JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

Maxillofacial Distraction Osteogenesis

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Abstract: Many traditional orthognathic surgical techniques are being replaced with Distraction Osteogenesis (DO) in the maxillofacial bones. This review includes recent research on the biology and biomechanical foundation of DO, as well as its benefits and drawbacks, and also unique concerns for maxillofacial distraction. The osteogenesis of intraoral mandibular distraction, maxillary and midfacial distraction, and alveolar distraction are all covered. Sutural expansion/maxillary protraction osteogenesis and orthodontically stimulated periodontal osteogenesis, which are similar to physeal osteogenesis, are also discussed in this review. Improved knowledge of the bio-molecular processes that drives DO might lead to the development of tailored treatment that utilises molecular mediators, growth factors, or stem cells to boost bone regeneration efficiency and quality in the near future.

Introduction: Distraction osteogenesis was originally implemented to solve skeletal and soft tissue abnormalities following a fracture or injury by elongating the long bones. The scientific rationale and clinical usefulness of distraction for extending long bones in the limbs were described by Ilizarov.[1] DO in the maxillofacial complex is also becoming a popular replacement for several traditional orthognathic surgical treatments. Distraction methods gives additional therapeutic options for an individual with moderate to severe anomalies of the maxillofacial bone. The first evidence of distraction of the maxillofacial skeleton was published by Malevez Ch et al. in 1984.[2] Since then, distraction has been employed effectively in the mandible,[2,3] maxilla or midface,[4] zygomatic arch,[5] and mandibular condyles.[6] In the last two decades, the application of DO in the craniofacial skeleton has progressed. The procedure is most commonly used in situations of severe hypoplastic maxillofacial bones; in maxillofacial asymmetry, such as hemifacial microsomia;[3,7] and in the lengthening of severe hypoplastic mandibles, such as Pierre Robin or Treacher Collins syndromes, which can lead to obstructive sleep apnea.[7,8] Hypoplastic maxilla in cleft lip and palate patients is another reason for distraction.[9,10] This review analyses and contrasts the various DO procedures employed in the craniofacial skeleton. Since there is so much study on DO, this review is thus only concentrated on current findings.

DISTRACTION OSTEOGENESIS: BIOLOGICAL AND BIOMECHANICAL CONSIDERATIONS.

Biological considerations: The goal of distraction osteogenesis is to influence the bone healing process by extending an osteotomized region before calcification to induce the synthesis of more bone and soft tissue. A soft callus is forcibly stretched to induce new bone formation. After distraction osteogenesis, the bone healing process is similar to that of any other bone fracture. Distraction osteogenesis, on the other hand, disrupts the normal fracture healing process by applying traction to the soft callus over time. The best outcomes are obtained when the distraction is conducted within a few days of early healing and callus development, and the segments are separated at a pace of 0.5 to 1.5 mm per day,[11,12] according to studies.

In both orthopaedic and craniofacial surgery, distractions conducted in this manner have proved helpful for bone lengthening. Although most new bone production (distraction regeneration) is direct intramembranous bone development, certain localised cartilage areas may occur. The regenerated bone is moulded into mature bone over time.[13] Mechanical stimulation causes biological reactions that aid bone healing in progressive bone distraction. A series of biological processes, including pluripotent cell differentiation, angiogenesis, osteogenesis, bone mineralization, and remodelling, help to rebuild bone.[14,15] Gradual bone distraction has been shown to be beneficial in the regeneration of maxillofacial bones in animal experiments, and it is currently widely used in clinical practise.

The actions of inflammatory mediators (cytokines, including interleukin-1 and IL-6), bone morphogenic proteins (BMPs, including BMP-2, BMP-4, and BMP-6) and angiogenesis mediators drive the DO process.[15,16] The osteotomy stage, the latency stage (the time from bone division to onset of traction during which reparative callus forms), the distraction stage (the time from application of gradual traction to formation of new bone), the consolidation stage (the time from discontinuance of traction forces until maturation and corticalization of regenerated bone), and the remodelling stage (the time from discontinuance of traction forces until remodelling of regenerated bone) are the five clinical stages of DO.[17]

Biomechanical considerations: Several variables must be considered while choosing and placing the distraction device. When situating the distraction appliance, the biological and mechanical forces that form the regenerated bone are the most important factors to consider. The surrounding neuromuscular membrane generates biological factors that influence the shape of regenerated bone. By adapting the distraction devices to skeletal anatomy, employing inter-maxillary elastics during the active period of distraction, and regulating the intercuspation of the dentition, the physician can optimise the mechanical forces. The doctor must carefully evaluate the potentially enormous implications of forces produced by both biological and mechanical systems and predict their effects while preparing the distraction technique.[18]

