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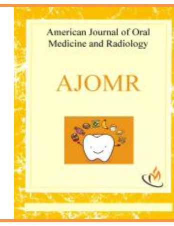

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DISTRACTION OSTEOGENESIS: THE NEW ERA OF TREATMENT

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ABSTRACT

Distraction osteogenesis is a surgical procedure used to reconstruct skeletal deformities and lengthen the long bones of the body. 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. Distraction osteogenesis has the benefit of simultaneously increasing bone length and the volume of surrounding soft tissues. The distraction technology has been used mainly in the field of orthopedics in humans. The results indicated that the process can be applied to correct deformities of the jaw for correction of dental defects. The technique is now extensively used by maxillofacial surgeons for the correction of micrognathia, midface, and fronto-orbital hypoplasia in patients with craniofacial deformities. The review presented shows an updated overview of distraction osteogenesis application in dentistry.

INTRODUCTION

Conventional orthognathic surgery and craniofacial reconstruction have experienced widespread success but in recent years the practice of surgery has been altered by an increased understanding and manipulation of biological systems. To law of tension-stress effect - Gradual traction of the tissues creates stress that activates tissue growth and regeneration. The shape and mass of the bone are influenced by the mechanical load and blood supply. Distraction osteogenesis of the craniofacial skeleton is based on this principle and has revolutionized the correction of major skeletal deficiencies [1].

It 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.

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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. The distraction device is held in place till new bone forms in the gap area [2,3].

Classification of Distraction Osteogenesis:

Depending on the place where tensional stress was induced, Distraction osteogenesis can be categorized as either callotasis, which means distraction of the fracture callus, or physeal distraction which is a distraction of the bone growth plate.

Distraction epiphysiolysis is a physeal distraction technique with a relatively rapid rate of distraction ranging from 1.0 to 1.5 mm per day. Rapidly increased tension at the growth plate produces a fracture. The subsequent separation of the epiphysis from the metaphysis leads to replacement of the growth plate by trabecular bone.

Chondrodiatasis involves a slow (approximately 0.5 mm per day) stretching of the growth plate without fracture. This stretching intensifies the biosynthetic activity of cartilage cells, resulting in accelerated osteogenesis [4.5].

Callotasis is a gradual stretching of the reparative callus that forms around bone segments interrupted by osteotomy or fracture.

Clinically, callotasis consists of three sequential periods: 1) latency, 2) distraction, and 3) consolidation. ***Latency*** is the period from bone division to the onset of traction and is the time required for callus formation. The ***distraction*** period is the time when gradual traction is applied and new bone, or distraction regenerate, is formed. The ***consolidation*** period allows maturation and corticalization of the regenerate after traction forces are discontinued.

Biology of Distraction

Bone formation in general may be through cartilaginous intermediate (endochondral ossification) or from recruitment and differentiation of primitive mesenchymal cells (membranous ossification) seen in distraction osteogenesis. As distraction healing is a highly dynamic cellular process, tensile strains are the leading stimuli for bone regeneration. Mechanical signals play an integral role in bone hemostasis. It is generally suggested that distraction forces leading to cellular deformation are signalled to the cellular genome through mechanotransduction. Nuclear proto-oncogene c-fos and c-jun are found to be unregulated at early stages of distraction and are related to the mechanotransduction and embryonic bone development [6].

Mechanotransduction

Mechanotransduction is an essential cellular mechanism for bone adaptation to mechanical loading. Bone cells can sense physical force signals, transform these physical stimuli into biochemical signals, integrate these signals into cellular responses of osteoblasts and osteoclasts, and then finally lead to appropriate changes in the architecture of bone.

