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The role of craniofacial distraction in contemporary orthodontics

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Abstract

Craniofacial distraction osteogenesis has become the treatment of choice for several conditions which has resulted in an increased interest particularly on part of craniofacial surgeons, orthodontists, plastic and reconstructive surgeons and otorhinolaryngologists. The number of publications on craniofacial distraction osteogenesis increased 170 folds from 1970s to 2011-2015 which reflects wide acceptance of this technique and its ever expanding applications. With the advent of improved diagnostic and treatment modalities the number of complications associated with distraction osteogenesis has reduced to minimal. Distraction osteogenesis has a wide range of applications in the orthodontics ranging from management of cases as simple as single tooth ankylosis, congenital and environmental deformities of maxilla and mandible, moderate to severe dento-alveolar defects and complex multi-sutural cranio-synostosis. This manuscript provides a general description of orthodontic management of patients before, during and after distraction osteogenesis. Moreover, this paper discussed the latest distraction techniques most commonly employed for the patients with orthodontic needs.

History of Craniofacial Distraction

Distraction was initially introduced by Codvilla in 1905 but this technique was not well elaborated.[1] Initial experiments resulted in several complications, like ischemia, infection, malunion, non-union etc. It was Ilizarov who established its clinical protocol and popularized it in 1940s.[2,3] His protocol was gradually accepted by the orthopedic community all around the world. But it was not later than 1973 when the distraction osteogenesis (DO) in the craniofaical skeleton was reported by Snyder firstly in mandibular canine.[4]

DO in craniofacial structures in experimental animals became common by early 1990s. Successful reports from New York University and Friedman et al[5] on lengthening of dog mandibles and for the closure of canine segmental lower jaw defects instigated the interest in the craniofacial distraction (CD).

Before we discuss the current concepts of DO it is necessary to mention that the rapid distraction of palate, which was a common practice in mid 20th century, is technically a form of DO. However, instead of making new osteotomy sites distraction is carried out at naturally occurring physis of the mid palatal suture. The specialty of orthodontics has inculcated the concept of mid-palatal sutural widening under the domain of maxillary expansion. Thus, the term "craniofacial distraction" is routinely used for lengthening of craniofacial bones like maxilla, mandible and calvarial bones.

The credit of introducing the DO technique for mandible goes to McCarty et al,[6] who in 1992 presented a case series of mandibular distraction in patients with congenital mandibular deformities. Later on several centers in world started sharing reports of successful distraction of mid-facial and cranial structures. Over the last two decades, the technique of CD has become more refined and has become a common practice.

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A variety of patients can now benefit from the CD, common examples are: patients having congenital craniofacial defects such as craniofacial microsomia, Nager's syndrome, Treacher Collins syndrome, Pierre Robin syndrome and the defects resulting from the environmental factors such as temporomandibular joint (TMJ) ankylosis, posttraumatic growth disturbances, etc. Most of the patients needing CD receive this treatment as a part of comprehensive orthodontic treatment which aims at improving the appearance of dentition and face along while aiming for optimal oral functions (Box 1).

Craniofacial DO has become the treatment of choice for several conditions which has resulted in an increased interest particularly on part of craniofacial surgeons, orthodontists, plastic and reconstructive surgeons and otorhinolaryngologists. Hashmi et al[7] evaluated the publication trends in the field of CD and found a 170 fold increase in the number of publication from 2011 to 2015 as compared to the number of publications in 1970s. This reflects wide acceptance of these techniques due to several advantages. With the advent of improved diagnostic and treatment modalities the number of complications has reduced to minimal. The advantages and disadvantages of CD are listed in Box 2.[8-12]

Box 1: Common Indications of craniofacial distraction

Lower Face (Mandible)

- Hemifacial macrosomia: Unilateral distraction of the ramus, angle, or posterior body
- Pierre Robin syndrome: Bilateral advancement of the body, particularly in infants with airway obstruction
- Occlusal plane correction: Vertical distraction of alveolar segments
- Symphyseal distraction: Horizontal distraction to correct crossbite deformities or to improve archform

Midface (Maxilla, Orbits)

- Midface deficiency: Maxillary advancement at LeFort I level
- Nonsyndromic/syndromic craniosynostosis: Midfacial advancement at the LeFort III level
- Cleft lip and palate: Closure of alveolar bony gaps

