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RESEARCH ARTICLE

DISTRACTION OSTEOGENESIS AS A REMEDIAL TECHNIQUE FOR A ORO FACIAL DEFECT: CONCEPTS AND FUNDAMENTALS

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ABSTRACT

Distraction osteogenesis (DO) is a technique used in cranio-maxillofacial surgery to achieve high bone volume gain in all spatial dimensions based on the biological principle of bone callus mechanical elongation through slow and progressive separation under tension of two bone fragments surrounding the callus to achieve new bone formation. It falls under reconstructive techniques of correcting the orofacial defect. Current literature is an effort for an easy understanding about concepts and fundamentals of distraction osteogenesis and also understanding the alveolar distraction osteogenesis along with it's current scope.

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INTRODUCTION

The ridge resorption is the term used to describe the change which affect the alveolar ridge following tooth extraction and which continue even after healing of the extraction socket. The most significant feature of this healing process is that the residual bony architecture of the maxilla and mandible undergoes a life-long catabolic remodeling. The rate of reduction of residual ridge is maximum in the first three month and gradually trapped off. Rehabilitation of the defect resulted from residual ridge resorption is always being a challenge for maxillofacial surgeon because residual ridge resorption is in-evitable bio-physiological process. Various surgical techniques and biomaterials have been developed to make possible the successful reconstruction in resorbed alveolar bone. Multiple bone grafting techniques, natural and synthetic graft materials have been tested for this purpose.

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Residual ridge is a term used to describe the shape of the clinical alveolar ridge after healing of bone and soft tissues following tooth extraction. Post tooth extraction, a cascade of inflammatory reactions is immediately activated, and the extraction socket is temporarily sealed by blood clotting. The most striking feature of the extraction wound healing is that even after the healing of wounds, the residual ridge alveolar bone undergoes a lifelong catabolic remodeling. The size of the residual ridge is reduced most rapidly in the first six months, but the bone resorption activity of the residual ridge continues throughout life at a slower rate, resulting in removal of a large amount of jaw structure.

This unique phenomenon has been described as residual ridge reduction. Figure 1 resorption pattern in maxilla and mandible. RRR is greater in the mandible than in the maxilla, the reverse may be true in any given patient who comes for treatment. One must treat the particular patient, not the "average" patient.

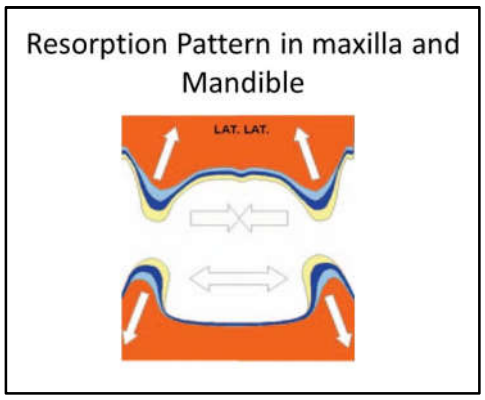

Fig. 1. Showing resorption pattern in maxilla and mandible

Distraction osteogenesis basically involves a minor surgical procedure to split bone, followed by rigid fixation of the distraction device. After a brief gap, the distraction device is activated, which pulls the split bone ends apart gradually. This is continued till the major deficiency in the bone gets corrected. This article aims to review the literature regarding distraction osteogenesis and alveolar distraction.

Corrective Techniques of Oro Facial Defect (Abdulsalam A. Zwiad, Dr. HEMANT GOEL, 2010)

Compensatory Technique:

e.g. Vestibuloplasty

Corrective Technique:

Regenrative technique:
Guided bone regeneration

Reconstructive technique:

- Vascularized free tissue transfer
- Block graft technique
- Natural Transplants and Synthetic Bone Replacement Graft Tissues and Biomaterials
- Regenrative cell therapies
- Growth factors
- Scaffold materials
- Distraction osteogenesis

Distraction Osteogenesis

Distraction Osteogenesis and bone regeneration are brilliant concepts which work basically by modifying normal bone healing process. Distraction osteogenesis (DO) is a technique used in cranio-maxillofacial surgery to achieve high bone volume gain in all spatial dimensions. Distraction Osteogenesis is based on the biological principle of bone callus mechanical elongation through slow and progressive separation under tension of two bone fragments surrounding the callus to achieve new bone formation (Jensen, 2002 and Rachmiel, 2001). The DO technique includes three phases: (i) the latency phase of 7 days, when soft tissues heal around the surgical site where the distractor is placed; (ii) the distraction phase, when the two bone fragments are separated incrementally at a rate of 0.5–1 mm/day; and (iii) the consolidation phase, when the newly formed bone mineralizes and matures (Davies, 1998).

