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Review on distraction Osteogenesis: A boon to maxillofacial reconstruction

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Abstract
Distraction Osteogenesis represents a biologic process of new bone formation between the surfaces of bone segments that are gradually separated by incremental traction, and is also termed as callotasis, and osteodistraction. It is an advanced surgical procedure of regenerating new bone and associated soft tissues along with biological tissue adaptation and modification without the need of any grafting procedures. This article covers a wide range of applications and implications in the field of oral and maxillofacial trauma, pathology, reconstruction and orthognathic surgeries which are documented in the literature for distraction Osteogenesis.

Keywords: Distraction osteogenesis, callotasis, reconstruction, callus.

Introduction
Definition- Distraction Osteogenesis (DO) is defined as the new bone tissue formation between osteotomized bone segments which are gradually separated by exerting an external force with the help of various distracting devices. The resulting callus tissue in the distraction gap will eventually mineralize, and a new bridge of bone tissue is formed between the osteotomy edges of the original bone segments [1].

The history of distraction dates back to 1901, when for the first time Alessandro Codvilla performed the 1st limb lengthening procedure using an external skeletal traction after oblique osteotomy of femur. In 1951, Gavril Ilizarov performed the corticotomy for limb lengthening and postulated the popular Ilizarov's principle of (a) tension and stress effect on genesis and growth of tissues, and (b) influence of vascular supply and loading on shape of bone and joints [2-5]. Snyder (1973) did the 1st experimental distraction on dog's mandible[6]. Joseph McCarthy (1989) was the first to perform extra-oral distraction in human craniofacial region[7].In 1995, Polley and Figuera designed the rigid external distractor for mid face. Chin and Toth (1996) did the 1st alveolar distraction [8, 9]. Introduction of 1st simultaneous distraction was in 1999 by Molina and Ortiz Monasterio [10].

Types of Distraction
Depending upon the place where tensional stress is induced, distraction can be classified as
1. Callotasis
2. Physeal distraction

Physeal distraction is the distraction of the bone growth plate and can either be distraction epiphysiolysis- where the separation occurs at 1-1.5 millimeters per day resulting in bone formation, or chondrodiatasis, where the slow rate of separation less than 0.5 millimeters per day is done. On the other hand callotasis refers to gradual stretching of the reparative callus forming around bone segments interrupted by osteotomy or fracture [11-13].

"Callotasis"- Phases of Distraction

Table 1: Principle Stages of Distraction Osteogenesis [11, 12]

Phases	Mechanism and Biological Events
1. OSTEOTOMY	Mechanical dividing of bone- Recruitment of osteo-progenitor cells followed by osteo-induction
2. LATENCY (5-7 days)	Normal healing process occurs - from bone division to onset of traction. Organization of hematoma followed by bone end necrosis, angioinvasion and cellular inflammatory phase lasting 1-3 days eventually forming soft callus.
3. DISTRACTION	Application of traction forces to the osteotomized bone segments and gradually but progressively increasing inter segment gap. Tension stress stimulates cellular changes, angiogenesis and fibroblast proliferation by 2nd week of distraction.
4. CONSOLIDATION	Period from cessation of the distraction and removal of the device. This refers to the complete mineralization of the distraction regenerate and ranges from 8-12 weeks till the radiographic appearance of new bone between osteotomy gaps.
5. REMODELLING	Complete remodeling occurs 6 weeks after consolidation which includes haversian system widening and osteoclastic resorption.

Factors for Success of Distraction

- Biomechanical parameters [1]
  - i) Extrinsic or, fixator related
  - ii) Intrinsic or, tissue related
  - iii) Distraction device orientation
  - iv) Distraction vector orientation
- Biological parameters[1]
  - i) Lower power osteotomy with maximum preservation of osteogenic tissues and periosteal/ endosteal blood supply
  - ii) Adequate period of latency
  - iii) Stable but not rigid fixation
  - iv) Precisely calculated direction of distraction and vector
  - v) Optimal rate and rhythm of distraction
  - vi) Sufficient time for consolidation and remodeling
  - vii) Proportional relationship between mechanical loading of new bone and its blood supply.

Classification of the Distraction Devices [14]

Relation with the skin surface

A. External: These devices are attached to the bone percutaneously by pins which are connected externally to fixation clamps. The fixation clamps, in turn, are joined together by a distraction rod which when activated, effectively pushes the clamps and the attached bone segments apart, generating new bone in its path.