Upper face (Fronto-orbital, Cranial Vault)

- Advancement of the fronto-orbital region, alone or in combination with the midface (monobloc or facial bipartition)

Box 2 - Advantages and disadvantages of craniofacial distraction

Advantages

- Safe and effective
- Can be performed on outpatient basis
- Distraction histogenesis results in soft tissue growth
- Result in long term improvement in condylar morphology
- Greater degree of improvement compared to conventional remodeling surgery
- Minimal skeletal relapse and need for grafts
- Reduced blood loss and amount of blood transfusion
- Satisfactory skull contour
- Reduced need of surgical dissection and bone resorption
- Early treatment to skeletal disharmony

Disadvantages:

- Infection around distractor
- Dislocation of the device
- Thin calvarial bones in neonates and infants pose difficulty in application of the distraction devices
- Second operation required for removal
- Additional contouring surgery may be required
- Additional cost of the device

Orthodontic Management of Patients Requiring Distraction Osteogenesis

Pre-distraction Orthodontic Management

The pre-distraction orthodontics may include orthodontic preparation similar to that for orthognathic surgery, like dental decompensations, arch coordination, and correction of occlusal plane. After the planned objectives are achieved, passive rectangular arch wires and hooks are placed. This rigid appliance helps in guiding the occlusion during active distraction phase by using inter-maxillary guiding elastics. This may help in adjustment of the vector of distraction. Hemi-facial microsomia patients may require occlusal splint for the maintenance of mandibular occlusal plane during distraction whereas, maxillary occlusal plane correction could be achieved in post-distraction phase.

Orthodontic management during Active Distraction

The vector of distraction is important factor to determine the skeletal and dental relationships. The elastic force modifies the direction of skeletal change along the linear activation of distraction device. These can be worn in class II, III, vertical and transverse directions helping in fine tuning of occlusal outcome. Anterior open bite tendency could be reduced by using anterior vertical elastics. The bones on either side of distraction pins have a tendency to rotate around the pins therefore, the use of elastics may help in more stable occlusal settlement by generating bone formation in the favorable direction. The use of elastics should be continued in consolidation phase to allow retention for the skeletal and dental change.

Rapid change in occlusion may occur during distraction may result in functional shift due to occlusal prematurities.[13] In young child deformity needs to be overcorrected whereas, in child close to end of growth phase may not require overcorrection.[14]

After complete activation of appliance the device is left in position for the consolidation period. The radiographic evaluation should present mineralization and then device can be removed as an outpatient procedure. Post-distraction records should be taken as photographs, cephalogram, orthopanoramic radiograph, and 3D CT scans.[15-19]

Post-distraction Orthodontic Management

Unilateral distraction of mandible may result in posterior open bite on the distracted side. The shift of mandible towards the opposite side may result in cross-bite on the contralateral side. The post-distraction bite could be managed by using bite plate with gradual adjustment. The use of trans palatal arch and cross bite elastics help in correction of cross-bite. The occlusal cant present in untreated maxilla can be managed at this stage by selective grinding of bite plate to allow eruption maxillary dentition while holding mandibular dentition in place. There are many alternative methods of orthodontically treating the post-distraction patient. Variable growth response was observed on the operated side.[20-22]

Contemporary Applications of Distraction Osteogenesis

Craniosynostosis

Craniosynostosis is a congenital condition which may vary in expression depending on the severity and sites of the sutures involved. Crouzon's, Apert's and Pfeiffer's syndromes are the common examples of this condition. This usually represents in the form of skeletal Class III malocclusion and concave facial profile. Ocular proptosis and mid-facial deficiency is usually severe raising severe esthetic and psychosocial concerns for the patient and family.

