ISSN: 2581-5989
PubMed - National Library of Medicine - ID: 101738774

International Journal of Dental Science and Innovative Research (IJDSIR)

IJDSIR : Dental Publication Service

Available Online at:www.ijdsir.com

Volume – 7, Issue – 5, October – 2024, Page No. : 216 - 222

Speedy Orthodontics: Distraction Osteogenesis – A Review

[1]Shivangi Mathur, PG Student, Department of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

[2]Atul Singh, HOD, Department of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

[3]Shabista Tahseen, Senior Lecturer, Department Of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

[4]Taw Mepu, PG Student, Department of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

[5]Pooja Sharma, Professor, Department Of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

Corresponding Author: Shivangi Mathur, PG Student, Department of Orthodontics and Dentofacial Orthopedics, KD Dental College, Mathura, India

Citation of this Article: Shivangi Mathur, Atul Singh, Shabista Tahseen, Taw Mepu, Pooja Sharma, “Speedy Orthodontics: Distraction Osteogenesis – A Review”, IJDSIR- October – 2024, Volume –7, Issue - 5, P. No. 216 – 222.

Type of Publication: Review Article

Conflicts of Interest: Nil

Abstract

Distraction osteogenesis (DO) is a surgical technique that leverages the body’s natural wound healing processes to enhance bone and soft tissue. This method is highly versatile and can be applied to almost any bone. In the craniofacial region, the cranial vault, midface, maxilla, and mandible are the most common areas for DO. This technique enables larger skeletal movements than traditional methods, reduces operative time and blood loss, eliminates the need for bone grafts and the associated morbidity of donor sites, and may enhance postoperative stability. DO can be utilized as a preparatory measure, as an alternative, or in conjunction with orthognathic surgery to correct dentofacial deformities. Achieving optimal results with DO requires careful and meticulous planning.

Keywords: Distraction osteogenesis, speedy orthodontics, orthognathic surgery, osteogenic traction, accelerated orthodontics.

Introduction

Distraction osteogenesis (DO), also called callus distraction, callotasis, osteo-distraction, or distraction histogenesis, is a biological process that generates new bone and soft tissue by gradually and carefully pulling apart surgically separated bone segments.[1] In simpler terms, it involves the slow and continuous application of force to create a gap in the bone, allowing new bone and soft tissues to form. As the bone edges move apart during distraction, the surrounding soft tissue is stretched, resulting in hyperplasia of the nearby tissues.

Traditionally, skeletal deformities have been addressed using functional orthopedics in growing patients or orthognathic surgery with skeletal fixation in non-growing patients. However, challenges such as the adaptation and stability of the surrounding muscles and soft tissues are limitations and points of debate for both orthognathic surgery and functional orthopedics. Many congenital deformities require significant skeletal movement, which may not be achievable with orthognathic surgery, potentially compromising both function and aesthetics. A major drawback of orthognathic surgery is that it only allows for sudden changes in the skeletal arrangement, rather than promoting new bone formation, often necessitating bone grafts. Additionally, it does not facilitate changes in the shape and size of bones that would enhance the patient's structural integrity, functional balance, and aesthetics.[2-4]

The distraction technique offers broad applications in various fields of dentistry, such as surgical orthodontics, facial orthopedics, and oral rehabilitation, where one of the primary challenges is alveolar bone loss, which affects support for prosthetics, implants, and surrounding soft tissues. Recent clinical studies have recognized the successful use of osteodistraction in treating craniofacial skeletal deformities. Gradual incremental traction of the mandible has enabled up to 20 mm of lengthening without causing pain.[4-6]

History

Since the 18th century, dental traction principles have been widely used in dentistry to correct skeletal deficiencies. In 1728, Pierre Fauchard demonstrated the use of the expansion arch, where a metal plate was attached to the crowded teeth to gradually widen them into a normal alignment. However, the main limitation of this technique was that it primarily caused tooth movement with minimal impact on the underlying skeletal tissue.

