

Review Article

Distraction osteogenesis: a review on management of acquired and congenital deformities

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Received: 20 August 2026

Revised: 19 September 2026

Accepted: 03 October 2026

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ABSTRACT

Distraction osteogenesis which is also called as callus distraction or callotasis is used to restore the skeletal deformities and in reconstructive surgery. Most commonly, it is carried out in the department of oral maxillofacial surgery, orthopaedics and paediatric surgery. It is a very favourable and effective method for stable long-term effects. The use of distraction osteogenesis is found to have increased multiple folds in the last decade. And this is attributed to its advantages like little relapse, bigger movements range, generation of soft tissue, less likelihood of nerve injury, less likelihood of idiopathic condylar resorption. Some important applications of distraction osteogenesis are as an alternative to conventional surgery for maxillary and mandibular lengthening and reconstruction of alveolar segmental defects after tumour resection before implant installation.¹ The distracter devices are found to transfer forces and they act as a rigid support for bone consolidation to occur. In this article, an attempt has been made to review the evolution of distraction osteogenesis over eons.

Keywords: Mandibular distraction, Obstructive sleep apnoea, Orthognathic, Midface distraction, Facial hypoplasia, Retrognathia

INTRODUCTION

Distraction osteogenesis is defined as neo bone generation in an osteotomy gap in response to tensional stresses applied across the osteotomy gap. Codivilla in 1905, was the 1st to elongate a femur by repeated distraction forces. The technique of bone lengthening by gradual distraction was further developed and popularized by Ilizarov.¹

He performed an extensive experiment on canine tibia.

Ilizarov and distraction osteogenesis

1st set: increasing level of stability of distraction apparatus; 2nd set: the effect of preservation of bone marrow and blood supply; and 3rd set: effect of rate and frequency.

Ilizarov's postulates

Maximum preservation of marrow and periosteal blood supply by performing a closed corticotomy. Stable fixation

to eliminate micromotion at distraction site. Delay of 5 – 7 days before commencing distraction (Latency phase); distraction rate of 1 mm / day; and distraction in frequent small steps instead of single step. Period of neutral fixation (Consolidation phase); normal physiologic use of the limb.

The five basic chronologic steps in distraction osteogenesis: application of the distraction device and performance of atraumatic osteotomy/corticotomy; mesenchymal proliferation during the 7-day latency period; gradual slow distraction of the viscoelastic growth interzone in the middle of parallel columns of intramembranous new bone; gradual ossification of the growth zone and maturation of the regenerated new bone with early neocorticalization during the postdistraction consolidation period under neutral fixation; and after removal of the distraction device slow final remodeling period with restoration of the normal cortical and medullary architecture.

Historical background

McCarthy 1992: 1st distraction osteogenesis for mandibular lengthening; Costantino 1990: segmental distraction osteogenesis; and Stucki et al: role of pseudodisc in RCU reconstruction.

Distraction histiogenesis

Simultaneous lengthening of soft tissue envelope along with distracted bone. It gives better, stable environment for the regenerated bone.

TYPES OF DISTRACTION

The types of distraction are monofocal distraction, bifocal distraction and trifocal and distraction.

Monofocal Distraction is used to lengthen abnormally shortened bones and involves separation of two bone segments across a single osteotomy.

Bifocal Distraction is used to repair a segmental defect and requires creation of a transport disk, which is then distracted across the defect until it docks with the opposing bony segment.

Trifocal Distraction is similar to bifocal distraction attempts to halve the distraction time by transporting 2 disks from opposite ends of a defect to dock in the middle.

TYPES OF DISTRACTORS^{2,3}

The two types of distractors are external and internal distractors.

Advantages of external distractors are multidirectional movement, freedom in selecting desired vector, ability to change vector of incremental advancements during activation, easy to remove.

Disadvantages of external distractors are unavoidable scars due to pin tracts infection, pin loosening, patient compliance during consolidation phase (psychosocial issue).

Advantages of internal distractors are elimination of skin scar, hidden intraorally, improved patient compliance, improved stability of the attachment of the device to the bone.

Disadvantages of internal distractors are the need for precise positioning of the device, alignment between devices on two sides and angulation, inability to alter the distraction vector during the process, need for a second major surgery for removal.

Mechanism of muscle lengthening

Distraction induced stretch in muscle. Focal necrosis, microlesions in individual muscle fibres. Damage to basal lamina releases satellite cells. Satellite cells induce massive proliferation of myoblasts which fuse into myotubes and get arranged in fibrils.

