Chapter 3

DISTRACTION OSTEOGENESIS IN ORAL AND MAXILLOFACIAL SURGERY

Yunus BALEL[1]
Serkan YILDIZ[2]
Mehmet Kemal TÜMER[3]

INTRODUCTION

Although orthognathic surgical procedures and traditional reconstruction procedures are frequently used in the correction of craniofacial deformities, many limitations are encountered in the acute movements of osteotomized bone fragments and overstretched soft tissues. In addition, more than one surgical procedure is generally required in large skeletal disorders and especially in patients with syndrome. In these cases where many procedures should be postponed until the child grows, there is a great risk for psychosocial problems as well as secondary deformities with postponing treatment. Traditional osteotomies performed to correct severe craniofacial deformities require a long stay in the hospital and pose a risk for infection and relapse.(1)

These limitations and risks have led researchers to look for new methods to correct excessive anteroposterior, transversal and vertical deformities. After examining the results obtained by the distraction osteogenesis of the endochondral bones, it has

[1] Research Assistant, Tokat Gaziosmanpaşa University, yunusbalel@hotmail.com. ORCID iD: 0000-0003-0496-8564

[2] Specialist Dentist, Istanbul Topçular Oral and Dental Health Center, serkanyildiz354@hotmail.com. ORCID iD: 0000-0002-5588-9367

[3] Associate Professor, Tokat Gaziosmanpaşa University, dr_kemaltumer@yahoo.com. ORCID iD: 0000-0002-6250-0954

been suggested that the membranous bones of the craniofacial complex can also be successfully distracted.[1] On top of that, distraction osteogenesis has found application in the craniofacial complex and has started to be used as a valid treatment option in the correction of craniofacial deformities.[2,3]

Distraction osteogenesis is the process of new bone formation in the space by applying a graded stretching force to the space between the two bone segments separated from each other.[4]

This process begins when the distraction force is applied to the callus of healing between the segments of separated bones and continues as long as the tissue is stretched.[5]

The use of distraction osteogenesis in oral and maxillofacial surgery has been widely used for the correction of bone deformities in the last thirty years.

INDICATIONS OF DISTRACTION OSTEOGENESIS

Common indications for distraction osteogenesis in the mandible can be summarized as mandibular hypoplasias due to congenital deformities such as Nager syndrome, Treacher Collin syndrome, Piere Robin syndrome, Cranofacial scoliosis and Hemifacial microsomia, and mandibular asymmetry of temporomandibular joint ankylosis.[6]

In addition, there are many indications for application: obstructive sleep apnea, mandibular stenosis, maxillary stenosis, mid-facial developmental retardation, cleft lip slits, bone loss due to a pathology (tumor resections, bone loss due to a large cystic formation), increasing the height of the fibula graft, elevating osteointegrated implants, maxillary arch shortness, poorly healed bone as a result of trauma, atrophic alveolar crest.[3,7-15]

CONTRAINDICATIONS OF DISTRACTION OSTEOGENESIS

Cases with insufficient bone volume and density, patients with weak immune system, osteoporosis, radiotherapy, diabetes are the main contraindications.[1,3,16,17]

DISTRACTION OSTEOGENESIS TECHNIQUES

Distraction Osteogenesis is divided into two as callotasis and physeal distraction depending on where the applied pulling forces affect:

a. Callotasis

It is formed by the gradual stretching of the callus formed around the bone segments formed after osteotomy. Clinically, callotasis consists of three successive periods, the latent period, the distraction period and the consolidation period. Callotasis is classified into three groups according to the number of distraction-tension regions:[18]

1. Monofocal Distraction Osteogenesis: It is a technique in which bone segments on both sides of the incision line are removed from each other by a single incision made into the bone. Here regeneration occurs in one region.
2. Bifocal Distraction Osteogenesis: It is a technique in which a vascularized bone piece that is separated from the remaining bone segment in the case of a wide bone defect is progressively moved towards the defect. The new bone transport is formed during the movement of the disc and the bone segment that is transported closes the defect region.
3. Trifocal Distraction Osteogenesis: It is a distraction osteogenesis technique in which two transport discs are created and brought closer to each other after osteotomies performed in the segment on both sides of the defect region in cases with very large bone defects.

b. Physeal Distraction

It is the distraction of bone growth plates. In this technique, it is divided into two depending on the distraction rate between growth plates:

1. Distraction epiphysiolysis: It is a fast physeal distraction technique performed in growth regions at a rate of 1–1.5 mm per

day. With rapid and increasing tension, fractures are formed in the growth plates. The epiphysis is then separated from the metaphysis and the growth plate is replaced by the trabecular bone formed.