In 1859, Wescott was the first to document the use of mechanical forces on the maxillary bones. He employed two double clasps connected by a telescopic bar to correct a crossbite in a 15-year-old girl. However, the main disadvantages of this method were its slow process and extended treatment time. Later, Angell introduced a similar approach using a differentially threaded jackscrew attached to the premolars, achieving palatal expansion by separating the maxillary bones at the mid-palatal suture within 2 weeks. In 1893, Goddard refined the palatal expansion technique by activating the device twice daily for 3 weeks, followed by a stabilization period to allow the deposition of "osseous material" in the resulting gap.[22]

In 1905, Alessandro Codivilla introduced surgical techniques for lengthening the lower extremities. In 1934, the New York Hospital for Joint Diseases worked on an early method pioneered by Ilizarov. The U.S. surgical team developed the idea of using a metal frame to stabilize the limb until healing was complete. A significant advancement came with Russian orthopedic surgeon Gavril Ilizarov, who developed a procedure that promoted new bone formation and regeneration of surrounding soft tissues through controlled tension.[7]

According to Wassmund in 1927, intraoral tooth borne appliances for first mandibular distraction osteogenesis which was gradually activated over a period of 1 month which was carried out by Rosenthal.[10] In 1937, Kazanjian implemented a new protocol for mandibular osteodistraction by using gradual incremental fraction. After L-Shaped osteotomies in corpus he attached a wire hook to the symphysis, thereby providing direct skeletal fixation.[14]

In 1948, although Crawford applied gradual incremental traction to fracture the callus of the mandible, this technique did not gain immediate acceptance.[15] In 1957, Trauner and Obwegeser introduced the concept of sagittal split osteotomy. Various experimental studies involving distraction devices on craniofacial bones, particularly in dogs, were conducted in 1976. The first publication highlighting the application of Ilizarov's principles to the mandible was published by Snyder et al. in 1973.[8,9]

McCarthy et al. first applied the principle of DO in craniofacial skeleton in lengthening of hypoplastic mandible.[11,12] In 1998, Liou and Huang first reported Periodontal Distraction followed by other authors.[13]

Biology & Mechanics of Distraction osteogenesis:

Bone is a highly complex and specialized structural component of the body, known for its stiffness, rigidity, and remarkable ability to repair and regenerate. According to Taichman, bone serves as a reservoir for calcium homeostasis, growth factors, and cytokines, and also contributes to acid–base regulation. Bone constantly undergoes remodeling throughout life to adapt to biomechanical stresses, replacing old bone with new, stronger tissue to maintain strength. This remodeling process is influenced by several factors, including nutrition, disease, and mechanical conditions, which can impact the quantity and quality of bone depending on their severity and duration.[16]

Functionally, bone can be viewed as a hierarchical composite material, composed of organic and inorganic components along with water. The organic component, primarily collagen, provides resilience and tensile strength, while the inorganic, mineralized matrix imparts compressive strength. Additionally, the inorganic matrix serves as a protective covering for osteocytes, the most abundant bone cells in the body. Osteocytes, once bone-forming osteoblasts, become encased in their own matrix and reside in small cavities called lacunae. These lacunae are interconnected by tiny channels known as canaliculi, which are immersed in interstitial fluid, enabling the exchange of nutrients. This lacuna–canalicular network may also play a crucial role in transmitting mechanical signals.[17]

The mechanical response of bone to stress is determined by its shape, size, and material composition. This response significantly influences how bone fractures in response to different types of trauma:

1. Low-Velocity Trauma: When bone is subjected to low-velocity forces, it has enough time to absorb the impact energy, resulting in a simple fracture characterized by a clean break with typically two fragments. Such fractures tend to heal more effectively and are generally more stable.
2. High-Velocity Trauma: Conversely, high-velocity impacts do not allow sufficient time for the bone to dissipate the energy, leading to more severe injuries known as comminuted fractures. These fractures occur when the bone shatters into multiple pieces, making them more complex to treat and complicating the healing process.
3. Distraction Osteogenesis: During procedures like distraction osteogenesis, which involve intentional bone lengthening, it is crucial to achieve a stable fracture at the site of osteotomy or corticotomy. A noncomminuted, simple fracture is vital for ensuring successful outcomes, as it provides the necessary stability for the newly formed bone to withstand the forces applied during the distraction process.[26]

