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Distractions Osteogenesis-An Overview of Challenges and Possibilities

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Summary

As facial deformities affect a significant portion of the world's population, a range of techniques have been developed to provide both aesthetic and functional correction. Distraction Osteogenesis (DO) is one therapeutic option that promotes new bone formation through a device that applies tension to two surgically sectioned bone segments, avoiding bone grafting and stretching surrounding tissues. This study reviews the literature on the Distraction Osteogenesis technique and its relationship to additional surgical procedures.

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Introduction

The subject of facial deformities encompasses inherited facial irregularities, syndromes, congenital anomalies, consequences of trauma or the resection of tumours and acquired deformities. To address these, therapeutic procedures are needed in order that both functional and aesthetic issues can be corrected. Various techniques have been developed to meet this demand, but the most common surgical treatment is orthognathic surgery, which acts as a benchmark for any new therapies.

Abnormalities of the middle and lower parts of the face can be caused by dental problems, issues with the bone structure or both dental and bone irregularities. Some of the most common causes of facial bone deformities are: vertical or horizontal excess or deficiency, irregular alignment, or the incorrect position of the alveolar bone relative to the basal bone. Taking this into account, it is important that facial analysis should be followed by cephalometric analysis. This allows both the diagnosis of the origin of the deformity and the establishment of a treatment plan based on objective parameters. It is essential for functional and aesthetic success that each case is planned in detail and individually.

The limitations of orthognathic surgery led to the advent of different therapies, among them DO, which consists of a surgical osteotomy to separate the bone segments and the installation of a Distraction device to correct the irregularities. The device is adjusted gradually, causing new bone growth at the interface of the fragments.

The advantages of DO include: the gradual formation of new bone and surrounding tissues, a lower risk of lesions to adjacent anatomical structures and greater stability for extreme movements, which are not provided for by conventional surgeries. The disadvantages meanwhile of Distraction Osteogenesis are the final result of the occlusion is unpredictable and that patient collaboration and careful postoperative follow-ups are both absolutely essential. In fact, it may be necessary to undertake orthognathic surgeries after the Distraction Osteogenesis in some cases, in order to either optimise the occlusal relationship or provide a more aesthetic result. It is important to know the limitations of Distraction Osteogenesis and what the implications will be for its use.

The objective of this article is to discuss the use of Distraction Osteogenesis, both on its own and in conjunction with orthognathic surgery to correct facial deformities, by means of a review of the relevant literature.

Literature Review

Facial deformities are extremely common and cause functional and aesthetic problems. Usually the treatment includes multiple osteotomies, numerous incisions and potentially bone grafts. Distraction Osteogenesis is a technique that produces new bone growth through an osteotomy, followed by the application of a Distraction device that applies traction to gradually separate the bone segments. [1]

The pioneering study, in which the principles of Distraction Osteogenesis were first described, was published in 1905 by Codivilla. He outlined the process for stretching a femur by applying axial forces through distraction and subsequently the technique was developed and popularised following the studies of Ilzarov. Since then, many further studies have been published attesting to the success of Distraction Osteogenesis as a therapeutic option for various craniofacial abnormalities. [1-4]

Once the Distraction device is put in place, the Distraction Osteogenesis technique has three phases. The first phase is called the "Latency Period", during which a bone callus begins to form. In the second phase, the Distraction device is mechanically adjusted to separate the bone stumps, concomitantly to the growth of the bone matrix. The final phase is characterised by bone consolidation. During this, remodelling and bone calcification take place, with the initial lamellae lying parallel to the direction of distraction.

To achieve success with Distraction Osteogenesis, basic biological principles have to be respected, such as preserving the blood supply and maintaining the stability of both the Distraction device and the segments under traction. The issue in respect of vascularisation is that the method employed to perform the osteotomy may interfere with the blood supply, which can cause damage (in cases of total periosteal rupture) and extensive manipulation of the adjacent soft tissues. As for stability, the lack of this can cause fibrous tissue to infiltrate the bone interface and, consequently, the procedure will fail. [5-9]

Among the advantages of DO, compared to other surgical approaches, is the simultaneous development of soft tissues, tissue matrix, blood vessels, nerves, muscles, skin, mucosa, fascia, ligaments, cartilage and periosteum. In addition, the technique also allows extensive bone defects to be corrected and provides greater stability for extreme movements. By allowing the surrounding tissues to adapt gradually, the risk of relapse is reduced and the aesthetic result is often improved. [10,11]