2. Chondrodiatasis: Osteogenesis is accelerated by increasing the biological activities of cartilage cells with a tension created at a rate of approximately 0.5 mm daily without creating a fracture.

BIOMECHANICAL STEPS OF CLINICAL APPLICATION OF DISTRACTION OSTEOGENESIS

- Detailed preoperative planning including sensitive corrections of angular deformities
- Selection of the appropriate distraction apparatus, whose constant properties are known in different loading conditions
- Selection of pins in appropriate diameter and design
- Atraumatic bone incision (corticotomy) in the most appropriate area
- Carefully forming the bone and pin interface and preventing pin loosening that may develop later
- Creating a stable external fixation configuration

Choosing the distraction rate and rhythm that fit the biological process of the dystraction osteogenesis

- In case of delayed osteogenesis, periodic break in activation and even reverse movement (compression)

Maintenance of conservative fixation after the completion of the distraction

Inductive bone grafting in delayed consolidation cases

- Distraction of the distraction apparatus after adequate maturation of the new bone
- Protection of distracted bone from excessive stress during the remodeling period

CLASSIFICATION OF TREATMENT MODELS OF DISTRACTION OSTEOGENESIS

There are four types of distraction treatment methods:

1- Extension procedures only
2- Corrective distraction osteotomies (used in cases where there is a false fusion, such as pseudoarthrosis cases.)
3- Bone segment transfer
4- Stimulation of bone growth region by distraction in applications in children [19,20]

BIOLOGICAL BASIS OF DISTRACTION OSTEOGENESIS

Distraction application involves the interaction of mechanical and biological factors that affect each other. The biological and mechanical forces that shape regeneration play a key role in determining the position of the appliance.

The biological forces affecting the bone regeneration morphology result from the neuromuscular sheath surrounding the region. Mechanical forces, which are under the control of the clinician, occur by activation of the distraction apparatus.[17,19]

The classic idea in the bone formation mechanism is that different tissue types can be formed or remodeling under a specific pressure or loading condition. Chondrogenic and fibroblastic expressions of osteogenic cells are considered to be the result of an unfavorable mechanical environment that causes indirect bone formation (endochondrial ossification) and even fibrous attachment. The presence of direct intramembranous bone formation that occurs during distraction is thought to be a response to osteogenic cells against the applied tensile force.

In fact, the primary target of the applied tensile force may be the induction of angiogenesis, which is known to occur before osteogenic activity, rather than osteoblasts.

The force applied during distraction therapy may increase systemic osteoblast stimulating factors that increase osteoblast activity systemically and locally. Holbein et al. stated that the serum of patients with distraction osteogenesis had mitogenic effects on osteoblastic cells. No effect has been observed in sera from patients in the traditional osteotomy control group. Studies have also shown that there is a difference in serum concentrations of the transforming growth factor (TGF) among patients. On the other hand, the groups showed a similar increase in platellet-derived whole factor (PDGF).[21]

The rate is known as the distance in which bone segments are moved, and the rhythm is known as the number of movements of bone segments per unit time. Many studies indicate that the daily rate of 1-2 mm results in adequate osteogenesis in craniofacial distraction osteogenesis. The rate of distraction is usually 1 mm per day. Some researchers try to prevent early consolidation by applying 2 mm distraction to young patients a day. Others try to prevent fibrous attachment by applying 0.5 mm distraction to elderly patients per day.[22,23]

The distraction applied daily can also be applied at once or in sections. Its application in sections is more advantageous as it helps the formation and development of tissues. In addition, frequent daily distraction in small pieces speeds up the formation of new bone, as a result of the biochemical analysis of this application and the observation that the released substances for osteoblast formation and maturation increase is a proof of this. In addition to increased osteogenesis, split distraction protocols provide less injury to soft tissue and increased vascularization.[3,17,19]

