Computer-Guided Mandibular Distraction Osteogenesis: A Clinical Study

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Disclosure

This thesis was a part of a clinical and experimental project conducted on distraction osteogenesis to assess the effect of Bone Marrow Aspirate Concentrate on bone quality during distraction osteogenesis. This project included thesis of my colleagues Yasser Mohamed Nabil El Hadidi entitled (The Effect of Bone Marrow Aspirate Concentrate on Bone Regenerate During Rapid Mandibular Distraction Osteogenesis), and Mohamed Seif entitled (The Effect of Bone Marrow Aspirate Concentrate on Bone Regenerate During Mandibular Distraction Osteogenesis: Experimental study)

Dedication

To my parents, who instilled in me all the values I have in life

To my wife, with whom I lead my life sharing these values

To my son, who we will try to instil the same values in

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2D	Two-Dimensional
3D	Three-Dimensional
ANB	Subnasale-Nasion-Supramentale Angle
CAD/CAM	Computer Aided Design/Computer Aided Manufacturing
CBCT	Cone-Beam Computed Tomography
CC	Costochondral
CT	Computed Tomography
DICOM	Digital Imaging and Communications in Medicine
DO	Distraction Osteogenesis
EBM	Electron Beam Melting
FDM	Fused Deposition Modeling
HFM	Hemifacial Microsomia
IAN	Inferior Alveolar Nerve
IO-OP	Infraorbitale-Occlusal Plane Distance
MDO	Mandibular Distraction Osteogenesis
MOP	Maxillary Occlusal Plane
MSCT	Multislice Computed Tomography
RP	Rapid Prototyping
SLA	Stereolithography
SLS	Selective Laser Sintering
SNB	Sella-Nasion-Supramentale Angle
STL	Standard Tessellation Language
TMJ	Temporomandibular Joint

Isolated congenital deformities of the mandible are conditions that affect a large number of the population. They may be unilateral as in hemifacial microsomia (HFM), or bilateral deficiency of the body of the mandible and severe micrognathia as in Pierre Robin syndrome, with horizontal deficiency across the midline causing cross bite and condylar deficiency.

On the other hand, pediatric trauma is the leading cause of acquired mandibular deficiency. In particular, condylar fractures have been shown to cause mandibular growth disturbance resulting in facial asymmetry, often severe enough to require corrective orthognathic surgery. Temporomandibular joint (TMJ) ankylosis has been shown to cause growth retardation and facial asymmetry as well. It can be caused by delayed or missed diagnosis and treatment, prolonged maxillary-mandibular fixation, and/or crush-type hit to the condylar area.

Bone reconstruction procedures for treatment of such conditions in the craniofacial region are considered a complicated endeavor. They usually require skeletal correction to overcome psychological, breathing and eating problems by reconstructing both soft and hard tissues. Grafting from distant sites to regenerate and reconstruct missing bony segments carries the risk of donor site morbidity, the risk of rejection, infection, or low bone quality. Hence, the need for alternative treatment options arises.

Originally, distraction osteogenesis (DO) was a surgical process used in reconstruction of skeletal deformities and lengthening of the long bones in orthopedics. However, it is currently used in the oral and maxillofacial region to correct deformities of the facial skeleton without grafting risk.

Distraction osteogenesis refers to a surgical technique designed to address defects and deficiencies in the skeleton. Although it was first mentioned by Hippocrates, Ilizarov introduced the modern concept of distraction osteogenesis 40 years ago, and the orthopedic community has employed distraction techniques to lengthen and reconstruct arms and legs ever since.

Distraction surgery was first reported to treat defects of the oral and facial region in 1992. Since then, the surgical and technological advances made in the field of distraction osteogenesis provided oral and maxillofacial surgeons with a safe and predictable method to treat selected deformities of the oral and facial skeleton.

However, maxillofacial DO is not without its draw backs. Distraction Osteogenesis is a long procedure in which patients are at risk of complications such as pain, re-fracture, infection, nonunion or non-compliance, as well as suffering psychological depression and economic burden. There are also numerous other complications related to the surgical procedure itself. Several forms of tooth injury have been reported during DO due to damage of unerupted molar buds either during the osteotomy placement, or because of inappropriate placement of the distractor pins.

Injury to the inferior alveolar nerve (IAN) has also been frequently reported in literature as a complication of mandibular distraction osteogenesis. These injuries may include hypoesthesia of the IAN, and/or transient paraparesis of the muscles innervated by the recurrent marginalis branch of the facial nerve, as well as Neuropraxia. Therefore, insufficient preoperative planning combined with inappropriate device construction and osteotomy placement can result in permanent nerve damage.

Inappropriate distraction vector is considered to be the most troublesome complication as it usually leads to a large number of clinical problems. The problems potentially caused by an inappropriate distraction vector may include malocclusions and laterognathism, manifested as sagittal rotation of the mandibular midline away from the side undergoing distraction due to excessive magnitude of distraction or an inappropriate net distraction vector. It typically occurs in patients undergoing unilateral mandibular distraction osteogenesis (MDO). It may also lead to condylar displacement, condylar resorption, and/or malocclusion consisting of a closed lateral bite and crossbite, and ultimately, a failure to correct the patient's esthetic complaint.

Hence, meticulous preoperative planning is of outmost importance to minimize the incidence of aforementioned complications. Fortunately, and with the recent advances in imaging techniques, better than ever preoperative diagnosis and surgical planning is now attainable. The entirety of the patient's anatomy can now be accurately viewed on Three-Dimensional (3D) reconstructed views, and the surgical procedure, including the site of the osteotomy and the distractor pins, can be accurately planned and virtually placed to avoid injury to any vital structures, as the inferior alveolar nerve, developing tooth buds, and roots of erupted teeth.

Careful preoperative planning does not only minimize potential complications, but also it plays a major role in improving the final outcome. There is a strong correlation between the distraction vector used, and the mandibular movement. The 3D planning and subsequent implementation of the planned vector can therefore greatly alter the post-distraction mandibular anatomy, facial symmetry, and overall esthetics of the patient. In addition, and with advanced in 3D analytical softwares, soft tissue changes can be predicted and accounted for. Mandibular distraction ostogenesis can now be planned with an End-in-mind approach.

Hence, the current study intended to plan the process of MDO by predicting the vector of distraction and the final patient's appearance precisely prior to surgical intervention. Three-dimensional printed surgical guides were then used to accurately transfer the virtual surgical plan into the surgical field, and the entire process was assessed clinically and radiographically.