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Role of Distraction Osteogenesis in Facial Deformity

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ABSTRACT:

Distraction osteogenesis (DO) is a tissue engineering technique used to regenerate new bone. It is a bone-lengthening procedure that stretches the skull, midface, and mandibular bones. It has effectively treated a number of facial deformities like craniosynostosis, midface hypoplasia, and mandibular hypoplasia. The application of DO in the field of oral and maxillofacial surgery represents a promising alternative as it can be integrated with conventional surgical techniques for bone lengthening or enlargement. This technique offers excellent bone lengthening, has the advantage of eliminating the need for autograft and donor site morbidity, can be used in younger patients, and allows simultaneous expansion of the surrounding soft tissue. However, this technique requires a thorough understanding of the clinical and technical components to avoid potential complications, including recurrence, infection, damage to adjacent structures, device failure, and other complications, is needed.

Keywords: Distraction Osteogenesis, Facial Deformity, Oral & Maxillofacial Surgery, craniomaxillofacial, Bone Lengthening.

INTRODUCTION:

Distraction osteogenesis (DO) is a method of generating new bone after a corticotomy or osteotomy and gradual distraction. The method is based on the tension-stress principle proposed by Ilizarov.[1,2] Distraction osteogenesis (DO) is a tissue engineering method that can be incorporated into a variety of craniomaxillofacial surgical techniques, using a mechanical device to control both traction rate and motion vector to Creates new bone by stretching the surgically osteotomized bone. This technique takes advantage of the fundamental healing properties of the human body by inducing callus formation and remodeling between osteotomized sites, also known as the distraction gap. The callus between the distraction gap is stretched using a distraction device to apply a uniform traction force that allows new bone formation. Distracted bone formation not only causes the

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formation of new bone, but also stimulates a process called neohistogenesis in which the surrounding soft tissue simultaneously expands to cover the newly formed callus.[3]

The evolution of DO technique in clinical application which was first introduced in orthopedics field has now been widely applied as treatment alternative in the craniomaxillofacial region particularly for the management of congenital and acquired complex craniofacial structural deformity such as mandibular hypoplasia, midface hypoplasia, and craniosynostosis.

These complex structural defects include conditions such as severe atrophic alveolar ridges, micrognathia (small mandible), and maxillary hypoplasia that cause respiratory problems, as well as intracranial space limitations and It includes complex craniofacial deformities that cause eye problems. The use of DO allows for superior structural expansion and bone lengthening and repairs important functional discrepancies associated with these deformities.[3]

In the craniomaxillofacial region, the first clinical use of DO was described by McCarthy in 1992 for mandibular lengthening. Successful mandibular lengthening has paved the way for many other craniomaxillofacial DO indications affecting other areas such as the alveolar ridge, maxilla, midface, as well as non-syndromic with craniofacial abnormalities. It has also paved the way for calvarial dilatation in both and symptomatic patients. It also provides superior functional results compared to other techniques.[4, 5]

INDICATIONS:

Distraction osteogenesis aims to extend the chosen bone to return more typical anatomical function, regardless of the anatomical site.

Mandibular Hypoplasia/Pierre Robin Sequence: Breathing difficulty may be present in newborns due to airway obstruction in the cases of mandibular hypoplasia. The Pierre-Robin sequence (PRS) is a triad of cleft palate, glossoptosis and micrognathia. These patients may encounter feeding difficulties and intermittent upper airway obstruction due to backward displacement of the tongue. Mandibular DO can be a viable option to correct these deformities.[6]

Midface Hypoplasia: Several craniofacial syndromes like Treacher Collins syndrome, Cohen syndrome etc. and cleft lip or palate deformity are attributed to midface hypoplasia. Patients may have some degree of malar retrusion, class 3 malocclusion and exorbitism due to isolated posterior dislocation of the inferior orbital rim. Patients may experience severe sleep apnea or airway obstruction. These types of deformities can be successfully corrected by distraction osteogenesis.[7]

Craniosynostosis: Craniosynostosis represents the premature fusion of the calvarial sutures. Severe craniofacial deformities, elevated intracranial pressure, cognitive impairment, developmental delay, seizures, blindness, and death can result from it if it is not addressed.

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Distraction osteogenesis can be employed to lengthen the skull's anterior or, more frequently, posterior fornix. The increased intracranial pressure brought on by craniosynostosis is lessened by expanding the calvarium.[4, 8]

CONTRAINDICATIONS:

Patients who are medically compromised should avoid distraction osteogenesis of the skull and face. Especially in young children conservative methods should be considered instead of distraction osteogenesis, if these can relieve the afflicted condition. Since positional plagiocephaly may only be treated non-surgically, it must be recognized from real craniosynostosis.[9]

CLASSIFICATION OF DISTRACTION DEVICES:

Distraction devices can be classified into two categories: internal and external.