Distraction osteogenesis begins with the formation of a repair callus. Callus forms the new bone with the effect of tensile forces.[3]

The distraction process is examined in 5 clinical stages according to the morphological process and remodeling of the new bone formation:

- Surgical period
- Latent period
- Distraction period
- Consolidation period
- Remodeling period [24]

Surgical Period: It includes the decortication of the bone or the complete osteotomy procedure. The important point in doing this procedure is the necessity of working with conventional methods so as not to disturb the nutrition of the bone. To minimize the risk of delayed consolidation, the corticomy should cause minimal damage to the endosteum and periosteum. In this way, it is aimed to maximize regeneration.[25,26]

Latent Period: To optimize the response of osteogenic tissue to distraction, a latent period has been proposed for early callus formation. It refers to the start of traction after the osteotomy and the process in which callus formation is allowed. Callus formation occurs with the formation of good vascularized granulation tissue with proliferation of endosteal and periosteal cells in the end regions of bone fragments. The events observed in the latent period are the same as those occurring in fracture healing. Traditionally, fracture healing consists of four phases. These include: inflammation, soft callus formation, hard callus formation and remodeling.[2,27]

There are several opinions about the ideal process for maximal osteogenic activity during this period. It is 5-7 days according to Ilizarov, 7 days according to Synder, and 10 days according to Califona. In young patients, this period can be shortened or the consolidation phase can be started without applying.[28,29]

Distraction Period: The distraction process begins by pulling the bone segments in separate directions with external or internal appliances. This action leaves the repair callus under tension. This tension activates skeletal growth factors and transforms capillary cells into osteogenic cells, resulting in new bone formation.[30]

The values of three variables should be determined during the distraction period. These are: the rate of distraction, the rhythm, and the total time required for distraction.[31]

Rate; The amount of daily activation applied to the appliance, and the rhythm; Indicates how many parts of daily activation applied to appliance.[30]

The rate of distraction is approximately 1 mm per day, regardless of species, bone segment distracted and age. The rhythm of the distraction changes as 1 turn per day or 0.25 mm 4 times a day. The total time required for distraction varies depending on the patient and the size of the deformity and the achievement of the desired clinical goals.[10]

Consolidation Period: It is the period from lifting the pulling forces to removing the distraction devices. This period includes the mineralization of immature bone. The distraction apparatus is left at the last stage brought on and the bone is stabilized until the new bone has sufficient strength. Usually 6-8 weeks is enough. According to Ilizarov, this period should not be less than the period in the distraction period.[3]

Remodeling Period: Remodeling is the period when full functional loading is performed on the newly formed bone. During this period, both cortical bone and bone marrow are restored. Havers channels are also remodeled. It takes a year or a little more for the formed bone to fully level with the normal bone. In maxillofacial applications, implants are placed following the 3-month consolidation period. Prosthesis is applied 3 months after implants.[17]

MANDIBULAR DISTRACTION AND APPLIANCES

Clinical distraction osteogenesis applications to the mandible have proven to be a major improvement in the treatment of various craniofacial deformities. Experimental applications in animal mandibular were pioneers in distraction osteogenesis in human

mandible by McCarthy et al.[19] The first experimental distraction study for the craniofacial skeleton was performed in 1973 by Synder et al.[32] Then, in 1977, they practiced Michielli and Miotti in Italy.[33] Until 1990, no study on this subject has been observed. Karp et al. performed unilateral angular osteotomy in the canine mandible.[34]

These researchers found that a very well-organized bioprocess emerged in the enlarged region of the cortical bone formation and histological examination of the area of expansion. In 1992, McCarthy et al. presented the results of the first clinical mandibular lengthening that they successfully performed in four young patients using a bicortical osteotomy and rigid external fixator.[35]

Although there are various details in mandibular distraction applications, the basic principles that must be taken into consideration are:

- Adequate bones must be available for osteotomy and appliance placement.
- Depending on the size of the space required for placement of the apparatus and the amount of mouth opening available, the required clearance can be achieved through an intraoral or extraoral approach.
- A number of factors should be considered when deciding between internal and external appliances. While external appliances allow multi-directional distraction control, this cannot be done with existing internal appliances, whereas external appliances can cause significant scar formation on the face and therefore different distraction vector applications can be preferred to permanent external scars with a series of internal distraction appliances.
- The location of the appliance and / or orientation determines the distraction vector, not the osteotomy of the mandible.
- Before performing an osteotomy, the appliance must be temporarily replaced. Because the proximal segment is mobile after osteotomy, it is difficult to insert the appliance. The osteot-

omy line does not need to be perpendicular to the distraction vector, but should be placed so as not to damage the nerve and developing dentition.

