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CASE REPORT

Computer-assisted preoperative simulation for positioning of plate fixation in Lefort I osteotomy: A case report

Hideyuki Suenaga*, Asako Taniguchi, Kazumichi Yonenaga, Kazuto Hoshi, Tsuyoshi Takato

Department of Oral–Maxillofacial Surgery, Dentistry and Orthodontics, The University of Tokyo Hospital, Tokyo, Japan

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Computed tomography images are used for three-dimensional planning in orthognathic surgery. This facilitates the actual surgery by simulating the surgical scenario. We performed a computer-assisted virtual orthognathic surgical procedure using optically scanned three-dimensional (3D) data and real computed tomography data on a personal computer. It helped maxillary bone movement and positioning and the titanium plate temporary fixation and positioning. This simulated the surgical procedure, which made the procedure easy, and we could perform precise actual surgery and could forecast the postsurgery outcome. This simulation method promises great potential in orthognathic surgery to help surgeons plan and perform operative procedures more precisely.

Introduction

Orthognathic surgery is carried out to improve facial aesthetics. Lefort I osteotomy is one orthognathic procedure performed in dysgnathic, skull-related repositioning surgery of the maxilla. Currently the need for maxillomandibular surgery has increased greatly, as more adults are seeking this treatment to improve their facial aesthetics.[1] The concept of the ideal result in orthognathic surgery is mostly subjective and its improvement is determined by the patient's expectation and the actual result. Therefore, there is a need for preoperative planning and the patient to know how they would look after the surgery.

The preoperative preview of visualized treatment objective in maxillomandibular surgery shows facial changes that are expected after orthognathic surgery. It uses cut-and-paste images, which are modified with the

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* Corresponding author. Department of Oral-Maxillofacial Surgery, Dentistry and Orthodontics, The University of Tokyo Hospital, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8655, Japan.
E-mail address: suenaga-tky@umin.ac.jp (H. Suenaga).

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help of a computer to show a facial change. However, it does not provide the clinician with the ability to determine the shift of underlying hard tissue and intermaxillary dental relationships.[2] Therefore, the visualized treatment objective is less informative to the surgeon during the procedure.

Lateral cephalometric radiographs are used in orthognathic surgery to predict the movement of the lower incisor and chin during the procedure. It overplays tracing or templates by manual pencil drawing to predict the profile.[3] This method is compulsory when the maxilla is positioned vertically and major movements of the teeth are simulated. In these two methods, the predicted post-treatment soft tissue outline is drafted based on the published changes of soft tissue/hard tissue ratios. In reality, however, producing the predicted soft tissue outline is more of an art than a scientific exercise.[3] Therefore, it was relatively informative to the surgeon and less important to the patients as they were shown only the line drawing profile of the surgical simulation.[4]

Computer-assisted planning programs can provide exact calculation and define exactly all three dimensions required during the skull-related target position of the maxilla.[5–9] However, the 3D control, intraoperative maxillary movement in relation to the skull has not been standardised and still requires great ability by the surgeon to achieve the planned position of the maxilla during the operation.[10]

The computer-assisted planning program is helpful in the predicting outcome, shortening surgery time, and is accurate.[11] It automatically measures, calculates and analyses the outcome from the results of cephalometric radiographic data from the published studies of the soft tissue reaction to the hard tissue movements and predicts the final treatment goal as a line drawing profile.

The rapid improvement in computer technology and software systems has helped the integration of photographic images with cephalograms.[12] The software superimposes the patients' profile photographs on the digitized cephalometric tracing and the computer-based estimation, displaying both line drawing tracing and the corresponding facial image. Recent software allows the clinicians to manipulate the digital representation of hard and soft tissue profile tracings thereby helping the preoperative image to simulate the treatment. In this case, we did a Le Fort I osteotomy, using preoperative computer-assisted simulation for positioning of plate fixation, which made our surgical procedure easy and accurate.