Internal device can be placed subcutaneously or intraorally and subdivided into bone-borne, tooth-borne or hybrid (a combination of bone-borne and tooth-borne).[16] Internal devices are both curvilinear and linear (have a straight-line vector of distraction), these are fully implanted and fixed to the bone with screws. To widen the distraction gap, an external activator is employed. During the phases of distraction and consolidation, parents and families can find these devices to be more aesthetically pleasing. When the consolidation phase is finished, they are removed again.[9]

External device is bone-borne, consisting of fixation clamps and distraction rods which are attached to the bone by percutaneous pins.[16] The distractor device is connected externally to the skin by titanium pins or wires that are implanted percutaneously into the proximal and distal bone segments for external devices. These are also available as multi-vector and linear devices. By modifying the distraction vectors during the treatment period, external distraction can provide multi-vector distraction and enable the rectification of asymmetries, which is not achievable with implanted devices. A second open surgery is not necessary after the consolidation phase is finished; the pins are removed in a minor procedure.[9]

Better vector control in multidirectional lengthening is made possible by an external device, with adjustments being possible during the distraction period. Internal devices carry less morbidity but both types of distractor devices are associated with their own complications.[16]

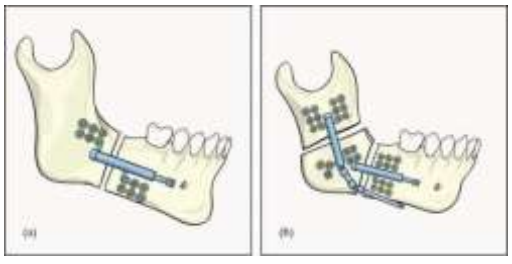

Figure 1.[16]

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Internal Distractor Device according to its vector. (a) Unidirectional distractor (b) Bidirectional distractor.[16]

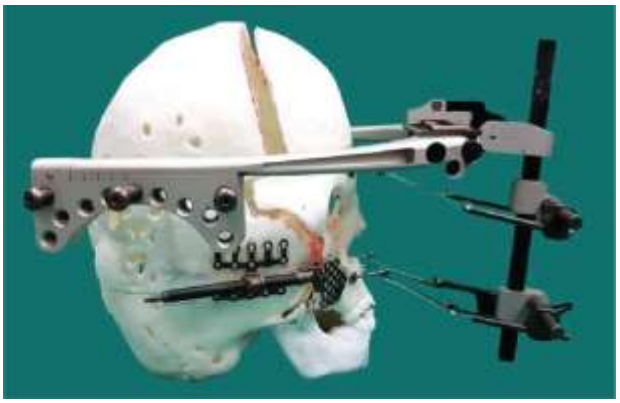

Figure 2.[16]

External Distractor Device with head frame[16]

DISTRACTION OSTEOGENESIS PRINCIPLES AND TECHNIQUE:

Callotasis, a soft callus that forms when a fracture heals normally, permits the fracture site to mend. In accordance with this theory, DO entails manipulating this callus in the distraction chamber for structural lengthening before calcification takes place. [16]

Corticotomy is a procedure in which the cortical layer of the bone is osteotomized to separate the segments while also maintaining the periosteum and medulla's blood supply to the bone. In DO, distraction rhythm refers to the frequency of device activation each day, whereas distraction rate refers to the amount of bone movement measured in millimetres (mm) per day.[16]

Craniofacial distraction osteogenesis can be divided into four phases:

Osteotomy/Distractor Placement: To install the distractor devices and establish an osteotomy in the desired bone, surgery is required. Distraction will take place in a plane that is perpendicular to the plane of the osteotomy. Following the osteotomy, the device is installed and evaluated under direct observation to make sure the bone segments may move freely. Depending on the anatomic site and surgical objectives, as mentioned above, distractors may be internal or external.[4]

Latency Phase: an amount of time necessary for the development of callus. Ilizarov suggested waiting of 5-7 days, but this depends on the bone's microvasculature and physiological state at the distraction site.[2] Through the development of a soft callus, this latency period enables the start of bone repair.