Mechanotransduction can be categorized in an idealized manner into [7]:

(1) Mechanocoupling
(2) Biochemical Coupling
(3) Signal Transmission
(4) The Effector Cell Response

Mechanocoupling

It is the transduction of mechanical force applied to the tissue into a local mechanical signal perceived by a bone cell. Duncan and Turner [8] concluded that there are four types of mechanoresponsive structures in cells to sense a load, including integrins, the cytoskeleton, G-proteins and ion channels. Gi-proteins were confirmed to co-localize with stretch-activated calcium channel. Fluid flow can activate stretch-activated calcium channel and/or L-type voltage-activated calcium channel, and further influence the transforming growth factor (TGF)-β expression in human osteoblast-like cells

Biochemical coupling

It is the transduction of a local mechanical signal into biochemical signal cascades altering gene expression or protein activation. Most studies demonstrate that mechanical stress stimulates osteoblasts to release prostaglandin E2 (PGE2) [9] and adenosine triphosphate and to secret nitric oxide [10]. In the downstream effect of PGE2, anabolic TGF-β messenger RNA (mRNA) and protein levels were both elevated following fluid flow shear stress in human osteoblast-like cells.

Signal transmission

Transmission of signals from the sensor cells to effector cells, which actually form or remove bone. ERK is considered to be a potential mediator that acts as a signaling convergence point and its activation is a prominent load-induced response of osteoblasts. Mechanical stress regulates Runx2 activation through Ras/Raf-dependent ERK1/2 activation [11] ·Ras-Raf-mitogen-activated protein kinase-ERK cascade can be activated by nitric oxide in response to the stimulation of fluid flow or direct cellular deformation.

Effector cell response

In osteoblasts, physiological levels of strain were shown to result in an altered expression of bone-specific proteins, such as alkaline phosphatase, collagen I, osteopontin, osteocalcin, Runx2 and osterix. Aside from early response gene c-fos, early growth response factor 1, hemeoxygenase 1 and basic fibroblast growth factor can also be induced by mechanical strain. These activities lead to the onset of mineralization, proliferation and differentiation [12].

DISTRACTION PROTOCOL

Adequate exposure of the site is performed; distractor is fixed in desired position and vector by one or two screw on either side of marked osteotomy line on the bone. Distractor is then removed and the osteotomy completed through and through. Distractor is then repositioned back on to the predetermined place. Osteotomy is checked by activating the distractor for unhindered separation of bone. Distractor is deactivated leaving a small gap between osteotomized segments and closure of flap is then performed. Distractor is finally activated for few turns depending upon size of the bone.

Osteotomy

Osteotomy is the surgical separation of a bone in to segments. Osteotomy of bone results in a loss of continuity and the mechanical integrity of the bone. This process stimulates the healing process, which triggers the grouping of osteoprogenitor cells, continues production of bone cells and creates an environment that is suitable for bone conduction. The formation of new bone starts at the fracture ends.

The Incision to access the bone must be conservative in length, with minimal dissection of the periosteum to ensure good blood supply close to the osteotomy site. Osteotomy must be performed with copious irrigation to prevent heating. After distractor is fixed, osteotomy is completed and distractor is activated 2 mm. Bell et al [13]demonstrated that marginal alveolar bone at interdental osteotomy sites had to be maintained in order to maximize bone formation within the regenerate tissue. In rabbit tibias, Richards et al [14] reported a greater bone regeneration when the distraction followed an osteotomy of 30° compared with one vertical to the bone. It has been speculated that an increase in shear forces may provide greater stimulation of osteoblasts and ossification centers.

Latency period

The duration of latency is controversial for facial bone distraction osteogenesis. An experimental study by Glowacki et al [15] in 2004 using 20 minipigs, demonstrated that the bone showed the same degree of stability with a 0 or 4 day latency period. Other animals studies supporting this idea, showed equal bone strength and callus formation between a latency duration of 0 and 7 days in the sheep model. Troulis et al [16] stated that the same radiological density was noted in the pig model with latency periods of 0 and 4 days. A shorter latency period was suggested to be sufficient for the early stage of healing process because the craniofacial bones have a rich vascular supply. In a review of published studies of craniofacial distraction osteogenesis in 3278 patients, there were no difference between the application and non application of the latency period. Mandibular distraction was reported to have a latency period of 0-2 weeks Based on the above inconsistencies, the suggested optimal duration is between 5 and 7 days [17,18]. 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.

