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Distraction Osteogenesis.

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ABSTRACT

For centuries, many different techniques have been used in an attempt to modify bone growth, both in terms of amount & the direction. Orthodontists, for example, use intraoral & extraoral appliance to restrict growth of the maxilla in hopes of accentuating mandibular sagittal growth. There are several new approaches that have been developed to correct severe anterioposterior, transverse & vertical deformities of the craniofacial skeleton. One of these alternative approaches is the method of gradual bone distraction known as "Distraction Osteogenesis". (DO)It is a biological process of new bone formation between the surfaces of osteotomized bone segments that are gradually separated by incremental traction. "Distraction is not a technique in search of applications. Its use should be focused on conditions that are not well addressed by conventional techniques and where distraction gives a truly superior result."

Keywords: Distraction Osteogenesis.

INTRODUCTION

For centuries, many different techniques have been used in an attempt to modify bone growth, both in terms of amount & the direction. Orthodontists, for example, use intraoral & extraoral appliance to restrict growth of the maxilla in hopes of accentuating mandibular sagittal growth. There are several new approaches that have been developed to correct severe anterioposterior, transverse & vertical deformities of the craniofacial skeleton. One of these alternative approaches is the method of gradual bone distraction known as "Distraction Osteogenesis". (DO)It is a biological process of new bone formation between the surfaces of osteotomized bone segments that are gradually separated by incremental traction. Distraction force applied on to bone creates tension in the surrounding soft tissue initiating a sequence of adaptive changes termed "Distraction histiogenesis". It can be seen in different tissues including: Gingiva, Blood vessels, Ligament, Cartilage, Muscles & nerves.[1]

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HISTORY

A significant contribution in the development of DO was made by the Russian surgeon Gavril Ilizarov. As early as 1728, Fauchard described the use of the expansion. The 1st surgical procedure for the correction of a craniofacial deformity was reported in 1848, by Hullihen. In 1927, Rosenthal performed the 1st mandibular osteodistraction by using an intraoral tooth-borne appliance that was gradually activated over a period of 1month.Crawford, in 1948, applied gradual incremental traction to the fractured callus of the mandible. Kole, in 1959, described a method for surgically correcting an anterior open bite due to maxillary anterior deformity. In the same year Kole developed the rapid canine distraction method. Using this type of device in 1989, McCarthy & colleagues were the 1st to clinically apply extraoral distraction osteogenesis.[2-6]

Classification of distraction osteogenesis techniques:[1]

Classification is done on the basis where tensional stress was induced;

a) Callotasis: distraction of the fractured callus.

b) Physeal distraction: distraction of the growth plate of endochondral bones

--- Distraction epiphysiolysis.

--- Chondrodiatasis.

Distraction epiphysiolysis:

1st experimentally demonstrated by Ring (1958) & Palskin (1967) introduced the term.Involves relatively rapid rate of bone segment separation, ranging from 1 to 1.5 mm/day. The rapidly increased tension at the growth plate produces a fracture of the physis. The subsequent gradual separation of the epiphysis from the metaphysis leads to the replacement of growth plate cartilage by trabecular bone.

Chondrodiatasis:
Noble (1978) 1st reported the evidence of chondrodiatasis, when the constant tension was applied across the rabbit growth plate & De Bustian & colleagues introduced this term. Involves a very slow rate of bone segment separation (less than 0.5 mm/day). This allows stretching of the growth plate without a fracture. Tensional stress developing in a slowly stretched physis intensifies the biosynthetic activity of cartilage cells, resulting in accelerated osteogenesis.

Callotasis:
Callotasis is a gradual stretching of the reparative callus forming around bone segments interrupted by osteotomy or fracture. This name was derived from two words. Latin noun callum meaning scar tissue between bone segments and a Greek noun Taois meaning tension or extension.

Distraction histogenesis
Distraction forces applied to bone also create tensional stresses in the surrounding soft tissues leading to active histogenesis in different tissues like skin, facial blood vessels, nerves, muscles, ligaments, cartilage and periosteum. This procedure known as distraction histogenesis generally accompanies distraction osteogenesis.