- Buccal corticomy is performed with a special saw, and the greenstick fracture in the lingual is created with a suitable osteotome and the inferior alveolar nerve is protected.
- Before closing the zone, the appliance should be tested and the patient should be told by emphasizing the direction of use of the part used to activate the appliance.

MIDDLE FACE DISTRACTION AND APPLIANCES

Indications of maxillary distraction;

1- Patients with moderate and severe retrusions with large advances requiring large advances.
2- Patients who do not need intermediate bone grafts that need to stretch forward and down
3- Early treatment for growing patients.[36]

Although there are various details in maxillary distraction applications, the basic principles that must be taken into consideration are:

- With the use of external appliances, preoperative preparation typically involves inserting a palatal appliance to guide the distraction vector.
- Osteotetomy should be done conventionally and mobilization of the middle face should be completed.
- To protect the developing dentition at the infraorbital foramen level in children with milk or mixed dentition, typical LeFort I osteotomy should be modified and taken up.
- Midface advances and frontofacial advances at LeFort III level can be done with external or internal appliances depending on the conditions. Internal appliances are placed at the level of the zygoma body and arc. External appliances need palatal apparatus and additionally wires from zygoma, nasal root and supraorbital regions.[37]

BIOLOGICAL BASIS OF DISTRACTION OSTEOGENESIS

In 1993, Rachimel et al presented the findings of the midfielder enhancement they made in the bay with external distractors. For the 43 mm expansion in the lateral maxilla and 36 mm expansion in nasofrontal junction, 2 mm expansion was made daily. [1]

Molina and Ortiz-Monisterio presented the use of an orthodontic protraction mask combined with Le Fort I osteotomy for distraction osteogenesis.[38] After applying this technique, Polley and Figueroa realized that the elastic face mask is not rigid enough to achieve the desired forward movement. They developed an adjustable rigid external distraction (RED) system for maxillary advancement. Indications for use; Some cases and treatments that require major improvement are cleft palates that have resulted in scarring. A crocheted occlusal splint is prepared in advance and a large LeFort osteotomy is performed. Immediately after the closure, the distraction device is placed symmetrically and fixed with 2-3 head screws. The guide wire is connected to the horizontal bar in the distractor by extraoral hooks extending from the splint. There is a 3-4 day latent period and the distraction rate is 1 mm per day. The horizontal bar of the appliance can be adjusted up or down to allow for versatile control of vertical movements with horizontal movements. The consolidation period is 2-3 weeks after the appliance is removed. With this appliance, LeFort I osteotomy, LeFort III osteotomy and monoblock osteotomies can be used. [1,39,40,41]

Molina designed a one-way orbital malar distractor used with Le Fort III osteotomy. The arm in the appliance itself is soft, this provides comfort and function. The active part of the arm extends percutaneously behind the ear and can provide 25 mm of enlargement. At the front end of the appliance, there is a fulcrum that provides flexibility in the displacement of the appliance behind the zygomatic bone.[1]

Chin and Toth designed their own internal appliances for use in the maxillofacial complex. The patients' skeletons used computed tomography information to plan the surgery and design their distractors. Chin and Toth's method for distraction is different from the principles published by Ilizarov in several ways. First, a full thickness osteotomy is performed without preserving the periosteum. Secondly, the latent period is not expected; however, distraction is started directly without closing the operation site.[42]

In 1997, Cohen et al. Developed a system called the Modular Internal Distraction System (MIDS). It is the first internal distraction appliance approved by the FDA. The first generation system includes expansion screws capable of 15mm and 30mm distraction. The flexible activation wire can be inconspicuously away from the operative area, behind the ear, between the hair, or inside the mouth. MID can be easily adapted for mid-face distraction. Appliances are generally well tolerated by patients. Besides all these, a major operation is required to remove the appliance and the amount of tissue removed is disadvantages of the appliance.[43,44,45]

With the currently used internal appliances, midface advances at LeFort I level are limited; because the adaptation and orientation of the appliances in a limited space is limited due to the difficulty of properly adjusting the appliances in the space. Fixation of the apparatus may damage the developing dentition. External multi-directional appliances are preferred because they allow more control in distraction application.[37] However, external appliances have disadvantages such as cumbersome, uncomfortable and poorly tolerated by the patient.[46] This led the researchers to search for new intraoral appliances.