Distraction phase

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 [19,20]. This type of spindle-shaped cell is situated peripherally and throughout the vessels, producing more type I collagen parallel to the distraction vector. Cope et al [22] in his study on beagle mandibular elongation model reported that after distraction there is atrophy of epithelium with disappearance of papilla and loss of intercellular connection in granular and spinous layers with increased formation of dilated capillaries in lamina propria, mild inflammatory infiltrate and distribution of collagen fibres parallel to distraction vector. At 2 weeks of consolidation, he found mucosa to begin having normal appearance, conjunctive papilla begins to appear with increased epithelial thickness, and cells recovered normal architecture. Epithelium completely gained normalcy at 8 weeks.

Rate of distraction

Tension-stress law, as proposed by Ilizarov [21] postulated distraction rate of 1mm per day as the optimum rate for bone regeneration during distraction osteogenesis. Daily distraction aligns collagen fibres into parallel bundles that channel growing vessels and perivascular cells into longitudinal compartments[19]. While intermittent distraction results in microtrauma in the distraction zone due to relative large movement and higher distraction force. Vessels are disrupted and micro-haematomas are formed. The healing process is interrupted and has to restart after each activation of the distractor leading to delayed healing [22].

Increasing rate (2 mm/day)-nonunion, fibrous union, or bone weakening. Increasing distraction rate is associated not only with poor bone formation but also with severe soft-tissue contractures and nerve problems. Decreasing rate (0.5 mm/day) leads to premature consolidation. Fratzl et al [23] have shown that low strains lead to a straightening of collagen fibres, whereas higher strains induce a molecular gliding within the fibrils, resulting ultimately in the disruption of the fibrillar organization. Furthermore, Landry et al [24] have suggested that osteoblasts are removed from the injury site via apoptosis. Recent investigations into distraction osteogenesis have revealed that incremental traction of osteotomized mandibles results in an enhanced rate of apoptosis. As a result of hyperphysiological strain application, some osteoblastic cells in the newly formed tissue at osteotomy sites undergo apoptosis. In contrast, mandibles exposed to low magnitudes of strain display only minimal, if any, evidence of programmed cell death [25].

Rhythm of distraction

Illizarov suggested rhythm of distraction in incremants of 0.5 mm 2 times a day or 0.25 mm 4 times a day. Excessive expansion pressure may cause ischemia, leading to possible tearing of the soft tissue, nerve, muscle, and periodontal problems.

Stabilization/consolidation period

Consolidation is a period after the end of the distraction when the fragments are stabilized in their final position. To enable this distractor is not activated anymore and then used as a rigid fixation device. This period varies from 8 to 12 weeks. During this period mineralization of callus occurs in osseous gap.

INDICATIONS

This technique may be used for: Deformity correction, lengthening, widening, bone transport, and alveolar ridge augmentation of the mandible, midface and upper face, in both congenital and acquired conditions.

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 [26].

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.

COMPLICATIONS

Immediate complication includes damage to the primary or secondary dentition. While early includes infection, distractor loosening, paraesthesia, problems of compliance. Late complications are occlusal disharmony, incorrect vector, relapse, premature bony consolidation, facial nerve damage, condylar resorption, alterations in the temporomandibular joint. Injury through the distractor and fibrous union correlated to decrease in level of osteocalcin and type I collagen fibres [27].

CONCLUSION

Osteodistraction provides new horizons to the in treating dental arches by increasing arch length or circumference in severe skeletal discrepancy cases.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. It provides a means whereby bone may be molded into different shapes to more adequately address the nature of skeletal deformities and asymmetries. This phenomenon allows larger skeletal movements without the inherent risk of relapse. Many of the congenital deformities that require extensive musculoskeletal movements may be addressed with fewer procedures eventually achieving the same structural, functional and esthetic results commonly seen with modern orthognathic procedures. In addition, it offers the possibility of regenerating new alveolar bone before implant or fixed partial denture placement in patients with alveolar ridge atrophy.

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