According to Karp et al., the histological healing process in distraction osteogenesis (DO) differs from that of a typical fracture in two fundamental ways:

1. Controlled Microtrauma: In distraction osteogenesis, controlled microtrauma occurs within the distraction gap.

2. Membranous Ossification: Unlike fractures that heal primarily through endochondral ossification, distraction osteogenesis is characterized by membranous ossification.[27]

Phases of Distraction osteogenesis:

The distraction process comprises three fundamental sequential phases, each inducing distinct biological phenomena:

1. Latency Phase: This phase occurs between the osteotomy and the activation of the distraction device. The purpose of the latency period is to allow the formation of a primary bone callus, which stimulates the influx of biochemicals that support bone growth. Ilizarov recommended a latency period of 5 to 7 days, although some studies have questioned the necessity of this delay.[18-20]
2. Distraction Phase: During this phase, the distraction device is gradually activated, leading to the neoformation of tissue along the direction of distraction. The rate of activation can significantly influence ossification within the gap and the expansion of surrounding tissues. Rapid distraction may result in nonunion or increased neuropraxia, while slow activation may lead to premature consolidation. The original Ilizarov protocol for long bones suggested a total activation rate of 1 mm per day, divided into four increments of 0.25 mm each. In contrast, in the maxillofacial skeleton, which has a rich blood supply that facilitates predictable healing, distraction rates of up to 3 mm per day have been successfully employed.[19,20]
3. Consolidation Phase: This phase begins once distraction is complete. The distraction device remains in place, providing stabilization to prevent micromotion of the separated segments while ossification occurs. The commonly reported consolidation periods range from 4 to 12 weeks, with 8 weeks generally considered sufficient. Insufficient consolidation can lead to non-union. Once the consolidation period is complete, the distraction device is removed.[18,21]

Indications

- Severe mandibular retrognathia/micrognathia
- Craniofacial syndromes: hemifacial microsomia, Treacher Collins syndrome, Nager syndrome, Pierre Robin sequence
- Severe mandibular asymmetry
- Post-traumatic deficient mandibular growth and temporomandibular joint ankylosis
- Revision mandibular orthognathic surgery
- Mandibular retrognathia with temporomandibular joint disease or juvenile rheumatoid arthritis
- Mandibular retrognathia with obstructive sleep apnea
- Mandibular defects from tumor resection[22]

Advantages

- ➢ Allows greater mandibular lengthening of 10–30 mm
- ➢ Can be applied to unusual bony and soft tissue anatomy
- ➢ Allows slow gradual soft tissue adaptation to extreme mandibular lengthening
- ➢ Minimal to no skeletal relapse after extreme mandibular lengthening
- ➢ Can be applied to neonates, infants, and pediatric patients with obstructive sleep apnea
- ➢ Less invasive surgery compared with bone-grafting procedures
- ➢ Avoids intermaxillary fixation 8. Avoids bone grafting and potential donor-site morbidity
- ➢ Can be used for mandibular widening

- Fewer adverse temporomandibular joint effects in response to asymmetric lengthening
- Decreased hospitalization time and cost compared with bone grafting
- Less need for blood transfusion.[22]

Disadvantages

- Cutaneous scars
- Technique sensitive surgery, equipment sensitive surgery
- Possible need for second surgery to remove distraction device and patient compliance
- Transient changes in temporomandibular joint
- An adequate bone stock is necessary to accept the distraction appliances and to provide suitable
- opposing surface capable of generating a healing callus
- Damage to tooth germ 8. Premature consolidation
- Damage to inferior alveolar nerve
- Bilateral Coronoid Ankylosis
- Tendency towards clockwise rotation.[22]

Orthodontic considerations in distraction osteogenesis

Pre-Surgical Orthodontics: The pre-surgical orthodontic preparation for mandibular distraction begins once a treatment plan has been developed. A thoughtfully designed pre-surgical orthodontic approach is crucial for achieving optimal functional and aesthetic results. It is important that the teeth are positioned ideally in relation to the basal bone to prevent any existing dental malocclusion from interfering with the maxillomandibular skeletal relationship.