Distraction Osteogenesis can be applied to the mandible, maxilla and other bones of the face for the treatment of different bone irregularities, without impairing breathing and achieving both occlusion and aesthetic targets. The main adjustments that can be achieved with Distraction are advancement, lengthening, and expanding. Deficiencies which require significant increases in bone and adjustments in different directions may be more successful if the treatment is staged, using DO in conjunction with conventional osteotomies. To illustrate the principles of this procedure, the Figures 1- 8 show the lengthening of the mandibular ramus in according of AO Foundation guidelines. The DO procedures also avoids the need for bone grafts, making it unnecessary to gain access to donor areas. As with orthognathic surgeries, the bone gained through grafting is limited by the ability of soft tissues to adapt. In addition, grafts are more susceptible to infection, failure to bind with bone segments and reabsorption. In 2000, Nocini., *et al*. published a clinical case study in which grafting in isolation had not been sufficient to achieve the desired facial symmetry, and so additionally they undertook Distraction Osteogenesis. [12-14].

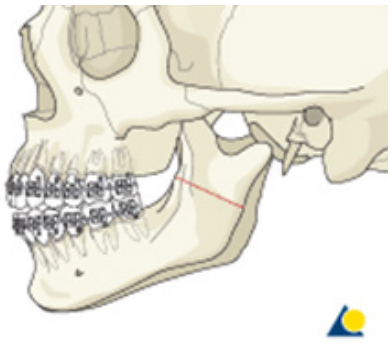

Figure 1: *The virtual distractor is selected and placed on the mandibular ramus. A horizontal osteotomy is marked above the lingula. The virtual osteotomy is completed and the distractor virtually activated. If the movement is not satisfactory, the virtual distractor position can be adjusted until the desired vector is achieved. Source: AO Foundation*

Figure 2: *A guide can be fabricated which allows the accurate positioning of the distractor and the osteotomy. Intraoperative navigation can achieve a similar result. Source: AO Foundation.*

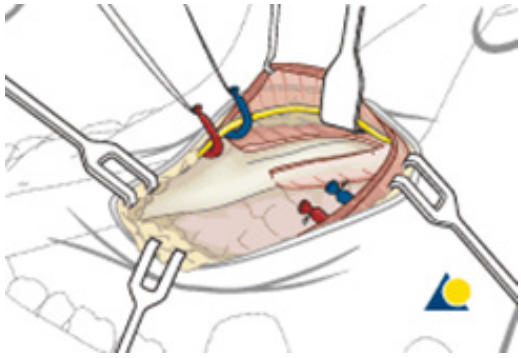

Figure 3: *A submandibular approach in combination with a transoral approach is used for the insertion of the distraction device. Source: AO Foundation.*

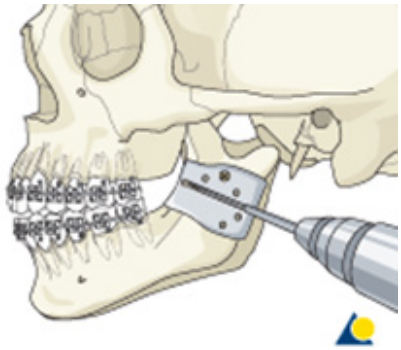

Figure 4: *Osteotomies- The surgical guide is positioned and stabilized with one screw. The holes for the distractor screws are drilled and the osteotomy line marked on the bone. Source: AO Foundation.*

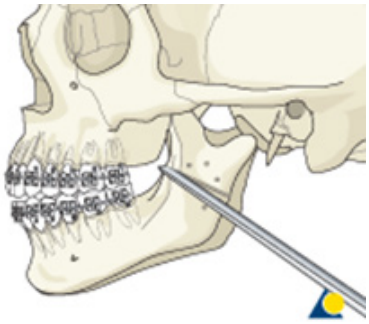

Figure 5: *The guide is removed and the osteotomy completed. Care should be taken not to injure the internal maxillary artery and the inferior alveolar neurovascular bundle. Source: AO Foundation.*

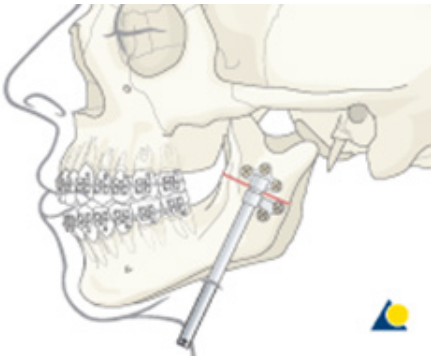

Figure 6: *Placement of the distractor-The distractor is placed and stabilized in the preplanned position using screws in the previously made screw holes. Source: AO Foundation.*