Distraction Phase: The rigid distraction device must be operated in accordance with the recommended protocol in order to achieve the desired bone growth. Axial screws that move

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0.25 to 0.5 mm (depending on the system utilized) every turn are used to turn the device on. The rate and frequency of the distraction determine its effectiveness. A malunion over the distraction site may result from ischemia at the cellular level if the distraction is carried out quickly by increasing the rate and frequency. On the other hand, decreased rate and frequency could result in early ossification, which would tangentially complicate the distraction. Clinicians all across the world often aim for a daily distraction rate of 1.0-1.5 mm and limit activation frequency to 2-4 times.[17] The distraction device gradually becomes active over a few days to a few weeks, typically once or twice a day. Osteogenesis is facilitated by the process of gradual tension on the bone callus. Until the required lengthening is attained, this phase is continued, frequently with a little amount of overcorrection to account for a possible relapse.

Consolidation Phase: After a distraction, the distractor is kept in place for a few weeks. During this phase, immature primary bone is formed; over time, it will mineralize and resemble mature secondary bone. Continued bone remodeling and ossification of bone development are made possible by the immobile distractor's solid fixation to the bony segments. The device is eliminated after the consolidation stage.[5] The consolidation phase lasts for approximately 4 to 12 weeks, with 8 weeks being the average. Clinical recommendations advise maintaining the consolidation phase at twice the length of the activation phase, with the length of the consolidation phase varying according to the distraction site's location and the rate of bone metabolism.[18]

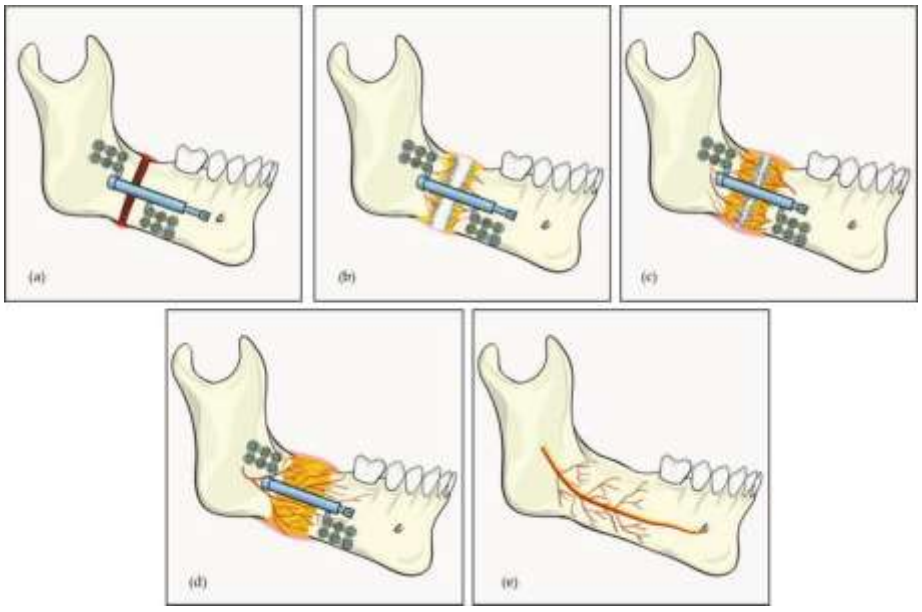

Figure 3.[16]

The phases of distraction osteogenesis. (a) Latency period (b) Distraction phase (c) Consolidation phase. (d) Maturation phase of the ossification (e) Bone remodeling and continuity of alveolar canal after completion of distraction osteogenesis.[16]

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CLINICAL SIGNIFICANCE:

CRANIOFACIAL DO

A craniofacial deformity such as syndromic craniosynostosis, Crouzon, Apert, and Pfeifer syndrome can be treated using craniofacial distraction osteogenesis. Distraction osteogenesis is frequently utilized in the treatment of patients with anomalies of the craniofacial skeleton, whether to prevent intracranial hypertension brought by by craniosynostosis or avoid tracheostomy for upper airway obstruction.[16]

Distraction osteogenesis may require less technical expertise than traditional single-stage vault expansion surgery, particularly in the posterior cranial vault. The successful treatment of cerebral hypertension is made possible by its lower risk of complications and significantly increased vault expansion.[8, 13]

MANDIBULAR DO

When superior mandibular body lengthening is required, mandibular DO may be used to treat micrognathia or mandibular hypoplasia in the anterior-posterior (AP) direction. Comparatively, a traditional bilateral sagittal split osteotomy may allow for up to 10 mm of jaw lengthening, whereas DO may allow for up to 30 mm of advancement, according to the size of the device.[16] In 97.6% of patients with isolated Piere Robin Sequence and >90% of patients with syndromic PRS, mandibular distraction osteogenesis successfully delays tracheostomy or permits decannulation; however, this success rate is significantly lower in patients who also have concurrent lower airway abnormalities, such as tracheomalacia.[12, 14] DO might raise bone level up to 16 mm at a rate of 1 mm per day in cases when there is insufficient alveolar bone height for implant placement.[16]