Case Report

A 19-year-old female student presented to our department with complaints of mandibular protrusion and unstable occlusion. She was planned to be operated using Horseshoe Le Fort I osteotomy to improve her facial aesthetics. She was photographed. The "L" shape plate and Lefort titanium plate (Lorenz Plating System, Biomet Microfixation, Jacksonville, FL, USA) was scanned by 3D scanner (Rexcan DS2, Solutionix, Seoul, Korea). The face was scanned using a 320-row area detector computed tomography (CT) scanner (Aquilion ONE, Toshiba, Tokyo, Japan), which acquired CT scans (slice thickness, 0.5 mm) of the jaw bones.

The 3D inspection and metrology of the upper jaw bones were constituted from Geomagic Qualify (Geomagic, Morrisville, NC, USA) and Freeform plus software (Geomagic). The cephalometric analysis and 3D planning was performed using simulation software from obtained CT data and normal profile for the occlusal relationship. The 3D surface data of titanium plate were imported to the Freeform plus software. The CT data, 3D scan of plate and surface model of the upper jaw bone were manipulated using medical image processing software (Mimics; Materialise, Leuven, Belgium). The 3D screw positions were calculated and marked using Freeform plus (Figure 1). The bone movement and positions was calculated using Freeform plus software. The Freeform plus was used to leverage CT and 3D scanned data to make holes accurately and fit a screw using a virtual drill. Six virtual plates (2 "L" shape titanium miniplates, 2 Lefort plates of 0 mm, and 2 Lefort plates of 2 mm) were used in the computer-assisted preoperative simulation and temporarily fixated. The occlusal surgical guides and intermaxillary fixation for maxillary positioning was not used because the temporomandibular joint is flexible, and the position of the mandible is not accurate.

The preoperative planning was performed, employing a virtual plate by setting the position of the maxilla in Lefort type I osteotomy. The fragments of the maxilla bone and a plate were moved simultaneously and the displacement and angulation was calculated. The virtual model of Lefort titanium plate (Figure 2) was positioned after obtaining required movement on the virtual image using Freeform plus software. We did not use any computer-aided design and manufacturing drilling guide for the maxillary repositioning.

During the real operation, the positioning of real titanium plate in Lefort I osteotomy was done based on this preoperative planning; the maxilla was moved to the planned final position. To translate the virtual fixation plate accurately into a real plate, this distance from the geometric shape of the plate, anterior to nasal spine and teeth were measured using a Vernier caliper in the operating room. The intersection point (screw position) was measured using a compass. The vertical position was adjusted using 3D screw positions if there was a vertical dimensional change. The black arrows show screw positions before the bone was moved, and the white arrows show the screw positions after the bone was moved (Figure 3). The actual operation was carried out by employing the titanium plate fixed to the fragment of maxillary bone as planned. Informed written consent was obtained from the patient to report the case. The authors followed the Helsinki Declaration guidelines in this investigation.

The accuracy of the simulation results was analyzed using the 3D comparison function in Geomagic Qualify. Since the cranial base and zygomatic arch are not altered by the surgery, it was used for the superimposition. The differences between the virtual plans and the postoperative results are shown in Figure 4. The comparison of CT scans made before jaw surgery and immediately after surgery clearly showed the approach to be accurate and the error of the maxillary position was < 1 mm. Thus, it can be said that the preoperative planning employing a virtual plate may prove a reliable surgery.