In 2004, Yamaji et al developed a new appliance called LeFort I internal distractor for use in mid-face hypoplasias. This appliance includes the top and bottom plates placed under and above the LeFort I osteotomy. The top plate is U-shaped while the bottom

plate is U-shaped. The anterior and posterior ends of the plates are fixed with screws to the priform protrusion and zygomatic support. The distraction screw is placed parallel to the sagittal plane in the maxillary sinus. The activation bar is attached to the distraction screw with a multi-purpose ligament and extends into the mouth along the maxillary buccal sulcus. This new appliance is designed to show some problems with traditional internal appliances. Advantages of the appliance; Placement of the distraction screw in the maxillary sinus facilitates the placement of the screw parallel to the sagittal plane and provides a wide room for changes in the vertical direction, and this localization is more tolerable by the patient since it does not cause regression in the buccal tissues. Disadvantages of the appliance; An additional application is required to remove the appliance, sufficient bone support is required for loading, and the distraction vector cannot be controlled, as with conventional internal appliances; however, the appliance allows precise control of the distraction vector for better occlusal results.[46]

Maxillary stenosis cases can be corrected by methods such as slow orthodontic expansion, rapid palatal expansion, rapid palatal expansion supported by surgery, and two-segment LeFort I type osteotomy with expansion. As a result of such treatments, unwanted movements may be observed in the supporting teeth and long retention and over correction may be required to prevent skeletal relapse.[37] To prevent these disadvantages, for the first time in 1999, Mommaters introduced a bone-assisted transpalatal distractor (TPD) for maxillary expansion. This appliance has 3 advantages. The first is that the forces are directly attached to the bone so that orthodontic movements are not required, the second is that by changing the telescopic distraction module given in four different sizes, the amount of distraction can be easily changed during the activation phase, and the third advantage is that it allows the teeth to be braced and leveled immediately in the retention phase after treatment. The disadvantage of the apparatus is that the functional components are loosened or damaged.[47,48]

CURRENT DEVELOPMENTS IN APPLIANCES

Distraction appliance has disadvantages such as causing the scar, requiring second surgery to remove it, prolonging treatment time, risk of infection around the appliance. These disadvantages prompted the researchers to make new discoveries.

Resorbable materials largely replace titanium and metal implants in pediatric craniofacial applications. In 1999, Cohen and his friends introduced a new mid-face distractor, which can be partially resorbed.[49] In 2001, Cohen and his friends performed Le Fort III distraction with a partially resorbable appliance. MID system is used in this process. The difference from classical MID is that Macropore meshes can be resorbed instead of titanium meshes. Only the distraction screw and wire need to be removed from the appliance. Since a resorbable stabilizer is used, the distraction wire and screw do not require a consolidation phase and can be removed after the distraction phase.[43,44,45]

In 2002, Burstein et al. developed three types of single-stage distraction appliance based on the LactoSorb resorbable implant system. The first appliance they developed (MOF Apparatus) is used for mid face, orbital and frontal bone distraction. The MOF appliance can be easily applied in any osteotomy design and can combine frontal and orbital bone expansions. The second appliance is the Mandibular Adolescent Appliance (MA Appliance) that can be used in older children and adolescents with sufficient bone volume. The third appliance is used for mandibular distraction in newborns, infants and young children with very low bone volume. (MI Appliance).[49]

Various agents are used clinically and experimentally as distraction osteogenesis mediators. In one study, the effects of calcium sulfate, hyalunaric acid and chitosan on distraction osteogenesis in early bone consolidation were investigated in canine models, and materials combined with calcium sulfate and calcium sulfate were found to be partially effective in early bone consolidation.[50]

Today, distraction osteogenesis is used safely in many treatment methods such as the treatment of skeletal deformities and providing the proper bone volume for implant treatment.

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