MIDFACIAL DO

Distraction osteogenesis can considerably diminish the sunken-in appearance of the face, protect the eyes from hazardous intraocular pressures, and lower intracranial hypertension when utilised to treat midface hypoplasia, and effectively treat obstructive sleep apnea. When compared to conventional rigid procedures, the approach may boost the success rate of facial advancement surgery and prevent the need for further operations, which are frequently necessary for conventional Lefort 3 osteotomies conducted in children.[7, 15]

TRANSPORT DO

When there is a major deformity present, the transport DO can be shown. A defect may result after a post-ablative operation, such as a maxillectomy or the enucleation of a large cyst, or it may be a congenital abnormality, such as a facial cleft.

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COMPLICATIONS:

Complications from Distraction Osteogenesis can be:

Relapse: Any distraction osteogenesis, particularly that of the mandible, is expected to experience some degree of relapse. Nevertheless, based on the anatomic site, an overcorrection of 10 to 30% will typically account for the anticipated amount of relapse and result in a positive clinical outcome.[9]

Device Failure: When the device itself breaks down, which doesn't happen very often. The highest rates of device failure occur during mandibular distraction, yet even in this instance, these rates are still below 1%.[9]

Device Extrusion: The device migrates through the bone instead of moving the bone itself in this uncommon complication where it protrudes through the skin. Instead of the desired orthopedic forces, this is an orthodontic expression. The bone's inability to move freely in the desired direction is due to the impingement of bony segments or some other underlying cause. To make sure the segments are free to move in the right direction, it is crucial to verify their mobility in relation to the osteotomy while being directly visualized intraoperatively.[9]

Injury to Tooth Buds: Though it can also happen in the maxilla, this is most frequently seen in mandibular distraction osteogenesis. This can be prevented by meticulous preoperative planning, and possibly enhancing prevention by 3D imaging and virtual surgical planning, allowing for optimization of the osteotomy site.[9]

Nerve Injury: Depending on the technique utilized and the bone to be distracted, the inferior alveolar nerve, facial nerve branches, supraorbital nerve, and infraorbital nerve are all susceptible to damage. Nerve damage can be prevented by taking care of the osteotomy site and dissection plane.[9]

Malocclusion: Malocclusion is a risk that comes with manipulating the tooth-bearing bones. The rate of symptomatic malocclusion is relatively high in individuals undergoing midfacial DO. Neonatal mandibular distraction patients have a very significant future demand for orthodontic treatment. Additionally, poor distraction vectors may lead to occlusal problems like open-bite deformities and temporomandibular joint complaints. Serial radiographs taken during the active distraction period, when coupled with preoperative cephalometric planning, aid in the early detection of this issue.

Cerebrospinal Fluid (CSF) Leak: It can happen during craniofacial distraction osteogenesis, this is uncommon. Most of the time, the leaks are minor and can be controlled gently by observing or by installing a lumbar drain. Despite the claim that it is less than the 10% from typical, open, monobloc advancements, the risk of CSF leak is highest with anterior craniofacial (LeFort 2, 3, and monobloc) distraction. Meningitis is another concern that comes along with this; it can be as high as 10% when using normal open procedures and

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just slightly lower when using distraction techniques.[11] Though it is substantially lower in monobloc advancement when using distraction rather than conventional open procedures, the chance of fatality is still modest (less than 10%).[11]

Scarring: Scar prominence can be reduced by using an irregular (sine-wave) or irregularly irregular (random) incision. To prevent the destruction of hair follicles, incisions should be closed in layers, and use of electrocautery should be minimized near the scalp's surface. For the same reason, Rainey clips should not be used to prevent pressure necrosis of the follicles at the borders of incisions.[9]

Infection: Systemic antibiotics taken before surgery and topical antibiotics applied to the incisions thereafter help to reduce this. Prophylactic postoperative antibiotics are advised in high-risk procedures like LeFort 2, 3, or monobloc advances since the untreated meningitis rate is getting close to 10%. Other antibiotics with good CSF penetration profiles but that also cover skin and hair flora are also frequently used, such as ceftriaxone.[4, 12, 13]

CONCLUSION:

DO can be used as an elective alternative in oral and craniomaxillofacial defects since it is a reliable method for regenerating new bone. The execution of the procedure necessitates a thorough comprehension of its fundamental concepts, suitable pre-surgical planning, professional technical handling, competent surgical abilities, and comprehensive post-surgical care to minimize potential consequences.

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