraction with a Dynamic Osteosynthesis System (MD-DOS) device is used for mandibular lengthening in mandibular retrognathism. It was introduced in 1997.<sup>9</sup> The MD-DOS device consists of four major components: a posterior fixation unit (PFU), a spacer, a distraction unit (DU), and an anterior fixation unit (AFU).

**ROD distraction devices:** ROD technique was developed by Razdolsky et al.<sup>19</sup> It relies primarily on tooth borne distractors and provides a predictable, convenient, less costly method for correction of Class II mandibular skeletal deficiency compared with traditional surgical advancement. In addition, it is now possible to distract first and then decompensate the teeth by moving them into the new regenerate bone, thus eliminating the need for presurgical extractions of lower premolar in Class II cases with lower incisor crowding or protrusion.

**MAXILLARY DISTRACTION OSTEOGENESIS**

Maxillary deficiency can be due to cleft lip and palate, craniofacial syndromes, trauma and it is frequently associated with nasal, malar and infra orbital deficiencies. Many devices are designed, they are<sup>20</sup>

**Rigid external fixator ;** It is an adjustable rigid external fixation system for maxillary advancement. Polley and Figuero<sup>21</sup> suggested that only disadvantage of RED is that it requires adequate dentition for fixing intraoral appliance. The main advantages of the appliance were freedom of osteotomy design, distraction control, placement, compliance, removal, age of the patient it can be used in 5 to 6 years of patients also.

**Maxillary sagittal correction with face mask:** This technique was given by Molina and Ortiz Monasterio.<sup>13</sup> Heavy orthodontic arch wires are placed before surgery to avoid extrusion of the lower anterior teeth and undesirable compensations. Hooks are soldered to the maxillary arch before surgery to facilitate appropriate elastic traction facilitated by the use of Delaire facial mask.

**Premaxillary distraction osteogenesis with tooth borne appliance:** Bands are constructed on maxillary first molars, maxillary first premolars, and the maxillary left lateral. Retention bars of 0.7-mm wire are soldered to the buccal surfaces of the premolar and lateral bands. The bands are seated in the mouth, an alginate impression is taken, and the bands are seated in the impression material.<sup>22</sup>

A Hyrax expansion screw is placed parallel to the midpalatal suture and soldered to the first molar bands while the anterior extension of the screw rested on the cingulum of the anterior teeth. The molar and premolar bands are connected with 0.7-mm wires to reinforce the rigidity and retention of the appliance.

**Transpalatal distractor (TPD):** Mommaerts (1999)<sup>23</sup> has described TPD for maxillary expansion. The TPD applies expansion forces high in the palatal vault, therefore segmental tilting in the frontal plane is minimized. The bone borne device thus avoids orthodontic relapse during and after expansion. The disadvantage of this technique includes inclination of palatal shelves and the scar tissue formation in the distraction midline gap.

**Modular Internal Distraction System (MID):** The MID system was developed by Cohen et al (2001)<sup>13</sup>. The design allows the surgeon to fabricate custom internal distraction devices for virtually any region in the craniofacial skeleton. Depending on the distraction site and the osteotomy, any configuration of titanium plates can be attached to the distraction screw to permit unidirectional, and possibly bidirectional, internal distraction. The flexible activation cable is brought through a distant, inconspicuous stab wound in the hair, behind the ear, or even intraorally.<sup>13</sup>

**BONE TRANSPORT**

It was introduced by Ilizarov<sup>9</sup> for treating long bone defects resulting from trauma, oncologic resection, and other severe congenital or acquired deformities. This method involves the gradual movement of a free segment of bone across the osseous defect. Under the influence of tensional stress, distraction osteogenesis occurs and a typical bony regenerate is formed between the residual host bone segment and the trailing end of the transport segment.

After the transport bone segment reaches the opposite or residual target bone segment, compression

forces are applied at the docking site until the bony margins of the transport and target segments are fused.

**TYPES OF BONE TRANSPORTATION**

Ilizarov's classification of distraction-compression osteosynthesis and related Osteogenesis methods include:<sup>24</sup>

**Monofocal Bone Transport:** Monofocal osteosynthesis is used primarily in cases with small osseous defects of up to several millimeters, where healing of the two bone ends is abnormal, resulting in nonunion.<sup>24</sup>

In cases not requiring an increase in limb length, compression forces are applied and the "pathologic" tissue undergoes reparative remodeling which results in reparative callus formation and fusion of the bone ends. This is termed monofocal compression osteosynthesis.