BIOLOGICAL FOUNDATION

Clinically distraction osteogenesis consists of 5 sequential periods;

1. Osteotomy phase
2. Latency phase
3. Distraction phase
4. Consolidation phase
5. Remodeling phase

Osteotomy Phase:
Divides a bone into 2 segments, resulting in a loss of continuity & mechanical integrity, this is also referred to as a fracture.This Discontinuity of a skeletal segments trigger an evolutionary process of bone repair known as fracture healing.

Latency phase:
The duration from the bone separation to the onset of traction is the latency phase. The histological sequence during this period is similar to that seen during fracture healing. This period is very important for adequate maturation of the callus. The soft callus phase of fracture healing begins 3 to 7 days after the injury & lasts 2-3 weeks; this time frame sets the boundaries of the latency period. If distraction is begun too early, it result is decreased bone formation. If the latency period is too long, the distraction device may be unable to further separate the bony segments.

Distraction Phase:
It is characterized by the application of traction forces to the osteotomized bone segments. Bone segments are gradually pulled apart, tensional stress develops and normal process of fracture healing is interrupted. This stimulates changes at cellular & subcellular level.
Rate of distraction - 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.
Rhythm of distraction - Ilizarov recommended 0.25 mm four times a day activation..
Histological changes seen during distraction phase over a period of time-
During 1st week capillaries grow into fibrous tissue, their terminals actively invade the fibrous tissue, supplying the less differentiated cells that differentiate into fibroblasts, chondroblasts, or osteoblasts.
During 2nd week, primary trabeculae begin to form. Osteogenesis is initiated at the existing bone walls & progress towards the centre of distraction gap.
By the end of 2nd week, the osteoid begins to mineralize. During this time the distraction regenerate has specific zonal structures. This zonal distribution of newly formed tissues in the distraction regenerate remains until the end of the distraction period. In addition 2 new zones of primary trabeculae remodeling may become evident at the junction of the regenerate & host bone segments.

Consolidation phase:
Is that time between the cessation of traction force & the removal of the distraction device.
This phase allows the maturation & corticalization of the regenerated tissue. The fibrous interzone gradually ossifies & one distinct zone of fiber bone completely bridges the gap. As the regenerate matures, the zone of primary trabeculae significantly decreases & later is resorbed completely.

Remodeling phase:
It is the period from the application of full functional loading to the complete remodeling of the newly formed bone. The initially formed bony scaffold is reinforced by the parallel-fibered lamellar bone. Both the cortical bone & marrow cavity are restored. It takes a year or more before the structure of newly formed bony tissue is comparable to that of the preexisting bone.

Distraction histiogenesis:
The effect of gradual traction on Skeletal muscles. Muscle tissue generally responds in 2 ways to injury, depending on the degree of trauma.
By connective tissue replacement & sclerosis of ruptured muscle fibers.
By regeneration of ruptured muscle fibers.
The effect of gradual traction on Peripheral nerves.

Damage of the nerve during distraction may be

1) Direct (intraoperative manipulation during osteotomy, contact with fixation pins or screws during distraction device placement)

2) Indirect (compression by postoperative edema or hematoma, or constriction by the narrowing medullary canal due to bone in growth during distraction/consolidation).

20% lengthening has been recommended as a safe limit of distraction for preventing overstretching of peripheral nerves.

The effect of gradual traction on gingival tissue:

Soft tissue generally responds in 1 of 3 ways to injury, depending on the degree of trauma

1) If the insult is minimal & an inflammatory reaction does not take place, then only mild adaptive changes occur (hyperkeratinization of gingiva).

2) If the injury is sufficient to elicit an inflammatory reaction, a healing response is evoked, resulting in either complete restoration of tissue architecture (regeneration) or

3) Restoration of tissue continuity with scarring with distortion of normal tissue architecture (repair).