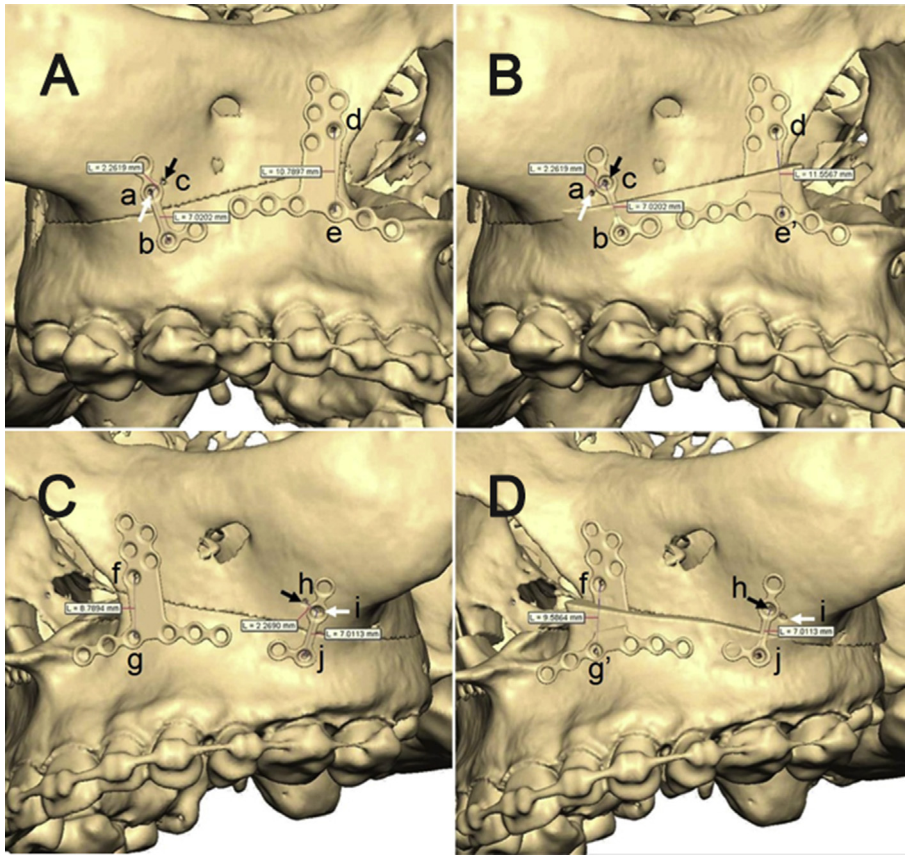

Figure 1 Preoperative planning and simulation using the virtual titanium plate. (A) Right side view before the bone movement; (B) right side view after the bone movement; (C) left side view before the bone movement; and (D) left side views after the bones movement. Distance between the points before and after the bone movement: a, b, d—g, i, j is a position before the bone movement; b—d, e′, f, g′, h, j is a position after the bone movement. The hole with the drill at the 3D position was computed by the preoperative simulation before the bone movement. Black arrows show screw positions before the bone was moved, and the white arrows show the screw positions after the bone was moved. a—b = c—b = 7.0 mm; a—c = 2.2 mm; d—e = 10.7 mm; d—e′ = 11.5 mm; f—g = 8.7 mm; f—g′ = 9.5 mm; h—i = 2.2 mm; i—j = h—j = 7.0 mm.

Discussion

Complex movements are performed in the three planes in bimaxillary surgery in particular.[13] The main concern during orthognathic surgery is the transfer of preoperatively simulated maxillary movements to the actual operation. Since the advent and incorporation of the new technology, the process has significantly changed the preoperative planning and simulation of surgery. We used 3D CT scan of the patient's face and titanium plate 3D scan to make preoperative planning.

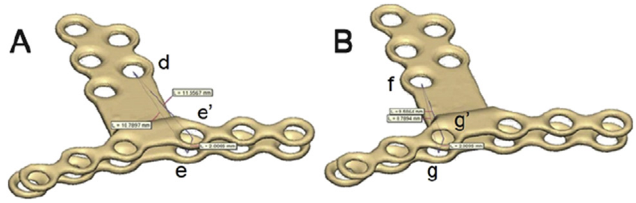

Figure 2 Virtual model of Lefort titanium plate. (A) Right plate; and (B) left plate. Distance between the points, which superimposed Lefort titanium plate of 0 mm and 2 mm. d, e, e′, f, g, g′ of Figure 2 corresponds with d, e, e′, f, g, g′ of Figure 1. d—e = 10.7 mm; d—e′ = 11.5 mm; e—e′ = 2.0 mm; f—g = 8.7 mm; f—g′ = 9.5 mm; g—g′ = 2.0 mm.