If an increase in limb length is desired, distraction forces would be applied to separate the bone ends. As distraction continues, the pathologic tissues are gradually transformed into regenerate bone. This is termed monofocal distraction osteosynthesis.

In cases involving a defect that is several millimeters wide, and an increase in length is desired, the segments may initially be compressed to stimulate reparative callus formation, followed by distraction to increase limb length (compression-distraction osteosynthesis).<sup>24</sup>

**Bifocal distraction osteosynthesis:** During bifocal osteosynthesis, a free bone segment is created from one of the residual segments. This transport disk is then moved from the residual host bone segment through the defect towards the residual target bone segment.<sup>24</sup>

**Trifocal Bone Transport:** In cases with large bone defects, two transport disks can be created from both residual bone segments and simultaneously moved centripetally towards each other so that they meet in the center of the defect. It is usually characterized by two simultaneously formed distraction regenerates (bifocal distraction osteosynthesis) that are subsequently compressed (monofocal compression osteosynthesis) at the docking site in the center of the defect.<sup>24</sup>

**Distraction of periodontal ligament:** One of the recent techniques for accelerating tooth movement is interdental distraction osteogenesis followed by orthodontic tooth movement into the rapidly mineralizing bone regenerate.<sup>24</sup> Orthodontic tooth movement in this situation can be initiated as early as 1 to 2 weeks after completing distraction osteogenesis with a rate as rapid as 1.2 mm per week in the mandible and 3.5 mm per week in the maxilla.<sup>25</sup>

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

### ALVEOLAR BONE DISTRACTION

With the advanced miniaturized distraction devices, alveolar bone distraction has recently been established as a treatment modality for ridge augmentation.<sup>1</sup>

#### Types of alveolar distractions:

1. **Vertical Augmentation:** In vertical augmentation, the transport alveolar segment is translated vertically and the height of the alveolar ridge is increased. Most cases with an atrophic alveolar ridge would require vertical distraction only.<sup>25</sup>
2. **Horizontal Augmentation :** In horizontal augmentation, the transport alveolar segment is translated Horizontally, thereby increasing the alveolar ridge width.<sup>25</sup>

### EFFECT OF DISTRACTION OSTEOGENESIS ON SOFT TISSUE.

#### Effects of distraction osteogenesis on gingival tissue:

The gingival tissues underwent mild atrophic reactive changes caused by stretching, followed by a progressive restoration of normal anatomic structure. Considering the normal response of soft tissue to insult or injury, it appears that the gingiva underwent regeneration as opposed to repair. This is suggested by the inflammatory response that occurs during distraction, yet no breakdown in gingival continuity occurred and no scar tissue developed. Therefore it is believed that the primary mechanism by which gingiva undergoes adaptation during osteodistraction is by neohistiogenesis, with perhaps a small amount of mucoperiosteal migration.<sup>25</sup>

**Effect of distraction osteogenesis on periodontal ligament ;** The mechanism of PDL adaptation to gradual incremental traction during craniofacial distraction osteogenesis is similar to that during orthodontic tooth movement. The initial tension/pressure stresses that accumulated in the stretched/compressed periodontal ligament fibers activate adaptive mechanisms such as bone resorption, osteogenesis, and cementogenesis, thereby restoring the equilibrium in length and tension of the PDL.<sup>25</sup>

### CONCLUSION

Distraction osteogenesis has evolved as one of the primary treatment for the correction of many clinical conditions. An update of the distraction current principles and future research is essential for everyone. A brief and small review is provided in this article, in depth evaluation and understanding the procedures are important before implementing distraction osteogenesis.

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### Corresponding Author

**Venkata Naidu Bavikati**

Post Graduate Student,  
Department of Orthodontics, Narayana  
Dental College, Nellore, Andhra  
Pradesh, India.  
Ph no. 919700627451  
e-mail: [naidu1661@gmail.com](mailto:naidu1661@gmail.com)