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Accuracy of maxillary repositioning in two-jaw surgery with conventional articulator model surgery versus virtual model surgery

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Abstract. The purpose of this study was to compare the accuracy of maxillary repositioning using the recently introduced computerized virtual model surgery (VMS) with conventional articulator model surgery (AMS). Forty-two patients who had undergone bimaxillary surgery were investigated retrospectively in this study. The patients were divided into two groups: conventional AMS ($n = 23$) and VMS ($n = 19$) for intermediate splint fabrication in maxillary positioning. Planned surgical movements and actual postsurgical changes of the lateral and frontal cephalometric measurements were compared. Although variations from the planned surgical movements were relatively small, both methods had statistically significant errors in some of the linear measurements. Both groups had a similar range of errors. The overall absolute mean discrepancy between the planned and actual surgical movements for the linear measurements was 1.17 mm (0–3.6 mm) in AMS and 0.95 mm (0–3.2 mm) in VMS. Of the total measurements, measurements reflecting a surgical discrepancy of more than 2 mm or 2° comprised 12.0% of the cases in AMS and 7.9% in VMS. The surgical accuracy of maxillary positioning with VMS was comparable to conventional AMS. Because VMS has the definitive advantage of eliminating the complex laboratory step and shortening the laboratory time, this can be accepted as an alternative to AMS.

Key words: accuracy; articulator model surgery; virtual model surgery; maxillary osteotomy.

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To achieve successful results after maxillary osteotomy, adequate diagnosis and treatment planning are fundamental requirements. Not every surgery is performed exactly as per the planned movement. To reduce the discrepancy in maxillary positioning, we need to reduce the error throughout the planning and surgical process. In particular, since the intraoperative maxillary position depends greatly on the intermediate splint fabricated from the model surgery, this step is important for accurate maxillary positioning in orthognathic surgery. The maxillary model surgery procedure relies greatly on the face-bow transfer, mounting of a dental cast onto the articulator, and the model surgery procedure itself. However, it has been shown that these steps are not free from potential errors.[1–3] At the same time, conventional articulator model surgery (AMS) requires various laboratory steps, and errors can occur during any of these laboratory steps. Moreover, it takes a lot of time and effort to complete the whole process.

Recently, three-dimensional (3D) computerized technology has been applied to various steps of orthognathic treatment planning.[4–6] Among the computer-assisted 3D planning procedures, 3D virtual model surgery (VMS) and stereolithographic intermediate occlusal splint fabrication have been proposed as alternatives to conventional model surgery.[7–10]

Briefly, this procedure consists of: (1) laser surface scanning of a set of maxillomandibular dental casts; (2) positioning of these casts according to the centric relation (CR) bite (presurgical position) virtually on a 3D computerized tomography (CT) or two-dimensional (2D) cephalogram; (3) maxillary repositioning according to the planned movements in the virtual space; and (4) fabrication of an intermediate splint by stereolithographic technique. Previous technical reports have emphasized the feasibility of VMS.[4,7,9,11,12] However, only two studies have compared the accuracy of AMS and VMS in fabricating an occlusal splint before surgery,[8,10] and these studies focused on the technical errors of the 3D splint fabrication process not on clinical reliability. Therefore, an objective evaluation of the surgical accuracy of VMS needs to be done and compared to conventional AMS.

The purpose of this study was to evaluate whether the accuracy of surgical movement with computerized VMS is comparable to that of conventional AMS in maxillary repositioning.

Materials and methods

Subjects

This retrospective study investigated 42 consecutive adult patients who received two-jaw surgery between March 2011 and February 2012. The following patients were included: patients who had undergone a one-piece Le Fort I osteotomy and sagittal split ramus osteotomy carried out by a single surgeon (TGK). The Le Fort I osteotomy was performed for translational or rotational repositioning (posterior impaction or canting correction) of the maxilla with or without maxillary dental midline correction. The frontal and lateral cephalograms were taken 1 month before and within 3–5 days after the surgery. Cases with incomplete data (model surgery information or radiographs) or craniofacial congenital anomalies, such as a cleft deformity, were excluded from the study.