ADVANTAGES AND DISADVANTAGES OF DISTRACTION OSTEOGENESIS

The potential advantages of distraction include: (1) its gradual effects on the bony skeleton as well as associated soft tissues like skin, subcutaneous tissue, and muscles pertaining to mastication and facial expression, (2) the larger potential movement it can achieve compared to traditional orthognathic surgery, and (3) its potential use for correcting a structural deficiency in the jaw bone at a young age. The biggest problem is that it is impossible to manoeuvre precisely. Distraction, for example, can shift the mandible or maxilla forward, but it can't attain a perfect pre-planned position for the jaw or teeth, which necessitates an orthognathic treatment.[19] Patients with craniofacial disorders who require early intervention to achieve significant lengths of mobility and do not require a very accurate repair of the jaw relationship are the prime choices for distraction of the jaw. Early therapy, on the other hand, is unlikely to result in normal development of the distracted region, necessitating further orthognathic surgery or a second round of distraction. The technique's second main drawback is the cutaneous scarring caused by the transcutaneous fixation pins. The recommended technique for the osteotomy and pin insertion is an intraoral technique if scarring is a serious issue.[20]

MAXILLOFACIAL DISTRACTION: SPECIAL CONSIDERATIONS

Distraction of the jaws, in contrast to distraction of the limbs, necessitates many particular considerations: (1) facial proportion and aesthetics increase the complexity of movement required in bony segments of the jaw; (2) different areas of the jaw may substantially differ in the shape of the bones, complex muscle attachments, function, and histology; (3) different areas of the jaw may significantly differ in bone developmental patterns, e.g., membranous bone in the jaw substantially differs between the mandible and the maxilla; (4) after early childhood, dental occlusive therapy is used to treat dental occlusive disease.[20] For sustained outcomes, maxillofacial retraction also needs several days of latency, several weeks of active lengthening, and many months of integration until mature lamellar bone is created. The requirement to wear distraction devices for up to many months may cause challenges with compliance, particularly in patients who must wear unpleasant external equipment.[21-24]

Intraoral distraction devices are now used all around the world because to developments in dental treatments and biomechanical engineering. These intraoral bone-borne distraction devices have reduced the necessity for large and unwieldy extraoral distraction devices, as well as their numerous drawbacks, such as external scarring, pin tract infections, nerve or tooth bud damage, and poor patient compliance.

MAXILLARY AND MIDFACE DISTRACTION

DO for Maxillary widening:

SARPE (surgically aided rapid palatal expansion) is the most common therapy for individuals with transverse maxillary insufficiency.[25,26] During the post-retention phase, however, SARPE has a significant relapse rate.[27] The mini-screw implant-assisted rapid palatal expansion (MARPE) treatment is the most reliable and stable method for addressing maxillary skeletal transverse abnormalities.[28,29] Adult patients with constriction and severe crowding in the maxillary arch can benefit from the MARPE. Implant stability, parallel expansions in the coronal plane, and bone-borne palatal expansion are all improved by bicortical hard palate anchoring.[30,31]

The MARPE technique not only separates the midpalatal suture without surgery, but it also increases the maxilla and associated craniofacial tissues. The surrounding craniofacial structures, including the zygoma and nasal bone, are widened as the circummaxillary sutures are opened. The usage of MARPE for nonsurgical orthopaedic expansion in adult patients is predicted to expand in the future because to its reduced cost and risk compared to alternative surgical treatment options.[32]

DO for Maxillary lengthening:

Children with craniofacial disorders (e.g., Crouzon and Apert syndromes), cleft lip and palate, hemifacial microsomia, and midface hypoplasia from different causes have all benefited from DO. An external or internal gadget can be used to divert the midface.[7] If the patient can endure an external device, the distraction process can be improved in three dimensions. Cranial fixation using a rigid external distractor (RED) device has also been found to be successful.[4] Although both external and internal approaches can be employed, the majority of accessible devices, like those used in mandibular applications, are unidirectional. The use of distraction to repair maxillary and midfacial abnormalities will almost probably rise as new bidirectional and multidirectional devices become available.[33]

When compared to miniplates, the MARPE opens the circummaxillary sutures and the skeletal miniscrew implants function as an orthopaedic anchoring device in producing advantageous maxillary protraction procedures. The MARPE treatments might potentially be used in adult patients with nonsurgical maxillary protraction.[32]