Indications of Distraction Osteogenesis in Craniofacial Region[7]

Craniofacial microsomia – unilateral on bilateral
Nager's syndrome
Treacher Collins syndrome
Pierre Robin Syndrome
TMJ ankylosis
Post traumatic growth disturbances
Developmental micrognathia
Midface hypoplasia (craniofacial synostosis syndromes)
Hypoplastic maxilla
Condylar regeneration
Correction of CI II skeletal discrepancies with underdeveloped manibles due to other cause.
Expansion of mandibular symphysis – brodie syndrome
Mandibular symphyseal distraction to resolve arch length discrepancies.
Ridge augmentation procedures
Maxillary development in cleft lip and palate.
Patients with prior bone grafting and before bone grafting
Non Union of fractures Ridge augmentation procedures
Surgically assisted rapid palatal expansion.
Rapid canine retraction

Advantages[8]

The process of distraction osteogenesis has a number of advantages over the conventional orthognathic surgery procedures in the treatment of maxillomandibular deformities or discrepancies. 2) Hospitalization and operating time is drastically reduced. It can even be performed on an outpatients basis. 3) Blood transfusions are generally not required during the placement or removal of the devices. There is no need for autogenous bone grafting.

Disadvantages and Limitations

Distraction osteogenesis cannot be useful in dysplasias due to excessive growth. It is treatment modality for deficiency problems only. 2) It is highly dependent on patient compliance. 3) The use of bulky extraoral appliances is psychosocially not very well accepted. 4) Scarring can occur if extraoral approach is used. 5) Risk of infection.

Preoperative Clinical Examination[9,10]

The function of the TMJ before distraction and the motor (muscles of mastication and facial expression) and the sensory (inferior alveolar, infraorbital) nerve functions of the patient are recorded. A transient limitation to opening can occur after distraction. Thus it is important to document mandibular excursion and original interincisal opening for use an objective goal during post distraction physical therapy.

Diagnostic records:

Photographs – Frontal, lateral, oblique, submental and intraoral.

Lateral and posteroanterior cephalograms

Three – dimensional cephalometrics

The landmarks seen in the 3-D cephalometric image include the orbital rims, Piriform aperture, maxilla, mandible and occlusal planes. The 3-D image can be rotated on the computer screen into typical views to assess the degree of craniofacial skeletal asymmetry and to plan the surgical distraction correction

Orthodontic Management of The Patient[11]

The role of orthodontics in treatment using distraction osteogenesis falls into three temporal phases:

Predistraction treatment planning and orthodontic preparation

Orthodontic/orthopedic therapy during distraction and consolidation

Postconsolidation orthodontic/orthopedic management

Presurgical Preparation

Orthodontic appliances are selected and treatment is initiated that is consistent with the overall goals of the distraction treatment plan. Dental malrelationships must be eliminated that would mechanically interfere with the movement of the tooth-bearing segment during the gradual distraction (eg; retroclined or extruded maxillary incisors, transverse maxillary deficiency).

During Distraction And Consolidation

Active orthodontics/orthopedics may continue throughout the distraction and consolidation phases.

This include the use of bands, brackets, distraction stabilization appliances, elastics, headgear, acrylic guidance appliances, maxillary expansion appliances functional appliance etc. This improves the quality of the surgical/orthodontic result by directing the tooth bearing segment towards its planned post distraction position. Interarch elastic traction applied during distraction has been shown to influence the vectors of distraction in the vertical, anteroposterior and transverse directions. The most important use of elastic traction during the active phase is to control laterognathism.

Post Consolidation Management

After consolidation, the distraction device is removed. Post distraction orthodontics/orthopedics is instituted at this time to accomplish the original treatment goals. Orthodontic treatment for growing children may need to take into consideration future distraction or orthognathic surgery. In nongrowing bilateral distraction patients, orthodontic finishing is completed at this time. In unilateral distraction the crossbite resulting from mandibular shift across the midsagittal plane may be corrected by a combination of transpalatal arches, lingual arches, intermaxillary cross elastics and a palatal expansion device. The open bite is at first maintained by the placement of a unilateral posterior bite plate.

Biomechanical Considerations[12]

Important biomechanical parameter of DO is the orientation of the distraction device & the resulting vector relative to the anatomic axis of the bone segments, occlusal plane, & desired direction of distraction. Biomechanical principle must be taken into account when applying distraction devices for craniofacial reconstruction, especially bilateral lengthening &/or widening of the mandible.