Early intervention is required to deal with the patient's concerns and to avoid ophthalmic complications. Initially, monoblock craniofacial advancement of midface along with the anterior cranial vault was usually carried out at the age of 7-9 years when the growth of midface is almost complete.[23] However, this procedure involves significant risks as the sinus-brain barrier in the anterior cranial vault is violated. This has resulted in reduced the frequency of this procedure and is usually limited on those cases with circumorbital symmetric retrusion in which conventional staged advancement of midface and anterior cranial vault is not possible.[24,25]

Contrary to this approach, gradual expansion and advancement with DO minimizes the risk of creation of dead space and subsequent morbidity associated with it.[26] Though some authors have advocated the use of frontofacial monobloc distraction at the age of one year, the long term results and final esthetic and functional outcome is yet to be investigated.[27] In this regards, the use of early monobloc distraction is usually limited to life-threatening dysostosis like Pfeiffer type-II deformity and the application of distraction procedures for such conditions are increasing.[28]

Apart from the surgical reopening at the sutures, the current trends are more focused on improving the facial appearance of these patients. The newer techniques offer better reconstruction of orbital and mid-facial regions in addition to the calvarial bones.[29-33]

Patients who were treated with craniofacial facial distraction were generally found to have more stable results with a better esthetic outcome of facial region.[34,35] This has led to the popularity of techniques like frontofacial advancement, rigid external distraction (RED) frames and its other modifications.[26,36,37]

In 2009, White and colleagues[38] published a report on posterior calvarial expansion with distraction osteogenesis for patients with craniosynostosis. This method was readily adapted by the Western surgeons but Caucasians started using this method quite late. It is now evident that greater amount of cranial expansion can be achieved by this method as compared to the conventional surgery.[39,40]

Currently, the use of craniofacial distraction in these patients has become a lot easier as newer protocols are being established. Moreover, recent advancements in the techniques of anesthesia, availability of option of auto-transfusion and marketing of distractors with versatile designs has made this procedure less invasive and of shorter duration.[33, 41,42]

Obstructive Sleep Apnea

Obstructive sleep apnea (OSA) is one the most common functional problems found in patients with craniosynostosis. OSA can be multilevel depending on the site of constriction in the upper airway. However, the possibility of central apnea must not be disregarded in these patients. Lefort III DO is considered a highly efficient method of treating both the facial deformity and OSA in children with craniosynostosis or severe achondroplasia. To reduce the risk of failure it is strongly recommended to include polysomnography in the pretreatment assessment of suitable candidates for this procedure.

There have been retrospective studies of clinical improvement in obstructive symptoms following Lefort III distraction osteogenesis, and with some demonstrating the airway expansion that occurs with this technique.[43-44] More importantly, it may not be the magnitude of linear distraction which may be related to the degree of correction of OSA rather the change in angulation of midface with respect to the Sella-Nasion-point A (SNA) angle which is better correlated to the degree of correction. The increase in nasopharyngeal airway volume was correlated not with the magnitude of linear movement of the maxilla, but rather with the increase in an angular measurement comparable to Sella-Nasion-point A (SNA) angle.[45,46]

However, it is important to diagnose the components of obstruction. Midface advancement may not be sufficient enough to treat the airway obstruction as it has little impact on retrolingual regions. Furthermore, advancement of midface may result in downward and backward mandibular rotation that may result in further deterioration of retrolingual space. Therefore, if the short mandible is a cause of obstruction, mandibular distraction with or without midface distraction may provide better and more predictable results.

Single and Double Jaw Distraction Osteogenesis

Single Jaw Distraction Osteogenesis

Mandibular distraction is usually recommended for patients suffering from craniofacial microsomia, Nager's syndrome, Treacher Collins syndrome, Pierre Robin syndrome and the defects resulting from the environmental factors such as temporomandibular joint (TMJ) ankylosis, posttraumatic growth disturbances. Patient suffering from cleft lip and palate are the most common candidates of maxillary distraction osteogenesis. Other patients needing maxillary distraction include patients having severe maxillary deficiencies secondary to congenital anomalies or environmental factors. Distraction protocols for such patients are well established and have been refined over time and can be found in published literature in the form of papers and books.[4,14,17,19] However, there is a significant number of patients needing both maxillary and mandibular distraction. Newer techniques for such patients continue to develop over last two decades which shall be discussed in this manuscript.

Double Jaw Distraction Osteogenesis

Orthodontists and surgeons treating hemi mandibular hypoplasia with ramal elongation observed improved facial asymmetry in hemi facial microsomia patients.[4,16,47] There is simultaneous expansion of the soft tissues resulting in remarkable improvement in aesthetics and functions. However, after mandibular distraction, occlusal changes occur resulting in posterior open bite of 2 - 4 mm and an anterior cross bite on the unaffected side. In younger patients, the occlusal correction can later on be achieved by using myofunctional appliances to allow selective eruption of teeth. This usually occurs rapidly due to the vertical growth of the maxilla as the constriction effect of the hypoplastic mandible is released.[47-51] However, in the older patient with completed maxillary growth the dental occlusion can be severely deranged after mandibular distraction that requires prolonged orthodontic management or secondary orthognathic surgery. Therefore, older patients' simultaneous maxillomandibular distraction is indicated in patients with untreated hemifacial microsomia to correct the facial deformity.