Effect of distraction rate on muscle growth

Rapid rates of distraction led to necrosis of muscle. 0.4 mm distraction is most adaptive for muscle growth but led to premature consolidation. A rate of 0.75-1 mm/day has been accepted clinically acceptable.

Effect of gradual traction on peripheral nerve

First 15% lengthening showed degenerative changes in myelinated nerves only. 20% lengthening showed changes in unmyelinated nerve as well. 25-50% lengthening showed severe nerve damage with wallerian degeneration. Barkate and colleagues showed that a peripheral nerve could be lengthened by no more than 15%-20%. Samchukhov et al reported that a gradual distraction of 10mm is safe for IAN in mandibular lengthening.

PHASES OF DISTRACTION

Phase I-surgery: Corticotomy is done to preserve blood supply.

Phase II-latency: Ilizarov recommended 5-7 days; McCarthy et al decreased latency period to 3-5 days. Hollier et al did osteodistraction of 22 children with zero latency and 2mm/day rate with satisfactory results.

Phase III-distraction: rate is no less than 0.5 mm and no more than 1.5-2mm; and rhythm: 0.5 mm twice daily.

Phase IV-consolidation: at least thrice the period of activation

MANDIBULAR DISTRACTION

Planning of vector

Ramal deficiency (vertical): perpendicular to the occlusal plane; corpus deficiency (horizontal): parallel to the occlusal plane; and combined deficiency: oblique placement.

SURGICAL STEPS

Access: Subfascial and epiglandular approach (corridor of access); osteotomy and vector transfer; corticotomy and device placement; activation testing; and final device fixation.

TRANSPORT DISC DISTRACTION OSTEOGENESIS⁴

Ilizarov in 1949 defined distraction osteogenesis as neo bone generation in an osteotomy gap in response to tensional stresses applied across the osteotomy gap. In

transport distraction the leading edge of transport disc becomes enveloped by the fibrocartilaginous cap and if the cap is not removed then a pseudoarticulation/pseudo-disc develops. Reverse L Osteotomy of ramus and Osteoarthrectomy under GA with placement of distractor is done followed by buccal fat interpositioning. Distraction and consolidation for 3 months is done and distractor is removed. Follow up is done for mouth opening exercises and excursive movements. Transport Disc Advancement is done 1mm/day till the discontinuity defect is filled.

The 3 points of fixation are necessary for transport DO: proximal stump; distal side; and transport disc.

Once the transport disc reaches the docking site, the segment is held in neutral position or fixed until cortical outline is formed. Transport disc becomes rounded and encased with fibro cartilaginous cap. Removal is necessary for bony union. At the time of distractor removal, surgeon might have to place bone graft between docking site and transport disc.

Table 1: Factors affecting distraction osteogenesis.

Local bone healing factors	Systemic bone healing factors	Distraction factors
Osteoprogenitor supply	Age	Rate of distraction
Blood supply	Metabolic disorders	Frequency of distraction
Infection	Vitamin D deficiency	Latency period
Soft tissue scarring	Connective tissue disease	Rigidity of fixation
Bone stock	Steroid therapy	Adequate consolidation period
Prior radiation therapy	Calcium deficiency	Length of regenerate

COMPLICATIONS

Intraoperative complications: Bleeding, neurosensory deficits, inadequate osteotomy, fracture of bone and device associated complications.

Interoperative complications: Inappropriate vector, pin infection/loosening, device loosening, dislodgement, device failure, soft-tissue entrapment, asymmetrical distraction, premature consolidation, dentigerous cyst formation, coronoid process interference, fibrous pseudoarthrosis, paraesthesia and trismus.^{5,6}

Post distraction: Open bite, relapse and poor growth.

MID FACIAL DISTRACTION

1942: Gillies published the first high maxillary osteotomy to correct midface deficiency secondary to Craniosynostosis. 1957: Longacre used autogenous rib grafts for improvement of total mid-face deficiency. 1967: Paul Tessier reported that mobilization and expansion of the entire midface by means of a sub-cranial LeFort III osteotomy was possible.

More recent work has been done using the technique of distraction osteogenesis on the midline, but the basic osteotomy cuts remain the same.

Indications

Syndromic: craniosynostosis (Apert's / Crouzon's); and non-syndromic midface retrusion or a post-traumatic deformity

Surgical technique

Coronal incision: exposure of the frontotemporal skull, lateral orbital region, nasion, zygomatic arch and the zygomatic body; Anterior cutaneous incision: to access orbital floor and anterior surface of maxilla for additional osteotomies; Subciliary/Infraorbital/Transconjunctival incision; and Intraoral maxillary vestibular approach.