B. Internal: These devices are placed subcutaneously or within the oral cavity. They can be placed above i.e. extra mucosal or below i.e. sub mucosal or buried under the soft tissue. Devices attached to the bone are bone-borne; to the teeth are tooth-borne or attached to the teeth and bones are the hybrid type of distraction appliances [14].

Type of anchoring tissue

A- Tooth-borne: Supported only by teeth

B- Bone-borne: Anchored exclusively on bone tissue

C- Hybrid: Fixed to both bone and teeth

Number of vectors of movement

A- Unidirectional: Provides only 1 possible direction of bone movement

B- Bidirectional: Bone can be distracted in 2 directions

C- Multidirectional: Bone can be distracted in more than 2 directions

Types of distractor material

A- Bioresorbable devices: used in infants with congenital disorders

B- Non-resorbable, metallic devices [1]

DO Can Be Also Classified Into Three Types

Monofocal: A surgical fracture creates a "distraction gap" (the interval between 2 bone surfaces where the healing events will happen) for posterior traction of the separated bone segments.

Bifocal: A solution of continuity is treated by moving a surgically produced bone segment along the defect, from one extremity to the other. The moving segment is a "transport disc." This approach is used frequently for mandibular reconstructions after tumour ablation.

Trifocal: Two transport discs are created from the two extremities of defect and moved until they meet. Usually, major corrections are done with trifocal processes [19].

What is the Need for Distraction?

There are limitations with acute advancement of osteotomized bone segments due to (a) inability to stretch the soft tissues, (b) when large scale skeletal movements are required surrounding soft tissues cannot adapt to the new position resulting in degenerative changes, relapse and compromised function and esthetics, (c) in the mid face most deficiencies involve three planes; vertical, sagittal and transverse. Most orthognathic procedures can only correct these in one plane and are limited by the confining soft tissues and need for bone grafts and (d) orthognathic surgery can only be taken up after active growth ceases unlike the distraction which can be performed in infancy too [19].

Table 2: Indictions/ Applications of Distraction Osteogenesis and Contraindications

INDICATIONS
a. Lower face (mandible)
1- Hemifacial microsomia.
2- Bilateral advancement of the body for severe micrognathia, particularly in infants and children with airway obstruction as observed in the Pierre Robin syndrome.
3- Vertical distraction of alveolar segments [18]
4- Horizontal distraction across the midline to correct cross bite deformities.[1]
5- Transport distraction to generate a neo-condyle in severe joint ankylosis.[26]

b. Mid face (maxilla, orbits) [1] 1- Advance the lower maxilla at the LeFort I level. [27] 2- Complete midfacial advancement at the LeFort III level. 3- Closure of alveolar cleft associated with cleft lip and palate deformities. 4- Upper face (fronto-orbital, cranial vault). 5- Advancement of the fronto-orbital bandeau, alone or in combination with the mid face as a monobloc or facial bipartition.[27] 6- Zygomatic distraction in cases of deficient zygoma.
c. Craniofacial DO include 1- Nonsyndromic Craniofacial Syndrome - Coronal (bilateral or unilateral) or sagittal. 2- Syndromic Craniofacial Syndrome (Apert, Crouzon, Pierre Robin syndrome, Treacher Collins syndrome, Goldenhar syndrome, Brodie Syndrome and Pfeiffer syndromes).

Contraindications	
Severe infection	Immuno-compromised patients
Metal allergy	Blood coagulopathies
Severe osteoporosis	Bleeding disorders
Poor patient compliance	Poor bone stock availability

Biological Concepts and Variety of Distraction Procedures

1. Distraction Histiogenesis

One of the biggest advantages of distraction is the effect on the overlying soft tissue drape including mucosa, skin, muscles, nerves and vessels. One confining factor responsible for the relapse is the muscular resistance to large scale movement. It has been shown that muscles oriented in a plane parallel to the distraction force adapt with compensatory regeneration whereas muscles aligned in a plane perpendicular to the force showed decreased protein synthesis and atrophy. [23]

It is believed that distraction causes alteration of the sarcomere length and the ideal rate of distraction to avoid irreversible injury to muscle is 0.7 millimeters per day. However, to balance bone and soft tissue regeneration, an optimal rate of 0.75-1 millimeters is practiced universally today. Another structure that is affected is the nerve specifically inferior alveolar nerve in mandibular body distraction. Peripheral nerves can only be stretched upto 15-20 % of its total length without any chance if irreversible injury. [23]

