Review Article

Alveolar Distraction Osteogenesis and Implantology

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Abstract Distraction osteogenesis (DO) is a biologically based technique that enables new bone formation through the gradual separation of surgically created bone segments under controlled mechanical tension. In addition to osteogenesis, DO promotes adaptive changes in surrounding soft tissues, a phenomenon known as distraction histogenesis. Over the past few decades, distraction osteogenesis has gained prominence in maxillofacial surgery for the correction of severe skeletal deformities and for alveolar ridge augmentation prior to implant placement. This narrative review aims to summarize the biological principles, indications, contraindications, phases, devices, and clinical applications of distraction osteogenesis, with particular emphasis on its role in implant dentistry.

Keywords: Distraction osteogenesis, alveolar distraction, maxillofacial reconstruction, implant dentistry, bone regeneration

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INTRODUCTION

Distraction osteogenesis is defined as a biologic process of new bone formation that occurs between bone surfaces gradually separated by incremental traction.[1] Initially described in the mandible in Germany in the 1930s, the technique takes advantage of the sequence of events during normal osteogenesis after any bony injury; the initial injury site initially develops a fibrous callus, which subsequently ossifies.[2] The technique is initiated following an osteotomy and the application of controlled mechanical forces that stretch the reparative callus, leading to new bone formation. Simultaneously, the surrounding soft tissues undergo adaptive changes, termed distraction histiogenesis occurring in gingiva, blood vessels, ligament, cartilage, muscle and nerves.[3] Originally developed in orthopedic surgery, distraction osteogenesis has been successfully adapted for craniofacial and maxillofacial applications. Compared with conventional bone grafting, DO offers several advantages, including reduced donor site morbidity, improved soft tissue adaptation, and enhanced stability of regenerated bone.[4] This review discusses the principles and clinical applications of distraction osteogenesis in maxillofacial reconstruction and implant surgery.

MATERIALS AND METHODS

A narrative review of the literature was conducted focusing on distraction osteogenesis in maxillofacial surgery and implant dentistry. Articles published in peer-reviewed journals were reviewed to summarize biological concepts, clinical indications, techniques, and outcomes related to distraction osteogenesis. Emphasis was placed on alveolar distraction techniques relevant to implant placement.

Biological Basis of Distraction Osteogenesis

Distraction osteogenesis relies on the principle that gradual and controlled mechanical tension applied to healing bone stimulates cellular proliferation and differentiation.[5] Following osteotomy, osteoprogenitor cells are recruited to the site, where osteoinduction and osteoconduction occur. The stretched callus forms new bone in the direction of the applied force, while angiogenesis and soft tissue adaptation occur concurrently.[6]

Distraction osteogenesis is indicated in various conditions as mentioned below.[7]

- Severe maxillary and mandibular deficiencies in transverse, vertical, and anteroposterior planes
- Temporomandibular joint ankyloses
- Condylar hypoplasia

- Obstructive sleep apnea
- Mandibular segmental defects following trauma or tumor ablation
- Vertical and horizontal alveolar ridge deficiencies
- Cleft-related skeletal deformities

However, the Contraindications of distraction osteogenesis are [8]

- Geriatric patients with delayed bone healing
- Irradiated bone
- Osteoporotic bone
- Systemic diseases affecting bone metabolism

PHASES OF DISTRACTION OSTEOGENESIS: Distraction osteogenesis progresses through five clinically recognized phases [9]

Osteotomy Phase- A surgical osteotomy divides the bone into two segments, temporarily disrupting skeletal continuity. Preservation of periosteum and endosteum during this phase is critical to maintain vascularity and ensure successful bone regeneration.

Latency Phase- The latency phase is the interval between osteotomy and initiation of distraction. During this period, a reparative callus forms at the osteotomy site, providing the biological foundation for distraction.

Distraction Phase- Gradual mechanical traction is applied to separate the bone segments, usually at a rate of 0.5–1 mm per day. This controlled separation stimulates new bone formation within the distraction gap and promotes soft tissue adaptation.