Phases of distraction osteogenesis (Fig 3 and Fig 4): Clinically Distraction Osteogenesis consists of five sequential stages.

- Osteotomy
- Latency
- Distraction
- Consolidation
- Remodeling

Osteotomy: Distraction osteogenesis begins with an osteotomy, which divides the bone into two segments, there by resulting in loss of continuity and mechanical integrity. Ilizarov recommended a green stick fracture after cortectomy for distraction of limbs. Discontinuity of skeletal segment triggers an evolutionary process of bone repair similar to observed during fracture healing (Biology of implant osseointegration, 2007). Firstly, recruitment of osteoprogenitor cells occurs, followed by cellular modulation or osteoinduction and establishment of an environmental template called osteoconduction. So, a reparative callus is formed within and around the ends of the fractured bone segments. Later the callus undergoes replacement by lamellar bone which is more mechanically resistant. The greater blood supply in the facial skeleton makes this unnecessary, and in maxillofacial distraction osteogenesis, osteotomies generally are recommended. A complete osteotomy is more reliable for distraction of the jaws. In dento-facial patient, an extra oral approach with minimal stripping of periosteum and minimal tissue damage secondary to retraction may be desirable as opposed to an intraoral approach, which would require a much greater degree of dissection and increase problems with visualization of the surgical site (Fig. 2).

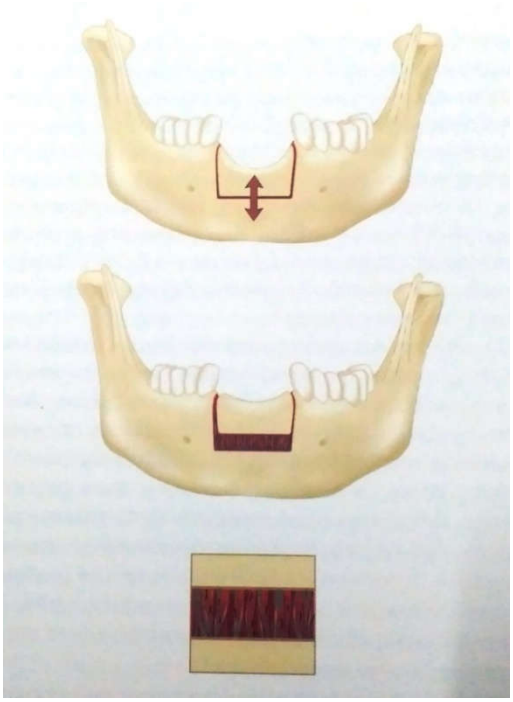

Fig. 2. Showing extra oral approach

Latency: The latency period is period from bone division to onset of traction and represents the time allowed for reparative callus formation. The sequence of events occurring during latency period is similar to that seen during inflammation and soft callus stage of fracture healing.[50] The stage of inflammation last from 1 to 3 days, at which time the bone

segments are surrounded by granulation tissue consisting of inflammatory cells ,fibroblasts, collagen and invading capillaries. During following stages of soft callus that last about 3 weeks, at this time granulation and loose connective tissues are converted gradually to fibrous and cartilaginous tissue. This phase is important for adequate maturation of callous, if callus tissue outgrows its blood supply, then cartilage, which temporary bridges the segments until the blood supply catch up. The soft callus phase of fracture healing begins 3-7 days after the injury and lasts 2-3 weeks; this time frame sets the boundaries of the latency period. Healing occurs more quickly in children. So in majority of cases, ideal latency period is selected as 5 to 7 days after the surgical injury.[9]