Model surgery is now being eliminated from clinical routine practice and its place is being taken by 3D-virtual simulations performed on computer screens. Over the years, several articles have highlighted the importance of 3D planning in orthognathic surgery.[14–16] In the present case, it was easy to perform as it was planned in advance.

In the traditional plaster dental models only the patients' teeth are represented in three dimensions.[17] The present 3D planning enables the craniofacial skeleton to be viewed at all times (while planning treatment and mobilizing osteotomized bone structures). Using the software option *prediction of outcome*, changes brought about in soft tissue can be visualized. In the present study, the 3D planning and simulated surgical scenario made the actual surgery easy and accurate; the error of maxillary position was < 1 mm.

The ability of computerized 3D has led to what is now known as 3D planning. The software program enables the surgeon to interact with the 3D images and all data can be

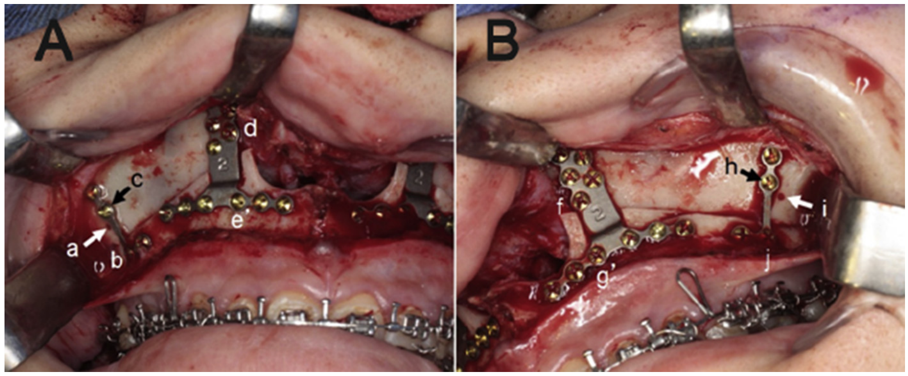

Figure 3 Plate and screw position during the actual surgery. (A) Right side view; and (B) left side view. After the bone movement, plate was fixed to the hole. a–d, e′, f, g′, h, i of Figure 3 corresponds with a–d, e′, f, g′, h, i of Figure 1 and d, e′, f, g′ of Figure 2. Black arrows show screw positions before the bone was moved, and the white arrows show the screw positions after the bone was moved.

stored as computer files, which facilitates data management. All preoperative information can be reviewed repeatedly and easily. Although studies have been carried out on a number of software programs, not all of these can store preoperative data in one place and provide access to images, which serve to simulate surgery, draw osteotomy lines, and plan 3D treatment with the prediction of postoperative outcome. This was not possible with model surgery or 2D analysis since the postoperative results could only be predicted in the 3D treatment planning system.[18] Working with 3D representations of the anatomic structures provides a more precise view of how the part of osteotomized bone is mobilized. When using 3D planning, all the necessary information is provided in images, which can be manipulated on a PC, whilst conventional planning makes it necessary to obtain data from different studies (radiographs, models and articulators, face bow, etc.) and to interpret the data before being able to develop a treatment plan. We also used the same technique to perform simulation surgery in the present case.