The simultaneous double jaw distraction brings three dimensional changes in occlusion and jaw bases bring both linear and rotational changes. To achieve maximum control orthodontic bands or arch bars are placed on the upper and lower dentition for the use of elastics. The maxilla is dissected from anterior and lateral aspect up to the level of pterygomaxillary junction. The nasal spine is dissected followed by a complete horizontal osteotomy at the level of the piriform aperture on both sides. However, the midface is not mobilized and the pterygomaxillary junction on the unaffected side left intact to serve as a pivot point to allow midface elongation-rotation movements on the affected side. A second incision is then made in the inferior buccal sulcus of the hypoplastic mandible to place the distractor after lateral corticotomy. A vertical vector for distraction is recommended to achieve a proper elongation of maxillomandibular bone. The distraction is initiated after the latency period of 5 days at a rate of 1 mm/day. The elastic bands are used from the same day to allow vertical distraction of maxilla. The distraction period is completed in 3 to 4 weeks with the correction of facial asymmetry and occlusal plane. The devices are removed after a consolidation period of around 8 to 10 weeks. The use of elastics results in simultaneous elongation and medial rotation along with the advancement of the maxillomandibular complex.

After the combined distraction results in simultaneous correction of occlusal cant with a minimal remaining cant of 2°. The vertical dimension of the maxilla and the vertical dentoalveolar discrepancy in posterior maxillary molar can be corrected that was usually corrected orthodontically or by orthognathic surgery in past. In simultaneous double jaw DO, the new bone formation allows simultaneous correction of the oblique nasal floor and the deviated nasal septum. The simultaneous distraction of the maxilla and mandible results in successful treatment for both the teenagers and adults suffering from various double jaw deformities resulting in good facial aesthetics and function.[52]

Combination of Orthognathic Surgery Distraction Osteogenesis

The treatment of dentofacial deformity using distraction osteogenesis has recently become one of the surgical treatment modality.[53] The soft tissue envelope regenerate under tension thus, resulting in simultaneous increase in bone and soft tissue. A combined surgical maxillary Le Fort I advancement and mandibular sagittal split osteotomy could be done and a curvilinear distractor is placed as per planned by computerized prediction prior to surgery. The digital templates are generated and superimposed to forecast surgical outcome corresponding to the distractor. The activation of digital distractor is done along the spiral growth curve template to achieve the ideal position mandibular position. This method helps in selection of the type, size and position of distractor, and the amount of distraction.

The presurgical orthodontic is done with a fixed orthodontic appliance to level and align the dental arches. The first step of the surgical procedure includes Le Fort I osteotomy and down fracture of maxilla. A surgical splint is used to accurately reposition the maxilla in the desired relationship and rigid fixation is done with miniplates. The mandibular osteotomy is performed by sagittal split ramus osteotomy with the modification described by Hunsuck[54] to increase bone interface. Inter-maxillary fixation is done with the distal segment of mandible in the desired place and the curved distractor is then fixed to the proximal and distal component. The inter-maxillary fixation is then released to allow the distractor to collapse. The distraction starts after the latency period at a rate of 1 mm/ day. After completion of distraction phase the distractor can be left for the consolidation phase. The distraction osteogenesis provides less accurate results as compared to orthognathic surgery,[55,56] The use of internal multidirectional curvilinear distractors allows the movement of mandible along the logarithmic spiral path of mandibular growth. This may reduce the chances of relapse due to physiologic movement.[53,57-60]

Dentoalveolar Distraction Osteogenesis

Orthognathic procedures are used to align the skeletal structures to improve the facial profile. The diagnosis is based on clinical and cephalometric analysis. There are cases in which facial profile does not requires improvement and the cause of discrepancy is dentoalveolar rather than skeletal base.[61] Dentoalveolar discrepancies are difficult to treat with orthodontic camouflage alone. The treatment may prolong to achieve tooth alignment and occlusion. Often this requires extraction or surgery assisted expansion and midline mandibular distraction to correct arch length discrepancy.[62] Long-term stability may require permanent retention as well.

