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Distraction Osteogenesis-Recapturing the Normal Contour of Gingiva and Alveolar Bone - A Review

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Abstract: ***Distraction osteogenesis have important application in orthopedic therapy for correction of bone anomalies .Its use in the field of dentistry begin in late 20th century ,with its common application in maxillofacial reconstruction of bone anomalies which are either pathological or developmental in origin. Particularly in periodontics the preparation of implant site incase of vertical ridge deficiency can be done using distraction osteogenesis with more predictable results than any other technique. This review summarizes the background, biological principles;phases involving distraction osteogenesis and molecular mechanism behind distraction osteogenesis.***

Keywords: Alveolar distraction osteogenesis, vertical alveolar ridge deficiency, vertical ridge augmentation

1. Introduction

Bone is a dense, semi-rigid, porous, calcified connective tissue comprised of organic and inorganic component which can undergo remodeling[1]. It has the substantial capacity for repair and regeneration in response to injury or surgical treatment [2]. Alveolar bone loss is a commonly encountered condition in dental patient which may result from extraction of tooth, trauma, periodontal disease and non replacement of missing teeth[1]. These bone loss can present itself as either vertical or horizontal deficiency ofalveolar ridge and can be classified as (sieberts classification).Class I: Labiolingual loss of tissue with normal ridge height in an apico-coronal dimension. Class II: Apico coronal loss of tissue with normal ridge width in a labiolingual dimension. Class III: Combination labio lingual and apico coronal loss of tissue resulting in loss of normal height and width [3].

There are various surgical procedures available to treat alveolar ridge defects such as a)Guided bone regeneration b) Onlay block bone graft c) Inlay graft d)Bone splitting for ridge expansion e) Tissue engineering f) Distraction osteogenesis[1]. Treating a horizontal ridge deficiency is comparatively predictable whereas vertical ridge augmentation seems to be unpredictable Vertical ridge augmentation is commonly attempted using onlay block bone grafting and distraction osteogenesis .The requirement of an second surgical site for obtaining a autogenous block graft restricts the common usage of onlay block grafting technique for ridge augmentation. Distraction osteogenesis is a surgical procedure which was widely used for treating long bones. Over the last 2 decades the technique of distraction osteogenesis has been under development for vertical ridge augmentation of the mandible and maxilla prior to implant reconstruction.

2. Distraction Osteogenesis

Codavilla, in, 1905 was the first to perform extremity lengthening by the application of external traction but it was popularized worldwide later on by GaurilIlizarov, a Russian orthopaedic surgeon[4]. Synder et al in, 1973 was the first to apply the illizarov's principle of distraction osteogenesis for the regeneration of the osteotomized mandible [5].

Distraction osteogenesis is defined as the creation of neoformed bone and adjacent soft tissue after the gradual and controlled displacement of a bone fragment obtained by surgical osteotomy. Distraction osteogenesis is also called as callus, callotasis, osteodistraction or distraction histogenesis. It has the ability to increase the bone length. A corticotomy is used to fracture the bone into two segments , and the two bone ends of the bone are gradually moved apart during the distraction phase, allowing new bone to form in the gap. When the desired or possible length is reached, a consolidation phase follows in which the bone is allowed to keep healing .It has the benefit of simultaneously increasing bone length and the volume of surrounding soft tissues.

Bone regeneration during distraction osteogenesis is believed to occur in response to the longitudinal mechanical strain applied to the callus during healing. The exact mechanism by which strain stimulates bone formation remains unclear.It has been suggested that living tissues become metabolically activated by slow , steady traction, a phenomenon called "mechano-transduction", characterized by the stimulation of proliferative and biosynthetic cellular functions (Ilizarov,1989). Also, recent molecular investigations have indicated that the molecular signaling cascade plays an important role in the relationship between induced strain and bone regeneration .Although distraction regenerates the bone tissues by a process very different from that of fracture repair , the molecular signals that drive the regenerative process are similar and include the pro-inflammatory cytokines ,the transforming growth factor beta superfamily, and angiogenic factors[2].