Distraction: During normal fracture healing the soft callus ossifies and becomes a hard callus which happens by replacement of the fibrocartilaginous tissues by osteoblasts. During osteodistraction the normal fracture healing is disrupted. The growth stimulating effect of tension activates the biologic elements of intersegment connective tissue. This includes:-

a. Prolongation of angiogenesis
b. Increased fibroblastic proliferation
c. Intensification of biosynthetic activity.
d. The shape forming effect of tension causes an alteration in the phenotypic expression of the fibroblasts. These 'distraction fibroblasts' give a hypertrophic appearance to the intermediate filament. These fibroblasts secrete collagen along the long axis of the distraction vector.
e. Between the 3rd and 7th day angiogenesis is seen .During this phase the rate of angiogenesis approximately 10 times higher than seen in normal fracture healing.[51]
f. During the second week of distraction primary trabeculae begins to form. Osteogenesis begins at the existing bone ends and progresses towards the center of the distraction gap. By the end of the second week the osteoid begins to mineralize. The mixture of fibrous and cartilage tissue within the interzone suggests that both membranous and endochondral process play an important role in distraction bone formation.
g. There are two important variables in the activation:
h. a) Rate or the amount of distraction per day
i. b) Rhythm or how frequently the device is activated.
j. Rate – If the rate of distraction is too small, there is a risk of premature consolidation. On the other hand, too great a rate of distraction may place induce stress on the soft callus, resulting in thinning of all dimensions in the mid portion of the regenerate distraction is found to be 1 mm per day.
k. Rhythm – Ilizarov recommended 0.25 mm four times a day activation. The most common protocol for maxillofacial is 0.5mm increments twice daily. It can be changes to 0.25 mm four times daily, in some patients, in whom pain occurs on 0.5mm twice daily activation.

Consolidation: The consolidation period is period between cessation of tractional forces and removal of distraction devices. Once adequate distraction has been obtained, the distraction device is left in place while the regenerate bone matures and remodels. After distraction ceases bone trabeculae continue to grow at the center of regenerate toward each other until they overlap and fuse.

Remodeling: In this phase the initial formed bony scaffold is reinforced by parallel fibers of lamellar bone. Both the cortical bone and the marrow cavity are restored. This process takes about one year get completed.

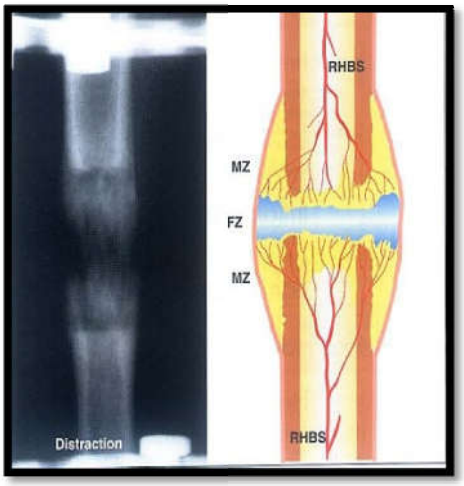

Fig. 4. Radiograph and schematic drowing of goat tibia showing three zonal structure of destraction regenerate

FZ-fibrous interzone
MZ-mineralization zone
RHBS-Residual host bone segment

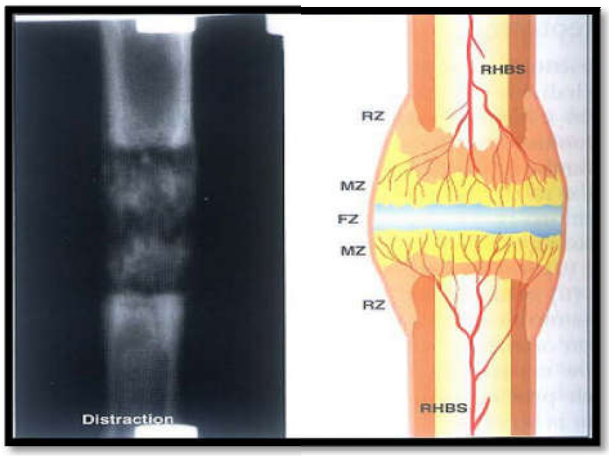

Fig 5. 5 zonal structure of distraction regenerate

FZ-radiolucent fibrous inter zone
MZ- two meneralization zone
RZ-two remodeling zone