INTRAORAL MANDIBULAR DISTRACTION OSTEOGENESIS

DO for Mandibular lengthening: When compared to lengthening a limb, distraction osteogenesis for the mandible is relatively challenging. The distractor's design and location are likewise more complicated. Manipulation from the ramus is superior than manipulation from the mandibular body in a short mandible to minimise dentition/tooth germ harm. Although extraoral devices were first designed for mandibular distraction, bone-borne or tooth-borne intraoral devices are increasingly popular.[18] The majority of tooth-borne appliances are made in orthodontic laboratories, although bone-borne appliances can be acquired from a variety of suppliers with a significant price difference. With either appliance, vector control can be problematic. In the mixed dentition phase or when the dentition is damaged by periodontal disease, tooth-borne appliances may not be feasible. Because they avoid the possibly unfavourable psychosocial impacts of using an extraoral distraction device, intraoral applications have a higher patient acceptance rate. However, removal will necessitate a second surgical surgery. Resorbable appliances may one day eliminate the requirement for surgical removal.[34]

In children with a severe Pierre Robin sequence, mandibular lengthening distraction is a therapeutic option for tongue-based airway blockage. This procedure has been shown to be successful in treating upper airway congestion caused by micrognathia, with a 95% success rate in avoiding tracheostomy.[35]

DO for Mandibular widening:

Mandibular widening through distraction, also known as mandibular symphyseal distraction osteogenesis, trans-mandibular symphyseal distraction osteogenesis, and mandibular midline osteodistraction, is the surgical widening of the mandible. Distraction osteogenesis is a very predictable method of enlarging the mandibular symphysis in the few cases where it is actually necessary. Distraction of the mandibular symphysis can result in both osteogenesis (the production of new bone) and histogenesis (the formation of new tissue) (new soft tissue formation). The symphysis can widen attributed to the generation of new periosteum over the distracted area. Soft tissue stresses in the corners of the mouth, however, can cause the canines to revert to their normal width and incisor crowding to reoccur if permanent retention is not achieved. There is presently no information on the stability of teeth following the removal of retainers in a symphyseal distraction.[36]

DISTRACTION OSTEOGENESIS OF ALVEOLUS

Alloplastic augmentation, autogenous onlay bone grafting, and directed tissue regeneration are some of the techniques used to restore alveolar ridge decrease (GTR).[37,38] However, in situations of severe alveolar bone abnormalities, each approach has its own set of restrictions. Alveolar distraction osteogenesis might potentially boost alveolar bone volume and mechanical strength by stimulating new bone formation in a quick and predictable way prior to dental implant insertion in these circumstances.[39] Bone grafting and distraction osteogenesis are two of the most often utilised alveolar bone augmentation procedures. Alveolar distraction osteogenesis has the benefit of increasing soft tissue development. As a result, it gives more vertical augmentation than bone transplantation. However, there are risks associated with using this method due to the distraction device and inadequate bone development.[40]

ORTHODONTICALLY INDUCED PERIODONTAL OSTEOGENESIS AND SUTURAL EXPANSION/MAXILLARY PROTRACTION OSTEOGENESIS

The periodontal membrane is an osteogenic tissue that connects a dental alveolus to a tooth, whereas maxillofacial sutures connect opposing membranous bones. In orthodontics and dentofacial orthopaedics, both of these osteogenic tissues have been extensively researched in both experimental and clinical studies. RME and/or maxillary protraction, as well as the tension side of the periodontal membrane during orthodontic tooth movement, are two examples. A method for fast canine retraction called orthodontically-induced periodontal osteogenesis was established. Maxillary protraction techniques that involve MARPE show promise for nonsurgical treatment of midfacial retrusion in adult patients, as seen in the previously stated maxillary and midface distraction osteogenesis studies.[31]

FUTURE PERSPECTIVE

Improved knowledge of the biomolecular processes that drive distraction osteogenesis might lead to the development of novel targeted tactics for enhancing bone regeneration employing molecular mediators, growth factors, or stem cells in the near future. Biodegradable gadgets also eliminate the need for a second operation to remove the distraction devices.

CONCLUSION

Distraction osteogenesis, like traditional orthognathic surgery, necessitates the collaboration of a team of clinical experts, including an orthodontist, an oral and maxillofacial surgeon, and a plastic and reconstructive surgeon. Researchers at a number of medical institutions are now working on three-dimensional computer models of distraction that can help physicians plan therapy by simulating and predicting treatment effects. Despite the fact that treatments for maxillofacial distraction osteogenesis are predicted to evolve as technology advances, distraction osteogenesis is projected to become an important therapeutic modality in orthodontics and oral and maxillofacial surgery for the management of maxillofacial abnormalities.

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