A novel design of a computer-generated splint for vertical repositioning of the maxilla after Le Fort I osteotomy

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Objective. The objective of this study was to evaluate the efficacy of a novel tooth/bony-supported virtual splint design to control the maxillary vertical, rotational, and anteroposterior intraoperative movements.
Study Design. A tooth/bone-borne splint was designed to position the osteotomized maxilla intraoperatively. Lateral cephalometric radiographs were obtained 1 week before the operation and 1 week after to compare the planned and actual movements of the maxilla.
Results. The paired *t* test showed no significant difference between the planned and actual movements in both the vertical and horizontal measurements ($P \leq .05$). The difference between the planned and actual horizontal movements in 4 (66.7%) of the 6 patients was 1 mm or less. For the vertical movements, 5 (83.3%) of the 6 patients showed a difference equal to or less than 1 mm.
Conclusions. The 2-piece surgical stent showed accurate control on the osteotomized maxilla and succeeded its repositioning to the preplanned positions. (Oral Surg Oral Med Oral Pathol Oral Radiol 2013;115:e16-e25)

Maxillary impaction is often required when treating maxillofacial deformities with vertical maxillary excess, and it has been established as a safe and reliable procedure for adults. Various studies have shown good postoperative stability after superior repositioning of the maxilla.[1-6] Traditional surgical planning for orthognathic surgery usually follows a systematic patient evaluation to create a problem list and treatment plan, which is then transferred to the patient in the operating room using acrylic surgical splints, which are fabricated on plaster dental models.

Numerous studies have evaluated the ability to accurately reposition the maxilla during surgery using the mandible to help position the maxilla; however, some horizontal and vertical inaccuracies of the planned position of the maxilla existed.[3-20] McCance et al.[15] compared the planned preoperative maxillary movements with the actual surgical movements and found that discrepancies persist despite careful planning and surgical technique. The differences ranged from 0 to 10 mm in the vertical and horizontal movements.

Sharifi et al.[21] evaluated the accuracy of model surgery prediction after orthognathic surgery. They found the principal cause of discrepancies to be errors in the face bow recordings owing to differences in the Frankfort horizontal plane and the upper arm of the semiadjustable articulator and differences between the condylar position in the supine position on the operating table and during the bite registration.

Three-dimensional (3D) surgical planning is becoming increasingly popular and has wide applications in the field of oral and maxillofacial surgery, such as orthognathic surgery, craniofacial surgery, trauma surgery, and distraction osteogenesis.[22-26] It is now possible to perform the entire virtual diagnosis, surgical treatment planning, and predicted outcomes in a computerized virtual environment.[27,28] The creation of computer-generated splints using 3D printing or stereolithography is now possible with a higher degree of accuracy as compared with conventional surgical splints.[29] Computer-assisted surgical planning will be a promising technique in the near future, in which the surgical treatment plan and splints will be virtually created in the computer and directly transferred into the operating room.[28-30]

Several studies have investigated the use of virtually designed splints to reposition the mobilized maxilla in

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the different planes of space (including rotations, translations, and leveling).[28,30,31] The aim of this clinical study was to evaluate the efficacy of a novel tooth/bony-supported virtual splint design to control the maxillary vertical, rotational, and anteroposterior intraoperative movements.

MATERIAL AND METHODS

Subjects

A pilot study of 6 patients was designed at the Oral and Maxillofacial Surgery Department, Faculty of Oral and Dental Medicine, Cairo University. Approval of the study design had been previously sought from and granted by the Faculty of Oral and Dental Medicine/Cairo University Research Ethics Committee.

All patients met the following inclusion criteria: (1) clinical and radiographic evidence supporting a diagnosis of vertical maxillary excess alone or combined with mandibular deficiency, (2) free of any craniofacial anomalies, (3) no previous maxillary or mandibular orthognathic surgeries, and (4) treatment plan included nonsegmented Le Fort I osteotomy.

Standard sets of clinical photographs and cephalometric radiographs were obtained and analyzed on surgical planning software (Onyx Ceph 2/6/24; Image Instruments GmbH, Göttingen, Germany) to aid in the surgical planning and predicting the amount of maxillary impaction. Conventional model surgery (mock surgery) was performed for all cases and the standard acrylic splints were available in the operating room.

Data acquisition

Computed tomography (CT) of the skull and mandible was acquired using a multislice helical CT machine (LightSpeed Plus, General Electric Healthcare Rosslyn, VA, USA); all images were acquired in a digital imaging and communications in medicine (DICOM) format. The image acquisition parameters were as follows[32]: (1) axial images only, (2) gantry tilt = zero, (3) slice thickness 0.625 mm, (4) slice distance 0.625 mm, (5) field of view extending 5 cm beyond the required region, (6) upper and lower teeth slightly separated, and (7) bony window. To eliminate streak artifacts, 2 patients had amalgam restorations replaced with composite. Also, we removed the orthodontic brackets in all of the patients before the scan.

The data were then imported into the 3D modeling software Voxim (IVS Solutions, Chemnitz, Germany). This software incorporates measurements, segmentation, repositioning, and importing tools to create the possibility of 3D surgical planning.

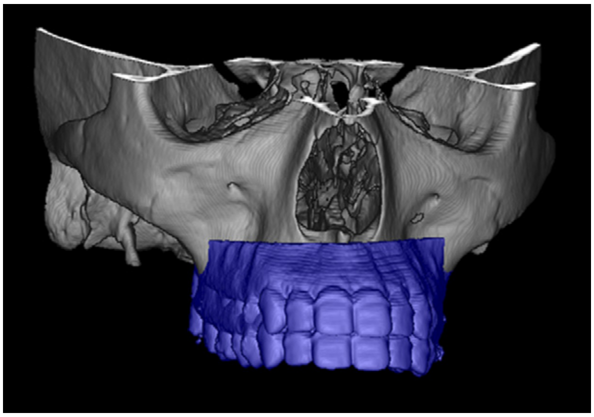

Fig. 1. Superimposing the pre- and postsurgical planned positions.

Segmentation process

A predefined image threshold (preset value in the software) in the axial cuts was used to eliminate all soft tissue and highlight only bone and calcified tissues.

Definition of symmetry planes

The whole skull dataset was manually aligned to the symmetry planes using the multiplanar view. Automatic procedures would have the disadvantage of including asymmetric parts of the skull in the calculations, which would lead to inaccuracy. The midsagittal plane was used for vertical orientation, and the Frankfort horizontal plane was used for transverse orientation. The maxilla was manipulated in the 3 planes of space (axial, coronal, and sagittal), then was repositioned according to the surgical treatment objectives (STOs) (Figures 1 and 2).

Splint fabrication

The virtually planned surgical procedure dataset was exported using a special export tool that allows the generation of Standard Tessellation Language (STL) files of the segmented parts. Then, the STL files were imported into another third-party software program (3 days Max 2009, Autodesk Inc., San Rafael, CA) that virtually designed a novel tooth/bony-supported splint.

A tooth-borne splint (occlusal wafer) was first virtually designed to fit on the maxillary teeth (Figure 3, *A*). Then, a bone-borne splint resting on the anterior wall of the maxillary sinus (using reference points, one at the lateral wall of the nose and the level of the inferior concha, another point is at the body of the zygoma and superiorly just below the infra-orbital nerve) bilaterally with 2 arms (wings) on each side directed downward to fit in the occlusal wafer. Each of the wings was connected with a transverse bar that controls the depth of