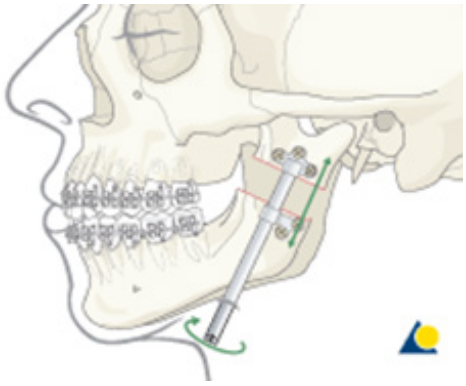

Figure 7: *The distractor is activated to ensure that it is working properly and is then deactivated (returned to starting position).The wounds are then closed with a dressing applied to the external port. Source: AO Foundation.*

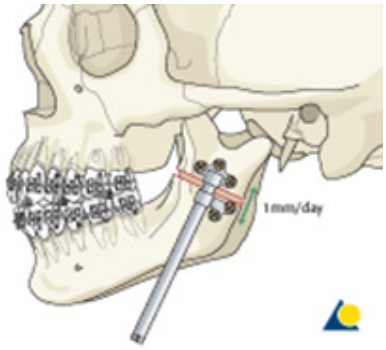

Figure 8: *After a suitable latency period, the ramus is distracted at a rate of 1.0 mm per day.Physical therapy and mandibular mobilization should be encouraged early in the postoperative period.Weekly review of the patient is valuable until such time as the required distraction has been achieved. After reaching the desired distraction the device is left in place to retain the distraction and to allow for bone consolidation.It is valuable to check that distraction is progressing well periodically with radiographs.Consolidation will take approximately 8 weeks and the regeneration of bone into the distraction gap can also be verified with radiographs. When sufficient bone is present in the gap, the distraction device is removed. Source: AO Foundation.*

In 2014, Gerbino G., used Distraction Osteogenesis, when treating unilateral mandibular hypoplasia in adults, to raise the mandibular branch prior to orthognathic surgery. Orthodontic treatment for decompensation and dental alignment was started after the period of bone consolidation. Finally, conventional orthognathic surgery was performed; combining a Le Fort I osteotomy, sagittal osteotomy of the mandibular branches and, in some cases, additional procedures such as genioplasty and rhinoplasty. [15]

There is also good evidence of the successful use of Distraction Osteogenesis to correct maxillary defects. In the maxilla, the most frequently used Distraction Osteogenesis technique is maxillary expansion to correct transverse deficiencies, either without surgical access (children) or surgically assisted (adults). In these instances, the technique consists of a Le Fort I osteotomy, followed by osteotomy in the sagittal midline and then the installation of a Distraction device. However, transverse deformities are usually accompanied by anteroposterior and vertical irregularities, requiring subsequent orthognathic surgery. [16-20]

In 2014, Kim., *et al*. published a clinical case in which Distraction Osteogenesis and orthognathic surgery were performed to correct severe maxillary hypoplasia in an adult patient with a unilateral complete cleft lip and palate and mandibular prognathism. The treatment consisted of maxillary advancement through Distraction Osteogenesis using an extraoral distractor, followed by orthognathic surgery combined with a Le Fort I osteotomy, to achieve horizontal rotation and maxillary posterior impaction, mandibular setback by means of a sagittal osteotomy of the mandibular branch, and genioplasty to vertically reduce the mental region. In this case, the required amount of maxillary advancement was greater than 10 mm, so orthognathic surgery on its own would be insufficient and unstable. The aforementioned Distraction Osteogenesis enabled the amount of maxillary advancement to be reduced, reducing the morbidity and compensating for the limitations of orthognathic surgery. [21]

Finally, in addition to mandibular and maxillary distractions, there is the potential to use the principles of Distraction Osteogenesis to bring forward the middle part of the face, after a Le Fort III or monobloc osteotomy. This potential solution would be highly valuable for the treatment of patients with syndromic craniosynostosis, since they display, among other features, hypoplasia of the middle facial area and obstructed upper airways. The syndromes, Apert, Pfeiffer and Muenke, all have these features in common and can be corrected from infancy to early adulthood. Usually they are surgically addressed at different times. [22-24]

Final Considerations

The use of Distraction Osteogenesis has expanded over the years, due to the high success rate reported from using this technique. At the beginning of its development, Distraction Osteogenesis was used only for the correction of severe facial deformities, but over time it became an option for less severe cases, providing an alternative to conventional osteotomies and advantages over dental extractions, in cases where dental crowding is caused by a deficiency across the maxillary or mandibular structure.

However, complex deficiencies that require bone gain beyond the limits of orthognathic surgeries, as well as multi-directional adjustments, benefit from a combined treatment conducted in stages, with Distraction Osteogenesis being performed prior to traditional surgical methods, so as to achieve good functional and aesthetic results.

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