3. Biological Principles

Based on clinical experience, Ilizarov discovered two biological principles called , "Ilizarov effects":

1) Tension-stress effect on the growth and genesis of tissues. This suggested that when two bone platesare separated, there is pressure acting on one side and tension on the other side of the device *in situ*.

2) The influence of blood supply and loading of shape of bone and joints[6,7].

Thus, due to these physiologic changes, the osteoblasts are stimulated to grow, thus helping in new bone formation.

4. Alveolar Distraction Osteogenesis

Alveolar distraction osteogenesis is a novel technique which is gaining acceptance in restoring the vertical bone discrepancy of alveolarbone.The process of alveolar distraction osteogenesis involves mobilization, transport and fixation of a healthy segment of bone adjacent to deficient site[8].

Surgical technique of alveolar distraction osteogenesis:
Distraction osteogenesis can be performed under general anaesthetia as well as regional anaesthesia.A full thickness flap is elevated buccally without exposing thecrest or lingual tissues. The horizontal or vertical osteotomies can be performed by fissure bur. As soon as distractor device is placed and osteotomies are completed, the device function tested for any interference. If there is no interference suturing is done. One week healing period is employed prior to initiation of distraction. A slow rate of distraction is done for older individual with proper tension stress .Continuous distraction will improve bone regeneration. Sometimes crestal resorption occur during consolidation phase. It is beneficial to over distract 2-3mm to compensate this resorption .As a minimum timeline for consolidation of the long bone literature has suggested 5 days/mm of distraction[9].

Phases of Distraction Osteogenesis:
Distraction osteogenesis consists of five sequential periods [10]:
a. Osteotomy
b. Latency
c. Distraction
d. Consolidation
e. Remodeling

Osteotomy:
Osteotomy is the surgical separation of bone into two segments. Osteotomy causes loss of mechanical integrity, triggering fracture healing, which involves recruitment of osteoprogenitor cells, followed by cellular modulation (osteoinduction) and establishment of environment template (osteoconduction).

Latency:
It is the period from bone division to the onset of traction and represents the time required for reparative callous formation between the osteotomised bone segments. Initially, there is formation of a hematoma, which is converted into a clot. This is followed by vasoformative elements leadingto capillary proliferation. Callus formation is a response determined by the osteoprogenitor cells originating in the periosteum and endosteum.

Distraction:
It is the time when a traction force is applied to bone segments and new bone or distraction regenerate is formed within the intersegmentary gap. The growth stimulating effect of tension activates the biologic elements of intersegmentary connective tissue. In this phase callus is stretched , a central fibrous zone, called the fibrous interzone forms[1].In between the fibrous interzone and microcolumn formation , a zone of highly proliferating cells, called the primary matrix or mineralization is formed.

Two major parameters of critical importance during this period are:
a)Distraction Rate
b)Distraction rhythm

- ***Distraction rate*** is defined as the numbers of millimeters per day at which the bone surfaces are stretched. An average distraction rate of 1-1.5 mm per day provesthe best clinical results[11] .

- ***Distraction rhythm***is the number of distractions per day, usually in equally divided increments to total the rate. Two activations per day are done, and the patient is usually admitted to the clinic and kept under observance. The pitch of the device is set in such a way that 1 mm of distraction is brought about after four turns of the screw (pitch of screw maintained at 0.25 mm or 0.5 mm).

Consolidation:
It begins when the traction force is discontinued and the desired amount of bone length has been achieved. This period allows mineralisation and the corticalization of the newly formed bone tissue prior to the distraction device removal.

Remodelling:
It is the time after the removal of the distraction device. Although this period usually continues for approximately 1 year after the completion of distraction, remodeling of the newly formed bone begins at the completion of distraction and continues throughout the consolidation period.