Alveolar Distraction: The process of alveolar distraction osteogenesis involves mobilization, transport, and fixation of a healthy segment of bone adjacent the deficient site. A mechanical device, the alveolar distraction device, is used to provide gradual, controlled transport of a mobilized alveolar segment. When the desired repositioning of the bone segment is achieved, the distraction device is left in a static mode to act as a fixation device. Displacement of the osseous segment results in positioning of a healthy portion of the bone into a previously deficient site. Because the soft tissue is left attached to the transport segment, the movement of the bone also results in expansion of the soft tissue adjacent the bone segment. At the original location of the segment is left a regeneration chamber which has a natural capacity to heal by filling with bone. This propensity of the regeneration chamber to heal by filling with bone instead of fibrous tissue is a function of the surrounding, healthy cancellous bone walls and location within

the skeletal functional matrix. As a result of the gradual distraction, the alveolar housing, including the osseous and soft tissue components are enlarged in a single, simultaneous process (Distraction osteogenesis for maxillofacial surgeon).

Indications

Primary Indications

- Combined deficiencies in bone and soft tissue.
- Compromised wound healing environment.

Secondary Indications

Alternative treatments (Use Lower slide as example) Expansion of the alveolar housing for:

- Create site for dental implant placement
- Improve ridge esthetics for pontic
- Improve periodontal environment of adjacent teeth
- Expand alveolus for orthodontic tooth movement

Limitations

- Must have a minimum quantity of bone
- Transport and anchorage segment must have adequate strength to withstand forces of mobilization and transport.
- Expansion occurs only in the direction of transport.
- Patient must cooperate with activation process

Complications

- Fracture of transport segment
- Fracture of anchorage segment
- Premature consolidation
- Undesirable transport vector

Objectives of Distraction Process

- Expansion of bone and soft tissue volume
- Displacement of bone into deficient site[13]

Combining Distraction with other techniques

The distraction process may not produce the anatomical objective in a single step. Maxillofacial skeletal deformities are most often complex and three dimensional in nature. Alveolar deformities are not an exception. It is rare that the distraction process alone would result in an alveolar ridge of ideal shape and size. Usually additional osteoplasty is indicated (Distraction osteogenesis for maxillofacial surgeons). The distraction process results in the substrate, increased bone volume and expanded soft tissue, which makes creation of an appropriate alveolar morphology possible. Knife edge bony alveolar ridges are usually removed and discarded. If the ridge crest is slightly palatal to the ideal position, the labial cortex may require labial displacement. The distraction process has raised the medullary component of the alveolus allowing the labial plate to be displaced. The resultant increase in alveolar volume is accommodated by the expanded gingiva so that a non-tension soft tissue closure is possible (Kls martin alveolar distraction overview).

Current scope of alveolar distraction (KANNO, 2012)

Correction of maxilla-mandibular deformities.

a) Maxillary lengthening.
b) Mandibular lengthening.
c) Mandibular widening.
d) Lengthening of the hard palate.
e) Correction in other craniofacial areas.
f) Alveolar ridge augmentation

Conclusion

Alveolar distraction has proven to be an extremely versatile, superior, promising and reliable method for the correction of dento-facial deficiencies. Distraction osteogenesis provides a means whereby bone may be molded into different shapes to more adequately stable positions in treatment of dento-skeletal deformities and asymmetries. Successful reconstruction of maxilla or mandible requires 3-dimensional movement unlike long bone where simple elongation is adequate. Precise control of direction of distraction in maxilla and mandible is difficult due to complex muscle attachments, function and histology. The uses of distraction osteogenesis in treating both simple and complex deformities of the craniofacial skeleton are restricted neither by the mechanical configurations of the distraction device nor by the biological capacity of the human body but are actually only limited by the boundaries of our imagination. Simplification and refinement of the instrumentation will make this technique more familiar and realistic.

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