2. Simultaneous Distraction

The efficacy of simultaneous distraction is best seen in the management of the most common congenital deformity of the facial skeleton – Hemifacial microsomia[27]. This deformity involving the 1st branch arch affects both hard and soft tissues. The main skeletal deformity is the mandibular hypoplasia or micrognathia[26] and it may also affects the maxillary growth, treatment should focus on increasing the bone stock of both bones and correction of the occlusal cant. The maxillary lefort osteotomy and mandibular ramus osteotomty are done and the device placed on the ramus along with the intermaxillary fixation. As the mandibular distraction occurs, it pulls down the maxilla on the same side thus lengthening the face on the same side. [27]

3. Transport Distraction

Gradual movement of a free segment of bone which is also called as transport disk, across an osseous defect which induces formation of a bony regenerate due to tensional stress between the residual host bone segment and the trailing end of the transport disk is called as transport distraction. On completion of the bridging, the leading edge of the transport disk is covered by fibro cartilage and this must be removed for the final union by compression of the two segments. Indications include mandibular continuity defects, calvarial defects, construction of a neo-condyle in TMJ ankylosis and cleft alveolus reconstruction. [25]

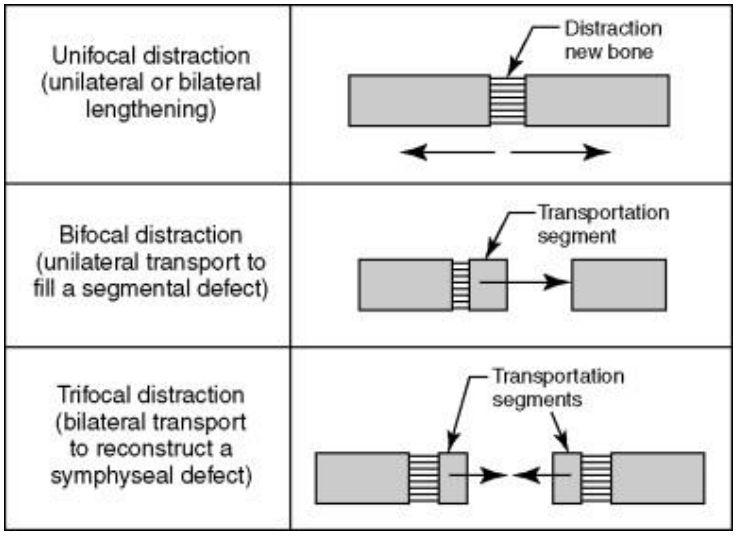

Fig 1: Types of Transport Distraction[17]

4. Alveolar Distraction

Alveolar ridge augmentation procedures in the past consisted of the soft tissue procedures like vestibule deepening and hard tissue procedures like bone graft, guided bone regeneration and alloplastic grafts for alveolar augmentation. It is indicated in atrophic alveolar process, segmental deficiencies of the ridge which compromise the implant placement, defects dueto removal of pathology, increasing height of the fibula graft [21-

[24, 28] and gradual shift of osseo-integrated implants. [15, 16, 18] A few contraindications include severely atrophic mandible, osteoporosis and advanced age.

Complications

Table 3: Complications Related To the Process of Distraction [1]

• **Potential Mistakes** 1. Iatrogenic 2. Primary- poor patient selection 3. Secondary – poor decisions while correcting a developing complication 4. Technical – improper fitting of distractor, improper distraction 5. Wrong activation	• **Potential Complications** 1. Regenerate malformation 2. Axial deviation 3. Soft tissue overstretching 4. Infection
• **Hardware Related** 1. Difficulty in device activation 2. Improper vector 3. Inadequate device length 4. Unstable device 5. Device deformation and breakage 6. Pin loosening	• **Hard and Soft Tissue Related** 1. Pain and infection 2. Hypertrophic scar 3. Cyst 4. Neuropraxia 5. Trismus 6. Premature ossification 7. TMJ ankylosis and degenerative changes 8. Fibrous union 9. Tooth follicle damage

Conclusion

Distraction Osteogenesis is becoming more valuable in the field of maxillofacial and reconstructive surgery and is increasingly being used for correction of cranio-maxillofacial deformities. Not only the bone increments but it is also very significant in increasing and helpful in the adaptation of the soft tissue drape. Distraction Osteogenesis enables correction of deformities earlier than osteotomy. The placement of a distractor is on the whole quite simple, complications are rare and the procedure does not require bone grafts. Having lots of advantages distraction Osteogenesis indication spectrum broadening can be anticipated.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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