5. Molecular Mechanism

The role of growth factors and cytokines in Distraction osteogenesis:
Molecular signaling cascade plays an important role in the relationship between induced strain and bone regeneration. The cytokines are produced and function immediately after injury for limited timeperiod. Among these Interlukin-1 and-6 and TNF-alpha have been shown to play a role in initiating the repair cascade[2].

a) **Bone Morphogenic proteins:**
The bone morphogenic proteins are produced by mesenchymal cells, osteoblast and chondrocytes. These BMP accelerate the differentiation of the precursor cells onto chondrogenic osteogenic cells. BMPs main function is that to promote the formation of cartilage and bone.

b)**Transforming Growth factors**
Suppresses osteoblast maturation by delaying differentiation of osteoblast during the mineralization of distraction osteogenesis. These are produced by degranulated platelets after initial injury, which initiate callus formation[12].

c) **Interleukin-1, Interleukin-6:**
They induce a downstream response to injury by recruiting other inflammatory cells, enhancing extracellular matrix synthesis and stimulate angiogenesis.

d) **Vascular endothelial growth factor:**
It induces neoangiogenesis for distraction osteogenesis

6. Devices Used For Distraction Osteogenesis

ACE Surgical Distractors:
The intraosseous ACE distractor (Fig1) is made of titanium alloy and has three main component during active distraction. The distractor body engages the bony transport segments with external threads that are of the same pattern as that of a conventional 3.75mm oral implant. The Axial distraction screw is threaded through the distractor body and used for active distraction.

The Leibinger Endosseous Alveolar Distraction System:
That intraosseous LEAD System (Fig 2) consists of a 2mm diameter threaded rod, a threaded transport plate, a stabilizing unthreaded base plate. The transport plate and base plate are bent and fixed into place with fixation screw. Horizontal forces should not be applied more because of narrow nature of threaded rod; If excessive forces occur then bone resorption occur and rod may be displaced from transport segments

KLS Martin distractor;
The extraosseous track distractor (Fig 3) is made of titanium with microplates that have been welded on to sliding mechanism of the actual distraction screw.

7. Combination of Distractor and Oral Implant Devices:

Aprosthetically restorable distractor was introduced by SIS Trade systems. This distractor becomes osseointegrated and can therefore function as a loaded oral implant[13]. The use of distractor causes some complication like crestal bone loss etc. The Veriplant distraction device is also a combination of oral implant and distractor device.

Enhancement of Bone Formation During Distraction Osteogenesis
There are many modalities have been used to promote bone growth during Distraction osteogenesis. They are

a) **Mechanical Modulation:**
Researchers found that by increasing the frequency of distraction and decreasing the amount of lengthening at each interval, bone formation can be improved[14].

b) **Low intensity Pulsed Ultrasound:**
These induce new bone formation during distraction period.

c) **Electrical stimulation**

d) **Growth factors and Stem cells:**
Bone Morphogenic Protein, Angiogenic factor, recombinant human bone morphogenic protein-2, Platelet rich plasma enhance bone formation during distraction osteogenesis.

e) **Hyperbaric oxygen and intermittent parathyroid hormone** also induce bone formation

Pre-Requisite for Alveolar Distraction Osteogenesis:
a) A minimum of 6-7mm of bone height must remain above vital structure.
b) Atleast 4mm vertical defect of sufficient length must exist when measuring from height of adjacent bony walls to vertical depth of osseous defect

Small vertical defect of only one or two teeth tend to have a higher rate of complication when distracted and should be treated with conventional bone grafting technique [15].

Indications:
a) Reconstruction of posttraumatic deformities.
b) Insufficient alveolar height and / or width.
c) Reconstruction of oncologic and / or aggressive cystic jaws defects
d) Previously failed bone graft sites
e) Situation where there is insufficient soft tissue coverage
f) Patient is not a candidate for a bone grafting

Advantage:
a) It can be used in young patient
b) Simple and easy technique
c) This technique allows expansion of associated soft tissues
d) Permits larger movements
e) Shorter hospital stays
f) Reduced blood loss, operative time
g) Bone graft is not necessary

Disadvantage:
a) Second surgery needed to remove distraction device
b) Sensitive surgery
c) Pain will be present during distraction phase