Alveolar bone distraction

Mucoperiosteal flap is elevated at the augmentation site & a U-shaped osteotomy of the alveolar bone is performed, forming the transport alveolar bone segment.Alveolar reconstruction is achieved by a bone transport technique whereby the transport segment would be moved using a special distractor.

Periodontal ligament distraction

Little has been done to enhance the rate of tooth movement because of the resistance offered by the alveolar bone for tooth movement .A modification of DO technique, wherein the interdental bone is undermined after tooth extraction, but prior to tooth retraction, have been shown to produce rapid tooth movement.

Regional Accelerated Phenomenon (RAP):

Osteopenia can be induced by surgically removing select portions of the alveolar cortex. Osteopenia softens bone and allows for more rapid tooth movement by orthodontics.

Rapid canine distraction

Before premolar extraction all teeth are bonded & molars are banded. Molars & 2nd premolars are anchor units.This also causes a decrease in the mechanical strength of canine PDL, thereby facilitating its tooth movement during distraction.This procedure provides differential changes in cellular activity, PDL strength, & a differential initiation of the lag period between the anterior teeth & anchor unit.

Distraction protocol[13]

Distraction device is activated 0.35 mm a day, twice daily. Canine has to be moved into the extraction socket within the 1st 2 weeks, other wise root resorption increase & anchor unit starts moving forward.

Distraction Devices[14]

Distraction devices can be Extraoral or intra oral

Depending on direction

1) Unidirectional distractor
2) Bidirectional
3) Multiplanar or Multidirectional distraction device

Depending on the location

Mandibular
Maxillary & midfacial
Craniofacial
Alveolar ridge
Periodontal ligament distraction
Mandibular distraction devices

Extraoral Distractors

External devices are attached to the bone by percutaneous pins connected externally to fixation clamps. The fixation clamps, in turn, are joined together by a distraction rod that, when activated, effectively pushes the clamps & the attached bone segments apart, generating new bone in its path.

Disadvantages of external devices

Patients are apprehensive about wearing bulky devices due to social inconvenience & the potential permanent facial scars. Pin tract infections.

Internal Distractors

The initial development of intraoral mandibular distractors progressed into 2 directions;

1) iniaturization of external distraction devices
2) modification of available intra oral orthodontic expansion device

These devices can be placed either submucosally or extramucosally.

They may be tooth borne, bone borne, or hybrid.

Tooth borne appliances:

1. Razodolsky Osteogenesis Device
2. Multiaxial intraoral distraction of the mandible:

3. A new spiral distractor for mandibular osteodistraction

Maxilla & Midface distraction[15]

Indication

Maxillary hypoplasia in vertical, horizontal, & vertical dimensions .Anteroposterior (AP) discrepancy, Flattened facial middle third .Absent or aberrant dental conditions with Class III malocclusion, moderate anterior cross bite, deep over bite and partial or total posterior cross bite.

There is an increased tendency for relpse (greater than 20%) with traditional lefort surgery.

Distraction Devices

1) Molina and Ortiz-Monisterio reported using an orthodontic face protraction mask combined with a Le Fort I osteotomy to achieve distraction osteogenesis.

2) Polley realized that the face mask with elastics was not sufficiently rigid . They developed an adjustable rigid external fixation (RED) system for maxillary advancement.

3) Maxilary advancement combined with posterior palate reposition via distraction osteogenesis

4) Maxilary advancement combined with posterior palate reposition via distraction osteogenesis

5) SARPE (surgically assisted rapid palatal expansion)

Complications of Craniofacial Distraction Osteogenesis Can Be Divided Into 3 Groups:

1) Intraoperative complication: includes bleeding problem, nerve damage, less than optimal bone split, device placement complications.

2) Intradistraction complications: includes pin infections, pin loosening, device loosening & dislodgement, pin tract formation with subsequent scarring, inappropriate distraction vector, paresthesia, trismus, premature consolidation, cyst formation.

3) Postdistraction complication: failure to achieve the planned result is the most common complication associated with the post distraction period. Other complications include development of malocclusion, open bite, early relapse & poor growth after distraction.

CONCLUSION

"Distraction is not a technique in search of applications. Its use should be focused on conditions that are not well addressed by conventional techniques and where distraction gives a truly superior result."

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