Another vital component of pre-distraction orthodontic treatment is the fabrication of a distraction stabilization appliance. These appliances are typically placed prior to surgery for patients undergoing distraction osteogenesis. They serve to maintain the mediolateral dental interarch relationship and are particularly beneficial for patients who do not need specific tooth movements and have limited compliance. The distraction appliance comprises a banded maxillary expansion appliance and a mandibular lingual arch, equipped with symmetrically positioned buccal and lingual ball hooks. These ball hooks provide multiple options for using interarch elastics, enabling effective control of the mandibular position throughout the distraction, consolidation, and post-consolidation phases.[23]

Orthodontic Treatment During Distraction and Consolidation: After completing the pre-surgical orthodontic preparation, the surgical procedure is carried out. The orthodontic and orthopedic treatment during this phase may involve various appliances, including bands, brackets, distraction stabilization devices, elastics, headgear, acrylic guidance appliances, and maxillary expansion devices, as well as functional appliances. These tools play a crucial role in enhancing the quality of the surgical and orthodontic outcomes by guiding the tooth-bearing segments toward their intended positions following distraction.[24,25]

Post-Consolidation Orthodontic/Orthopedic Management: Once consolidation is complete, the distraction device is removed, and the tooth-bearing segment of the mandible receives support from the new bone formed across the distraction gap. The post-distraction orthodontic requirements differ based on whether the mandibular distraction was unilateral or bilateral. For patients undergoing bilateral distraction who are still growing, a temporary treatment objective may involve overcorrecting the mandible to compensate for any deficiencies.[22]

Conclusion

Distraction osteogenesis of the craniofacial skeleton has introduced significant new opportunities for treating both severe and mild skeletal deformities. The development of efficient and precise mini-distraction devices is expected to greatly enhance the ability to address mild skeletal growth abnormalities. These devices can be placed beneath the skin and adjusted using small transcutaneous screws. As a result, surgeons and orthodontists are now collaborating in a process that gradually modifies the direction and magnitude of craniofacial growth.

References

1. Cope JB, Samchukov ML, Cherkashin AM. Mandibular distraction osteogene sis: a historic perspective and future directions. Am J Orthod Dentofac Orthop 1999;115:448–60.
2. Trauner R, Obwegeser H. The surgical correction of mandibular prognathism and retrognathia with consideration of genioplasty: Part I. Surgical procedures to correct mandibular prognathism and reshaping of the chin. Oral surgery, oral medicine, oral pathology. 1957 Jul 1;10(7):677-89.
3. Schendel SA, Epker BN. Results after mandibular advancement surgery: an analysis of 87 cases. Journal of oral surgery (American Dental Association: 1965). 1980 Apr;38(4):265-82.
4. Converse JM, Horowitz SL. The surgical-orthodontic approach to the treatment of dentofacial deformities. American journal of orthodontics. 1969 Mar 1;55(3):217 43.
5. Cassidy DW, Herbosa EG, Rotskoff KS, Johnston LE. A comparison of surgery and orthodontics in “borderline” adults with Class II, division 1 malocclusions. American Journal of Orthodontics and Dentofacial Orthopedics. 1993 Nov 30;104(5):455-70.
6. Longaker MT, Siebert JW. Microsurgical correction of facial contour in congenital craniofacial malformations: the marriage of hard and soft tissue. Plastic and reconstructive surgery. 1996 Nov 1;98(6):942-50.
7. Codivilla A. On the means of lengthening, in the lower limbs, the muscles and tissues which are shortened through deformity. JBJS. 1905 Apr 1;2(4):353-69.
8. Ilizarov GA. The tension-stress effect on the genesis and growth of tissues: Part I. The influence of stability of fixation and soft-tissue preservation. Clinical orthopaedics and related research. 1989 Jan 1;238:249 81.
9. Ilizarov GA. The tension-stress effect on the genesis and growth of tissues: Part II. The influence of the rate and frequency of distraction. Clinical orthopaedics and related research. 1989 Feb 1;239:263-85.
10. Wassmund M. Lehrbuch der Praktischen Chirurgie des Mundes und der Kiefer. Band 1. Leizig: Hermann Meusser 1935;275.
11. McCarthry JG, Schreiber JS, Karp NS, Thorne CH, Grayson BH. Lengthening the human mandible by gradual distraction. Plast Reconstr Surg 1992;89:1–10.
12. McCarthy JG. The role of distraction osteogenesis in the reconstruction of the mandible in unilateral craniofacial microsomia. Clin Plast Surg 1994;21:625–31.
13. Liou EJW, Huang CS. Rapid canine retraction through distraction of the peri odontal ligament. Am J Orthod Dentofac Orthop 1998;114:372–82.
14. Kazanjian VH. The Interrelation of Dentistry and Surgery in the Treatment of Deformities of the Face and Jaws. American Journal of Orthodontics and Oral Surgery. 1941 Jan 1;27(1):C10-30.