Complication
The complication can be divided into intraoperative, intradistraction and post distraction complications. Intradistraction complication occurs during distraction. Post distraction occurs during splinting and removal of distraction device [5]. Compromised wound healing environment

8. Studies

There are many studies where distraction osteogenesis has been used for vertical ridge augmentation. *Matteo Chiapasco et al in* 2004— Compared the guided bone regeneration and distraction osteogenesis for their ability in maintaining over time the vertical bone gain obtained before and after implant placement. 11 Patient was treated by vertical guided bone regeneration and 10 by distraction osteogenesis. It was concluded that guided bone regeneration and distraction osteogenesis improve the deficit of vertically resorbed edentulous ridges, although distraction

osteogenesis is more predictable as far as the long term prognosis of vertical bone gain is concerned [16].

Esposito M, et al in 2009 –Evaluated the most effective technique for horizontal and vertical bone augmentation. The data collection was done by screening of eligible studies, assessment of methodological quality of trials and data extraction. It was reported that osteodistraction osteogenesis allows for more vertical bone augmentation than other techniques, which, on other hand, can allow for horizontal augmentation at any time[17].

9. Conclusion

Distraction osteogenesis has become increasingly popular as an alternative to many conventional alveolar ridge augmentation procedures. Distraction osteogenesis represents an exciting new development in ridge augmentation with several potential benefits, including less invasive surgery, the ability for earlier intervention, and the potential correction of more severe deformities with improved post treatment stability. However it is very important to consider surgical and dental concerns. These include osteotomy design location, selection of distraction device, distraction vector orientation, and duration of the latency period, the rate and the rhythm of distraction, duration of consolidation period and functional loading of regenerated bone. The exact role of distraction osteogenesis relative to conventional technique requires ongoing assessment. Improvement of the technique and of the devices used, with an adjusted protocol, could lead to a reduction in the number of complications.

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Figure 1: ACE Surgical Distractor
(CourtesyBradley S.Mcallister ,Perio 2000)

Figure 2: LEAD System (Courtesy-Bradley S.Mcallister , Perio 2000)

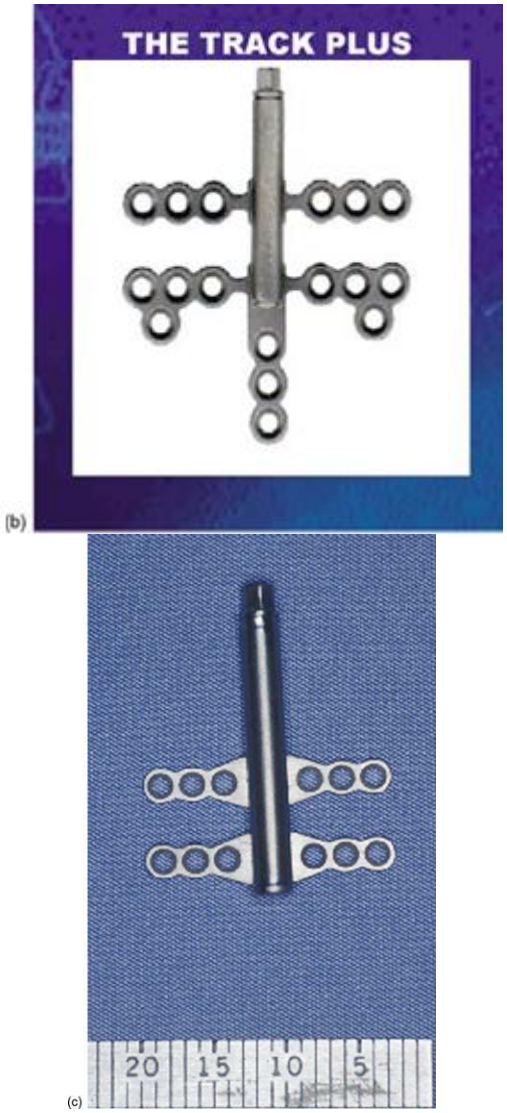

Figure 3: KLS Martin Distractor (Courtesy-Bradley S.Mcallister ,Perio 2000)