Consolidation Phase- The consolidation phase follows cessation of distraction and allows mineralization and maturation of the newly formed bone. The fibrous interzone gradually ossifies to form a stable bony bridge.

Remodeling Phase- During remodeling, the regenerated bone adapts to functional loading and gradually attains structural and biomechanical properties similar to native bone. This phase may extend for one year or longer.

Distraction Devices- Distraction devices employed in the maxillofacial region are required to fulfill two fundamental criteria: effective transmission of distraction forces directly to the bone and adequate mechanical rigidity to permit proper osseous consolidation. Distraction devices used for craniofacial osteodistraction can be classified into two basic types: extra oral and intra oral devices.[10] [Table 1]

Extra Oral Devices	Intra Oral Devices
Unidirectional	Tooth-borne
Bidirectional	Tissue-borne
Multidirectional	Hybrid (tooth- and tissue-borne) devices

Table 1: Types of devices used for distraction osteogenesis

ROLE OF DISTRACTION OSTEOGENESIS IN IMPLANT DENTISTRY

Vertical Alveolar Distraction Osteogenesis

Was first used clinically by Chin and Toth in 1996.[11] Vertical alveolar distraction is indicated for vertical alveolar defects greater than 5 mm. Following osteotomy, a stabilizing plate is secured to the basal bone, and a transport plate is fixed to the mobilized segment. Gradual activation of the distractor moves the transport segment coronally. After a consolidation period, the distractor is removed and implants may be placed either simultaneously or in a staged approach. The size and vascularity of the transport segment are critical to prevent sequestration or late resorption. Bone distracted beyond the level of adjacent teeth may not be stable and requires careful planning.[12]

HORIZONTAL ALVEOLAR SPLIT DISTRACTION OSTEOGENESIS

Horizontal distraction is indicated when the alveolar ridge is too narrow for implant placement, commonly defined as a crystal width of less than 4 mm. Unlike conventional split-ridge grafting techniques, distraction osteogenesis allows ridge widening without the need for bone grafts. Implants are typically placed approximately six weeks after osteotomy, during early consolidation, when the regenerate consists of vascular woven bone favorable for Osseo integration. Excessive periosteal reflection should be avoided to prevent vascular compromise and late bone resorption.[13]

Distraction osteogenesis has emerged as a reliable alternative to conventional bone grafting techniques for alveolar ridge augmentation. The ability to generate both bone and soft tissue simultaneously offers a significant clinical advantage, particularly in implant dentistry. Although complications such as device failure, infection, or inadequate bone formation may occur, most are minor and manageable with proper technique and patient selection. Despite favorable outcomes reported in the literature, distraction osteogenesis remains underutilized. Limited familiarity with the technique and preference for traditional grafting methods continue to influence clinical decision-making.[14] Distraction osteogenesis has become an important technique in craniofacial reconstruction;

however, it is associated with several limitations. The quality of regenerate bone can be unpredictable, with risks of delayed consolidation, fibrous union, or relapse, particularly when distraction rate and vector control are suboptimal or in older patients. Although the technique allows gradual adaptation of surrounding soft tissues, excessive tension may still result in scarring, instability, or incomplete correction. Technical challenges include difficulty in achieving precise three-dimensional control, device-related complications such as loosening or breakage, and limited accuracy compared with conventional orthognathic procedures for fine skeletal adjustments. The prolonged treatment course, which includes latency, distraction, and consolidation phases, demands high patient compliance and can impose a significant psychological and social burden, especially when external devices are used. Additional concerns include scarring, occlusal discrepancies requiring secondary procedures, increased cost, and a steep learning curve for the surgical team, making distraction osteogenesis unsuitable for certain complex craniofacial deformities without adjunctive interventions.[15]

CONCLUSION

Distraction osteogenesis is a versatile and biologically sound technique for maxillofacial reconstruction and implant site development. When appropriately indicated and meticulously executed, it provides predictable bone regeneration with minimal morbidity. Greater awareness, improved device design, and better understanding of biological principles may enhance its acceptance as a routine treatment modality in implant dentistry.

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