Accurate treatment planning is an important element of orthognathic surgery for obtaining optimum aesthetic and occlusal results.[19] Preoperative planning requires the collection of data for precise diagnosis of the dentoskeletal deformity and devises a treatment plan, which is then reproducible in the operating room.[13] Advances in 3D

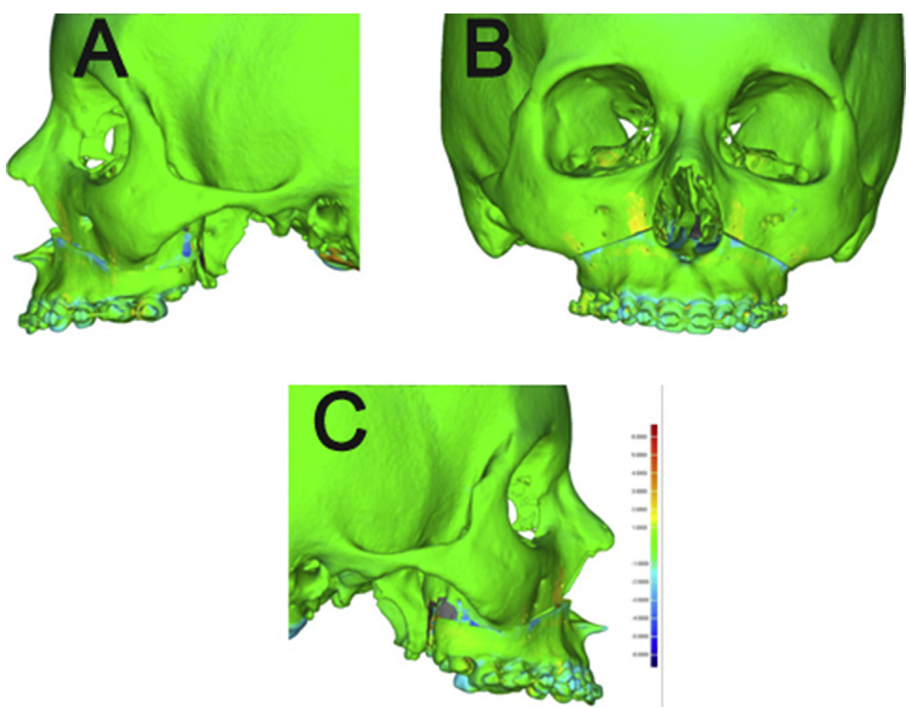

Figure 4 Distance maps to visualize the distances between pre- and postcomputed tomography scan. (A) Right side view; (B) frontal views; and (C) left side view. Superimposed pre- and postcomputed tomography scan on cranial base and zygomatic arch. Green < 1.0 mm, yellow 1.0–2.0 mm, Light blue −1.0–−2.0 mm. The thickness of the plate is 0.7 mm.

imaging technology have resulted in a series of projects designed to provide new computerized tools for use in diagnosis, preoperative planning, result assessment, manufacture of surgical splints,[20–22] and in result assessment in orthognathic surgery, where error-prone and time-consuming planning steps, such as model surgery and transfer of the face bow, can be avoided. Although numerous positioning devices have been described to transfer 3D treatment plan to the intraoperative site, the use of positioning devices and intraoperative splints are failure-prone and time-consuming steps, which have to be performed during the operation and during general anesthesia of the patient. Gander et al[23] described a novel time-sparing and failsafe technique using patient-specific implants as positioning guides and concurrently as rigid fixation of the maxilla in the planned position. This technique avoids elaborate positioning and removal of manufactured positioning devices and allows maxillary positioning without the use of occlusal splints. Mazzoni et al[24] also showed that the use of computer-aided design and manufacturing cutting guides and customized titanium plates for upper maxilla repositioning represents a promising method for the accurate reproduction of preoperative virtual planning without the use of surgical splints.

In this study, we carried out computer-assisted preoperative simulation for positioning of plate fixation in Lefort I osteotomy using 3D CT in the operating room to objectively evaluate the differences numerically; it made the procedure easy, and we could perform precise surgery and could forecast the postsurgery outcome. Therefore, this simulation method is likely to be introduced increasingly into orthognathic surgery to help surgeons to plan and perform operative procedures more precisely. However, the procedure should be performed in a large series of cases to standardize the technique. Our future work will include an augmented reality surgical navigation system based on vision-based markerless registration using stereo vision.[25]

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