OSTEOTOMIES

Zygomatic osteotomy: Vertical osteotomy at the body of the zygoma, splitting the lateral orbital rim in half extending slightly above and medial to FZ provides larger bone surface and callus for distraction osteogenesis.

Lateral orbital wall osteotomy: With careful globe protection, the lateral orbital wall osteotomy is initiated 10mm behind the lateral orbital rim through the inferior orbital fissure to meet previous osteotomy above frontozygomatic suture.

Frontonasal osteotomy: The horizontal osteotomy extending over the nasal bones is completed 5mm inferior to the nasofrontal suture in a direction posterior-inferior and superior to the medial canthal tendon and nasolacrimal apparatus.

Medial orbital wall osteotomy: It is performed using an osteotome posterior to the posterior lacrimal crest directed towards the floor of the orbit. This osteotomy meets the lateral wall osteotomy in the floor of the orbit anterior to the inferior orbital fissure.

Pterygomaxillary junction: It is separated bilaterally using a curved pterygoid osteotome approach via the temporal fossa. The same can also be done through intraoral maxillary vestibular approach. The curved osteotome should be directed anteriorly, medially and inferiorly at the pterygoid plate.

Nasal septal osteotomy: It is the last step because this area is highly vascular and leads to troublesome bleeding. The nasal osteotome is used to separate the nasal septal osteotome is used to separate the nasal septum from the cranial base. The direction of the osteotome is parallel to the base of the skull and directed toward the posterior nasal spine as palpated transorally.

Maxillary disimpaction forceps: These are applied to mobilize the midfacial segment. Care must be taken to avoid excess traction on the orbital neurovascular structures or excessive unilateral traction on the zygomas, resulting in fracture.

FIXATION

The subcranial Le-Fort III osteotomy requires four points of fixation at two separate vertical levels to achieve optimal multivector distraction i.e. Infraorbital foot plate, Intra oral orthodontic wire splint, Maxillary footplate (Nasomaxillary, Zygomatic buttress).

Halo frame fixation

For sub-cranial Le-Fort III, external Distractor placement is done by adjusting the transverse width of the device, allowing the lateral arm to extend wider than the scalp or hair by 2 cm, bilaterally. The halo frame should be aligned parallel to the Frankfort horizontal plane.

Le-Fort III distraction protocol

DO initiated after 1 week. The rate of distraction is 1mm/day in twice daily activation. The duration of DO depends on the desired advancement. During the

distraction period, vector modifications can be done, when necessary, in patients treated with an external distractor. In all patients, a consolidation period of 3 months after the distraction is advisable.

Intraoperative complications^{7,8}

Hemorrhage result primarily from the pterygomaxillary dysjunction and down-fracture, can be managed by reimpacting the maxilla; The pterygomaxillary separation procedure used in Le-Fort osteotomies can cause an atypical fracture that extends to the skull base, orbit or pterygoid plate; Patients with syndromic craniosynostosis in which the cranial base is abnormal may be particularly vulnerable to unexpected fracture; Lethal subarachnoid hemorrhage after Le-Fort III osteotomy followed by fracture of base of skull may occur; CSF Leak (Rhinorrhea) due to fracture of cribriform plate while nasal septal osteotomy; Chemosis; Minor complications include: Infra-orbital nerve injury,⁹ fracture of zygoma during mobilization and partial exposure of the nasal bone.

Postoperative complications

Major complications include: Respiratory distress requiring tracheostomy; Subgaleal hematoma or orbital hematoma; Cerebro-spinal fluid leakage and fistula; Visual loss after retro-orbital hemorrhage; Strabismus; and Partial anosmia.

Late complications include; Ptosis: due to loss of support of lids by the globe, when the lids are moved forward with bony orbits.¹⁰ Most important shortcoming is the tendency of medial canthi to drift away from nose causing widening of inter-canthal distance.

DISTRACTION IN SLEEP APNOEA^{11,12}

Sleep apnoea is classified as central, obstructive and mixed.

Central OSA: Respiratory muscle activity ceases simultaneously with air flow at mouth and nostrils. CNS Disorders includes brainstem neoplasms, infarctions and spinal injury.

Obstructive OSA: Sleep induced obstruction of the upper airway that results in cessation of airflow from the nostrils/mouth for atleast 10 seconds with preservation of respiratory effect, respiratory centre drive and diaphragmatic contraction.

Mixed OSA: Combination of both. Begins with an episode of central apnea with no airflow at nostrils/mouth and no respiratory muscle activity ends with an episode of OSA with only cessation of airflow at the mouth/nostrils.

