International Journal of Innovative Research and Advanced Studies (IJIRAS)
Volume 5 Issue 6, June 2018

ISSN: 2394-4404

Distraction Osteogenesis: A Review

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Abstract: ***Rehabilitation of the alveolar ridges before placement of implants has become the norm for ideal ridges for the best possible treatment outcome. Alveolar distraction osteogenesis is a recently introduced surgical technique that is rapidly gaining widespread acceptance. It is a process of new bone formation between the surfaces of bone segments gradually separated by incremental traction. The application of osteodistraction offers novel solutions for surgical-orthodontic management of developmental anomalies of the craniofacial skeleton as bone may be molded into different shapes along with the soft tissue component gradually thereby resulting in less relapse. Therefore the aim of this review is to describe distraction osteogenesis in details.***

Keywords: Distraction, Osteogenesis, Dentoalveolar distraction

I. INTRODUCTION

Inadequate alveolar ridge/ridge deformity is a problem that is frequently encountered which can affect the esthetic & restorative outcome of implant & prosthesis. Therefore, rehabilitation of the alveolar ridges before placement of implants has become the norm for ideal ridges for the best possible treatment outcome. Alveolar distraction osteogenesis is a recently introduced surgical technique that is rapidly gaining widespread acceptance. It is a process of new bone formation between the surfaces of bone segments gradually separated by incremental traction. Distraction osteogenesis is a technique of applying controlled traction across the site of surgically produced bone disruption while it is healing. The mechanical forces are directed predominantly away from the site, and the technique takes advantage of the regenerative capacity of bone by creating and maintaining an active area of bone formation in the surgically created gap. The bone is lengthened along with it's envelop. Therefore the aim of this review is to describe distraction osteogenesis in detail.

Historical background:

- ✓ Dr. Alessandro Codvilla (1905): first limb lengthening procedure, using an external pin fixator & oblique osteotomy of the femur.
- ✓ Synder et al (1979): applied a surgical device for the osseous distraction of a dog mandible.
- ✓ McCarthy et al (1992): treated four cases of unilateral mandibular hypoplasia using miniaturized Hoffman device.
- ✓ Cohen et al.,(1995) were among the first to apply distraction osteogenesis to the midface in a patient with unilateral craniofacial microsomia.
- ✓ Block et al (1996): intraoral distraction device for ridge augmentation in animals.
- ✓ Chin & Toth (1996): use of distraction osteogenesis for site development prior to implant placement in humans.

II. CLASSIFICATION OF DISTRACTION OSTEOGENESIS

According To Their Bone Localization:

INTRAOSSEOUS – ACE surgical distractor
Leibinger Endosseous Alveolar Distraction system
EXTRAOSSEOUS - KLS Martin Distractor

According To Direction Of The Regenerated Bone

Vertical distractors
Horizontal distractors

Indications:

- ✓ Severe atrophy of edentulous ridge

- ✓ Segmental deficiencies of the alveolar ridge that compromise the implant placement esthetically or functionally
- ✓ Narrow alveolar ridges, where horizontal distraction can be applied.
- ✓ Gradual vertical movement of ankylosed teeth, when orthodontic displacement is impossible or has not been successful.
- ✓ Gradual vertical shift of an osseointegrated implant together with the surrounding alveolar bone.

ADVANTAGES

- ✓ No bone transplantation with the difficult resection of the bone graft.
- ✓ Minimal risk of infection because vital bone is distracted.
- ✓ Not only the bone but also the soft tissue is distracted, so that the new bone is permanently stabilized.
- ✓ The results of the distraction can be reproduced.
- ✓ Simple surgical procedure which does not essentially differ from standard osteosynthesis techniques used in OMF surgery.
- ✓ The distraction regenerate has neovascularity, which appears to be more resistant to infection than is the case with bone grafting.

DISADVANTAGES

- ✓ Require a second surgical procedure for removal.
- ✓ Soft tissue scars may develop at the pin tracts.
- ✓ Difficult to apply to small bone fragments.
- ✓ The range of movement is limited.

III. BASIC STEPS IN DISTRACTION OSTEOGENESIS

STEP I: OSTEOTOMY

It is the surgical separation of bone into two segments using an oscillating saw or fissure bur. This results in the loss of mechanical integrity, triggering fracture healing, recruitment of osteoprogenitor cells, cellular modulation (osteoinduction), establishment of enviormental template (osteoconduction). After distractor is fixed, osteotomy is completed and distractor is activated 2 mm. Bell et al., [11] demonstrated that marginal alveolar bone at interdental osteotomy sites had to be maintained in order to maximize bone formation within the regenerate tissue. It has been speculated that an increase in shear forces may provide greater stimulation of osteoblasts and ossification centers.