Dentoalveolar Distraction to Treatment Sagittal and Transverse Discrepancies

Dentoalveolar distraction osteogenesis (DDO) helps in correction of anteroposterior alveolar discrepancy. Earlier such cases were treated with jaw advancement like mandibular alveolar discrepancy treated with mandibular advancement but used to be done along reduction genioplasty to maintain facial profile. Dentoalveolar distraction osteogenesis uses expanded orthodontic principles and combine them with the regional acceleratory phenomenon (RAP) and distraction osteogenesis. This combination allows for the tooth to move the alveolar segment on skeletal foundation. RAP enhance the rate of tooth movement. This procedure includes vertical and horizontal corticotomies to separate teeth from the basal bone. Recently, piezo surgical knives allow precision in segmentation. There are least chances of root resorption and denervation. The segmented blocks are then distracted and mobilized by orthodontic tooth movement.

Orthodontic management of patient needing dentoalveolar distraction depends on the type of discrepancy. In case of severe crowding the dentoalveolar distraction surgery is performed 2 weeks after the placement of appliance. This minimizes the chances of dentoalveolar compensation to accommodate teeth in tooth size arch length discrepancy. When a sagittal or transverse skeletal discrepancy originates from the dentoalveolar structures, it is recommended to allow leveling and alignment and then perform DDO on rigid wires to allow change in relationship with skeletal base. Multistage DDO may help in cases with more complex problems. The use of absolute anchorage may assist in achieving best possible outcome.

Development of Dentoalveolar Process

Dentoalveolar process may fail to develop in cases of congenital absence of tooth germ, early loss of a tooth, dental ankylosis at a young age, traumatic avulsion of tooth along with the alveolar bone and secondary to different respective surgical procedures. To restore satisfactory esthetics and function, a prosthesis needs to be provided on a sound bony base. Previously, the use of allogenic or xenogenic bone grafts has been regarded as the traditional approach in such cases. More recently, the process of dentoalveolar distraction has been presented in literature along with well-defined protocol and elaboration of the working mechanism of distraction devices.[63]

Management of Ankylosed Teeth

Treatment options for ankylosed teeth in the past were restorative buildup, extraction and replacement, extraction and space closure, and surgical reimplantation.[64] However, the lack of vertical alveolar growth results in significant vertical alveolar defect that often makes prosthetic replacement difficult or impossible. Therefore, surgical orthodontic correction is a better option.[65] The soft tissue limitations rendered the augmentation of vertical alveolar ridge defects by guided bone regeneration unsuccessful resulting in dehiscence.[63] However, concomitant histogenesis during the alveolar distraction osteogenesis predictably correct vertical alveolar defects,[66-70] During the process of distraction controlled and gradual displacement forces are applied on surgically created fracture to vertically transport a mature bone segment into the alveolar ridge defect.[71]

The protocol of distraction comprises of same 3 phases: latency, distraction, and consolidation.[72] Isaacson et al[73] performed block surgical osteotomy of ankylosed incisor and then he used standard orthodontic appliance to move the ankylosed tooth into the occlusion. However, this was different from distraction osteogenesis which treats the lack of growth of the alveolar process that occurs due to ankylosis whereas, the protocol followed by Isaacson treats the ankylosis itself.

The chances of relapse or need of overcorrection depends on the amount of patient's remaining growth potential. The patient should be informed regarding timing of distraction and possible need for retreatment. During planning the procedure and designing the distraction device, several important aspects should be considered. Adequate space should be provided for the osteotomies at the surgical site. The vector of distraction should be considered along with three dimensional effects in the planned movement, and complete osteotomy and mobilization of the distracted must be done to ensure a successful distraction osteogenesis treatment.

Concluding Remarks

Distraction osteogenesis has a wide range of applications in the orthodontics ranging from management of single tooth ankylosis to multi-sutural craniosynostosis. Newer protocols and surgical techniques are continuously being reported. The twenty-first-century orthodontic must be aware of these procedures and techniques so that he can not only recommended certain distraction procedures where needed but may also provide the optimum care to the patients before, during and after the distraction.

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