Predisposing factors involve, anatomical: Jaw malformation, enlarged tongue, nasal obstruction, enlarged tonsils and adenoids, upper airway tumor,

enlarged soft palate, laryngopharynx, floppy epiglottis, obesity.

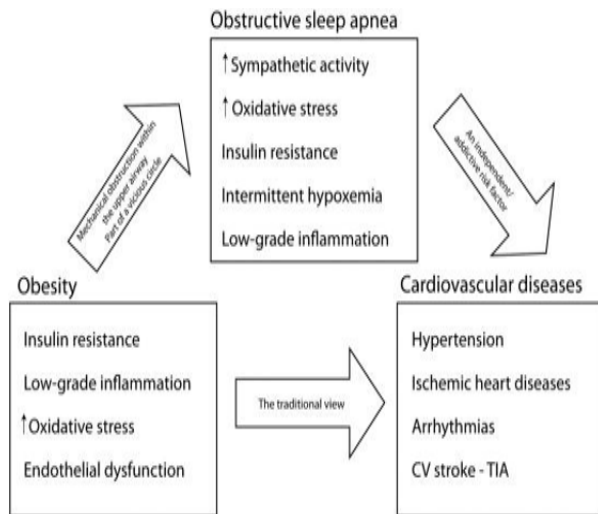


Figure 10: Distraction osteogenesis in OSA.

Indications for distraction osteogenesis in OSA

Infants and children with airway obstruction as a result of congenital micrognathia or midface hypoplasia Treacher Collins or Nager syndromes, craniofacial microsomia, syndromic or nonsyndromic Robin sequence and syndromic or nonsyndromic midface hypoplasia Retrognathia secondary to TMJ ankylosis. Significant number of these patients are tracheostomy-dependent and they require large advancements (>15 mm) to adequately improve the upper airway. Because of the magnitude of advancement needed, DO is the treatment of choice. The ultimate goal is to prevent tracheostomy or to decannulate the trachea in patients who already have a surgical airway.

RECENT ADVANCES AND FUTURE PERSPECTIVES

Major disadvantage relates to the prolonged consolidation phase. During this time period many complications can occur, including local infections, distractor device or pin loosening and refractures.

Table 1: Summary of mandibular distraction osteogenesis studies with growth factors and hormone proteins.

Author	Country	Model	Study material	Control groups	Assessment methods	Results
Issa et al ¹³	Brazil	Rats	BMP-2/monolein gel (acute distraction)	Conventional and acute distraction without BMP-2	Histomorphometry	Significantly higher bone volume in the study group No difference in the degree of new bone formation between acute and gradual distraction groups
Zheng et al ¹⁴	China	Rabbits	BMP-2 at different doses and at 3 different time sequences	No BMP-2	Micro CT Histology	Significantly dose dependent increases in bone formation and remodeling in the BMP-2 groups No difference between different dosage regimens.
Terheyden et al ¹⁵	Germany	Rats	BMP-7 injections	Acetate buffer injections	Histology Mechanical testing	More mature bone formation in the study specimens Significantly greater strength in the study specimens
Cho et al ¹⁶	South Korea	Dog	Growth hormone injections	Saline Injections	BMD Micro CT Mechanical testing Histology	Higher radiodensity and more mature bone in the study group Significantly higher BMD, BMC, and peak load in the study group
Mutlu et al ¹⁷	Turkey	Rabbits	Hyperbaric Oxygen	No Hyperbaric Oxygen	Occusal Radiographs Histomorphometry	Significantly higher density in the study group More mature bone formation in the study group

CONCLUSION

DO allows large advancements (more than 15 mm) without the need for bone grafting and with less risk of relapse. Phases of distraction osteogenesis are surgery, latency, distraction and consolidation. DO is a boon in treatment of obstructive sleep apnoea. TDDO can be used in treatment of RCU reconstruction and segmental defects of mandible with least morbidity. Transport disk should be of sufficient length to reduce the chances of resorption at least 1.5 cm. Acquired or congenital deformities can be successfully managed by nice planning and execution of DO. Multiple adjuvant therapies have been used for enhancing bone formation in consolidation phase like BMP2, low level laser and hyperbaric oxygen with favorable results. Close follow up and individualized treatment is necessary to reduce the chances of untoward outcomes.

Funding: No funding sources

Conflict of interest: None declared

Ethical approval: Not required

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Cite this article as: Kour R, Grack V, Kour A. Distraction osteogenesis: a review on management of acquired and congenital deformities. Int J Res Med Sci 2026;14:5493-8.