The surgery protocols were the same for all of the patients. Model surgery was done by either AMS or VMS. The intermediate splint was fabricated according to the model surgery method used.

The Le Fort I osteotomy was done by the conventional method.[13] The maxillary position was determined by an external reference point[14] and intermediate splint. After elimination of the bony interference, the maxilla was fixed with miniplates at the maxillary lateral bony wall. A bilateral sagittal split ramus osteotomy was done as previously described.[2] Two-jaw surgery with AMS was performed in 23 patients (15 male, 8 female, average age 23.1 ± 5.2 years), whereas VMS was done in 19 patients (14 male, 5 female, average age 21.9 ± 3.0 years). This work was approved by the institutional review board.

Intermediate splint fabrication with AMS

The maxillomandibular dental casts of individual patients were mounted in an articulator (Hanau, Buffalo, NY, USA) by face-bow transfer and bite registration, in accordance with the recommendations of Ellis et al.[15] AMS was performed based on a treatment plan (surgical treatment objectives, STO) using the Erickson model surgery platform (Great Lakes Orthodontic, Tonawanda, NY, USA). Using an acrylic resin (Caulk®, DENTSPLY, Milford, DE, USA), the intermediate splint was fabricated between the desired postoperative maxillary position and the preoperative mandibular position (Fig. 1).

Intermediate splint fabrication with VMS

For VMS, the patient's maxilla and mandibular dental cast and CR-positioned maxillomandibular dental cast set were scanned with a 3D laser surface scanner (accuracy 20 μm; Orapix, Seoul, Korea). The scanned dental cast was overlapped with the maxillomandibular position on the 2D cephalogram by synchronizing the dental occlusion area using the 3Txer program (3Txer® ver. 2.5; Orapix, Seoul, Korea). The postoperative maxillary position was determined according to the surgical treatment plan. The stereolithographic intermediate splint was fabricated using a computer-aided design and manufacturing (CAD/CAM) system and photoactivated resin (Accura SI 40 Nd-type stereolithography resin; 3D Systems, Valencia, CA, USA). The step-by-step procedure used for the VMS was similar to that used in a previous report[16] (Fig. 2).

Analysis of the surgical accuracy with AMS and VMS in maxillary repositioning

Cephalometric tracing and landmark digitization of each pre- and post-surgical radiograph was carried out with computer software V-ceph® ver. 6.0 (Osstem, Seoul, Korea). Cranial base landmark structures (nasion, sella, porion, orbitale, and basion) were used to achieve the best-fit superimposition of the pre- and post-surgical lateral cephalograms. In the lateral cephalogram, the horizontal reference plane (HRP) was established as 7° to the sella–nasion line passing through the sella, and the perpendicular line to the HRP was defined as the vertical reference plane (VRP). On the lateral cephalogram, the distances from the VRP or HRP to the A-point (A(x) or A(y)), upper central incisal edge ((U1(x) or U1(y)), and the first molar mesio-buccal cusp tip (U6(x) or U6(y)) were measured. The angle between the line from the posterior nasal spine (PNS) to the anterior nasal spine (ANS) and HRP was defined as the 'palatal plane angle'. On the frontal cephalogram, the bilateral sphenoid bone orbit junction points (Lo–Lo) served as the horizontal reference plane,[17] and the angle between Lo–Lo and the frontal occlusal plane (line passing through the right and left first molars) was defined as the 'maxillary canting'. The vertical line perpendicular to Lo–Lo that bisects the middle of Lo–Lo was defined as the 'facial skeletal midline'. The distance between the interproximal area of the bilateral upper incisor and the facial skeletal midline represents 'maxillary dental midline deviation' (U1(z)). Surgical changes in these linear and angular measurements were compared to the planned surgical movements before surgery (STO) (Fig. 3).

Statistical analysis

Planned surgical movements and the actual surgical change of the maxillary position were compared. The paired t-test was used to identify the positional difference of the maxilla for each of the linear and angular measurements. The surgical accuracy with the two different model surgeries was compared with the