15. Crawford MJ. Selection of appliances for typical facial fractures. Oral Surgery, Oral Medicine, Oral Pathology. 1948 May 1;1(5):442-51.
16. Taichman RS. Blood and bone: two tissues whose fates are intertwined to create the hematopoietic stem cell niche. Blood 2005;105:2631–9.
17. Saunders MM, Lee JS. The influence of mechanical environment on bone healing and distraction osteogenesis. Atlas Oral Maxillofac Surg Clin N Am 2008;16:147–58.
18. Karaharju-Suvanto T, Peltonen J, Kahri A, Karaharju EO. Distraction osteogenesis of the mandible. An exper imental study on sheep. Int J Oral Maxillofac Surg. 1992;21:118–121.
19. Troulis MJ, Glowacki J, Perrott DH, Kaban LB. Effects of latency and rate on bone formation in a porcine mandib ular distraction model. J Craniomaxillofac Surg. 2000;58:507–513. discussion 14.
20. Biskup N, Altman AL, Runyan CM, et al. Neonatal man dibular distraction without a consolidation period: is it safe? Is it effective? J Craniofac Surg. 2017; 28:1942–1945.
21. Pereira MA, Luiz de Freitas PH, da Rosa TF, Xavier CB. Understanding distraction osteogenesis on the maxillofa cial complex: a literature review. J Oral Maxillofac Surg. 2007; 65:2518–2523.
22. Vedavathi H.K., Chirag Arora, Bharath Reddy, Sowmya K.S., Goutham N. The role of orthodontist in distraction osteogenesis. Indian Journal of Orthodontics and Dentofacial Research, July-September 2017;3(3):141-147
23. Hanson PR, Melugin MB. Orthodontic management of the undergoing mandibular distraction osteogenesis. In Seminars in orthodontics 1999 Mar 1 (Vol. 5, No. 1, pp. 25-34). WB Saunders.
24. Grayson BH, McCormick S, Santiago PE, McCarthy JG. Vector of device placement and trajectory of mandibular distraction. Journal of Craniofacial Surgery. 1997 Nov 1;8(6):473-80.
25. Losken HW, Patterson GT, Tate D, Coit DW. Geometric evaluation of mandibular distraction. Journal of Craniofacial Surgery. 1995 Sep 1;6(5):395-400
26. Singh M, et al. Biological basis of distraction osteogenesis – A review. J Oral Maxillofac Surg Med Pathol (2015), http://dx.doi.org/10.1016/j.ajoms.2015.05.006
27. Karp NS, McCarthy JG, Schreiber JS, Sissons HA, Thorne CH. Membranous bone lengthening: a serial histologic study. Ann Plast Surg 1992;29:2–7.