STEP II: LATENCY

It is the time between the osteotomy and onset of traction which represents the time required for the reparative callus to form. Callus formation is a response determined by osteoprogenitor cells originating in the periosteum and endosteum. Histologically, it involves gap healing and direct bone apposition. The Period is usually 5 days, but it is advised to wait 4 to 12 days. During this period histologically initial clot formed is converted at 3 days into granulation tissue which becomes increasingly fibrous due to the presence of collagen and increasingly vascular through the appearance of new capillaries. There is initiation of recruitment of mesenchymal stem cells from the bone medulla and adjacent periosteum.

STEP III: DISTRACTION PHASE

Distraction is the actual process of separation of the two bone ends by means of a mechanical device. Two basic principles are to be followed in distraction:

- ✓ *RATE*: the amount of separation that can be done per day is 1mm, and the total amount of distraction that can be achieved is around 10-15 mm.
- ✓ *RHYTHM:* denotes number of activations required for alveolar distraction. Two activations per day done.

This phase usually lasts 1-2 weeks, and the traction modifies the normal development of the regeneration process. A dynamic microenvironment is created with formation of tissue parallel to the distraction vector, Increase and prolongation of angiogenesis, increased proliferation of spindle shaped fibroblast-like cells, which present a phenotypic variation. This type of spindle-shaped cell is situated peripherally and throughout the vessels, producing more type I collagen parallel to the distraction vector.

STEP IV: CONSOLIDATION PERIOD

It is the period after completion of distraction which allows the mineralization of the newly formed bone predominantly by intramembranous ossification and presence of isolated islands of cartilage suggesting endochondral bone formation. In addition, focal regions of chondrocytes surrounded by mineralized bone are seen suggesting transchondroid bone formation. This period varies from 8 to 12 weeks.

STEP V: REMODELLING

It begins at the completion of distraction and continues through the consolidation phase. It may extend up to 1 year after completion of distraction. It is initially formed bony scaffold which is reinforced by parallel fibers of lamellar bone. Both the cortical bone and the marrow cavity are restored.

Histology of Distraction osteogenesis:

Panikarovski *et al*., performed the first significant histologic evaluation and demonstrated following zonal structure of the distraction which has two zones of mineralization with longitudinally oriented primary osteons, divided by a fibrous interzone with collagen bundles directed parallel to the vector of distraction.

Animal studies by Karp *et al*., reported current concept of five histomorphologic zones with four transitional areas between the zones. The five zones are: The central zone, the two paracentral zones, and the two proximal/distal zones. The four transitional areas are the two areas of vasculogenesis and the two areas of mineralization fronts. The central zone is the most cellular and most blastema-like. The transitional area of

mineralization front shows nascent trabeculae in perfect alignment with the line of tensile force. Karp *et al*., [14] observed longer and thicker bone trabeculae toward the center of the distraction gap at 14 days after the end of distraction and a continuity of bone bridges between the ends of the two original bones at 1 month. At 2 months after distraction, the initial gap was filled with mineralized bone and showed remodeling areas, mainly in dense cortical zones.

COMPLICATIONS RELATED WITH DISTRACTION OSTEOGENEIS

- ✓ Infection of distraction chamber.
- ✓ Fractures of transported/basal bone.
- ✓ Distractor fractures
- ✓ Premature consolidation.
- ✓ Consolidation delay & absence of fibrous union.
- ✓ Wound dehiscence.
- ✓ Slight resorption of the transported fragment.
- ✓ Distraction instability.
- ✓ Deviations from the correct distraction vector.
- ✓ Neurological alterations.

TREATMENT AND THE CONSEQUENCES OF THE COMPLIOCATION OF ALVEOLAR DISTRACTION

Complications	Treatment	Consequences
Fracture of transport segment	Appropriate preventive measures	Absence of bone formation
Difficulties in completing the osteotomy on lingual side	Use of appropriate instruments	Extended surgery time
Excessive length of threaded rod	Cut the rod	If not corrected interference with the occlusion
Incorrect direction of distraction	Care in positioning the distractor at the correct angle Take into account the effect of the lingual mucoperiosteum Use of orthodontic devices	Bone formation in the wrong direction
Perforation of mucosa by the transport segment	Smooth the extremes of the segment with a burr or rongeur	Lingual ulcer
Suture dehiscence	No attention is usually require, closure by second intention.	No sequelae observed
Bone formation defects	Guided bone regeneration	
Dysesthesia of the mental nerve	Application of titanium membrane during the osteotomy.	Gaps in the bone around the implant

Table 1

IV. CONCLUSION

Over the past 10 years, distraction osteogenesis has become increasingly popular. It is a first-choice solution to restore vertical mandibular deficiency due to previous resections, atrophies, or trauma. The Systems used in this technique are relatively simple to apply. It produces more rapid, predictable, and permanent outcomes compared with other regenerative techniques. The Complications related with this technique may be solved with simple treatments. Large skeletal discrepancies require such extensive bone movements that the surrounding soft tissues might not adapt to their new position, resulting in relapse or compromised function and esthetics. The application of osteodistraction offers novel solutions for surgical-orthodontic management of developmental anomalies of the craniofacial skeleton as bone may be molded into different shapes along with the soft tissue component gradually thereby resulting in less relapse.

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