Case Report
pISSN 2383-5389 / eISSN 2383-8116
Journal of International Society for Simulation Surgery 2015;2(2):71-75
http://dx.doi.org/10.18204/JISSiS.2015.2.2.071

Accuracy of Maxillary Segmental Osteotomy using 3D Simulation: A Case Report

Yong Bin Lee, D.M.D., Gisung Yeo, D.M.D., Young-Soo Jung, D.M.D., Ph.D., Hwi-Dong Jung, D.M.D., Ph.D.

Department of Oral and Maxillofacial Surgery, College of Dentistry, Yonsei University, Seoul, Korea

To overcome limitations of conventional diagnosis and planning for orthognathic surgery, surgeons have begun to use 3-dimensional (3D) virtual simulation to plan complex orthognathic surgery. In many literatures, it has shown that better surgical outcome achieved with 3D virtual simulation than that with conventional methods. But, there is still lack of data about accuracy of maxillary segmental surgery with 3D virtual simulation. The purpose of this paper was to report the case of maxillary segmental orthognathic surgery with 3D virtual simulation and to assess the actual surgical outcome. Though the result was clinically acceptable, discrepancy between 3D simulation and actual surgery was not superior compared with conventional method. The accuracy of 3D simulation surgery and intermediate wafer fabrication for maxillary segmental surgery needs to be improved. Advancement in 3D software program and careful surgical technique will make it more precise and reliable method.

Key Words Orthognathic surgery · Virtual simulation · Maxillary segmental osteotomy · 3D printing.

Received: October 19, 2015 / **Revised:** October 31, 2015 / **Accepted:** November 6, 2015
Address for correspondence: Hwi-Dong Jung, D.M.D., Ph.D.
Department of Oral and Maxillofacial Surgery, College of Dentistry, Yonsei University, 50 Yonsei-ro, Seodaemoon-gu, Seoul 03722, Korea
Tel: 82-2-2228-3138, **Fax:** 82-2-2227-8225, **E-mail:** CANCER7@yuhs.ac

Introduction

The disharmony of facial skeleton, soft tissue, and dentition results in dentofacial deformity. To solve this problem, the orthognathic surgery has been used widely. The success of orthognathic surgery depends on exact planning based on precise diagnosis and clinical examination, acquisition and analysis of images determines the surgical process (1). Lateral and posteroanterior cephalometric radiographs, clinical photographs, anthropometric measurements, and plaster dental models are traditional surgical planning methods (2). And traditionally, dental splints are used with plaster study models. It is an established and accepted method, but theoretically there are several sources of error and inaccuracy (3). Simulating the operation on plaster models is difficult owing to the lack of connection between cephalometric analysis and plaster model surgery. Rotation and translation of models are insufficiently controlled during model surgery (4). By virtue of recent advance in 3-dimensional (3D) imaging technique, clinicians have tried to develop 3D based diagnosis and operation. Especially, development in the degree of precision of 3D CT image and 3D printing technique has allowed making accurate patient's skull, jaw, and dentition 3D models and performing 3D based diagnosis and wafer fabrication. The importance of 3D surgical planning increases with the complexity of the deformity needed to correct it. Computer based simulation provides the clinician with an opportunity to perform virtual surgery, increasing the possibility of a successful outcome with no risk to the patient (5).

The purpose of the present paper is to report accuracy and predictability of maxillary segmental orthognathic surgery using 3D based diagnosis, planning and intermediate wafer fabrication.

Case Report

A 23-year-old male patient was referred for orthognathic surgery with complaints of facial asymmetry. Routine preoperative examination was carried out including 3D cone beam computed tomography(CBCT). Diagnosis and analysis was performed with reconstructed 3D object of patient's craniofacial skeleton. As a result of analysis with Simplant (simplant pro,

Fig. 1. A 23-year-old male with mandibular prognathism and asymmetry before operation. Facial photographs, intraoral photographs, lateral cephalometric radiograph and panoramic radiograph.

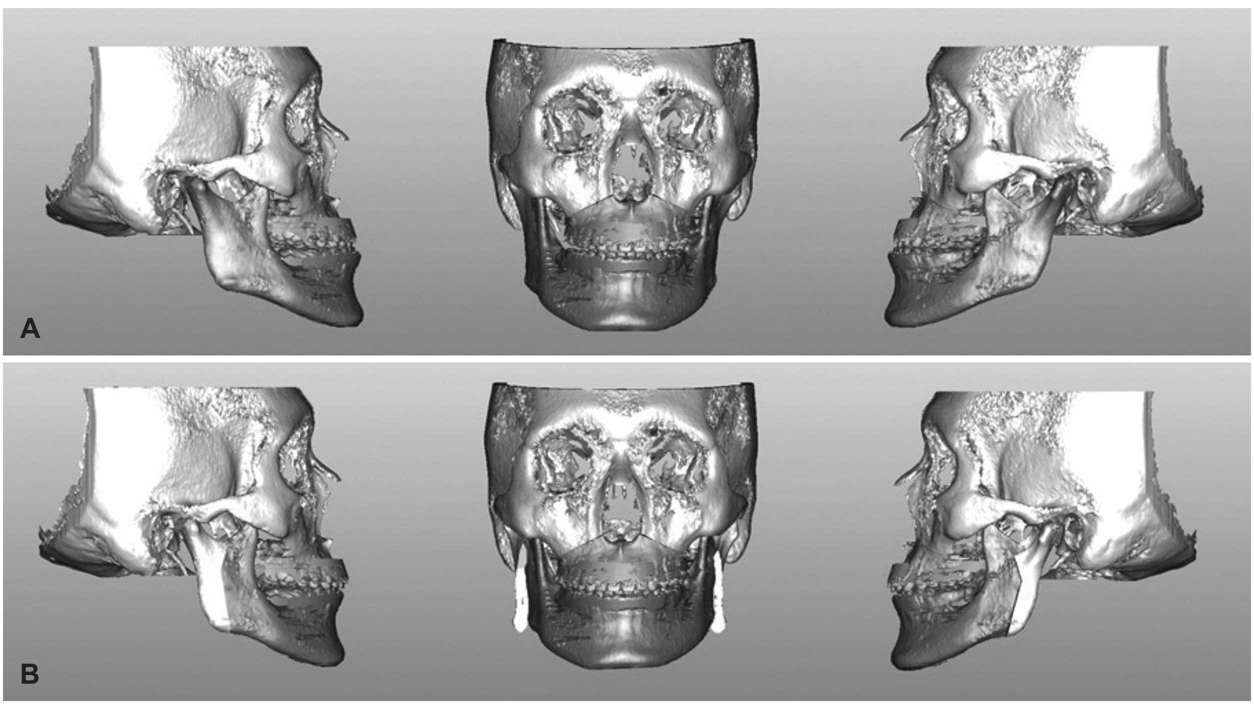

Fig. 2. Virtual 3D simulation surgery. A: Repositioning of the segmented maxilla according to the STO in a 3D virtual skull model. B: Rotation and setback of mandible according to the STO in a virtual 3D skull model.

Materials®, Belgium) software, the impression of the patient was mandibular prognathism and facial asymmetry and we planned bimaxillary orthognathic surgery including maxillary segmental osteotomy for maxillary arch expansion and mandibular setback (Fig. 1).

After 3D data acquisition using CBCT, the DICOM files were imported and craniofacial skeleton was reconstructed as 3D object. To make the virtual craniofacial skeleton model with accurate upper and lower tooth rows, laser scan of each single model was used. Based on 3 dimensional cephalometric anal-

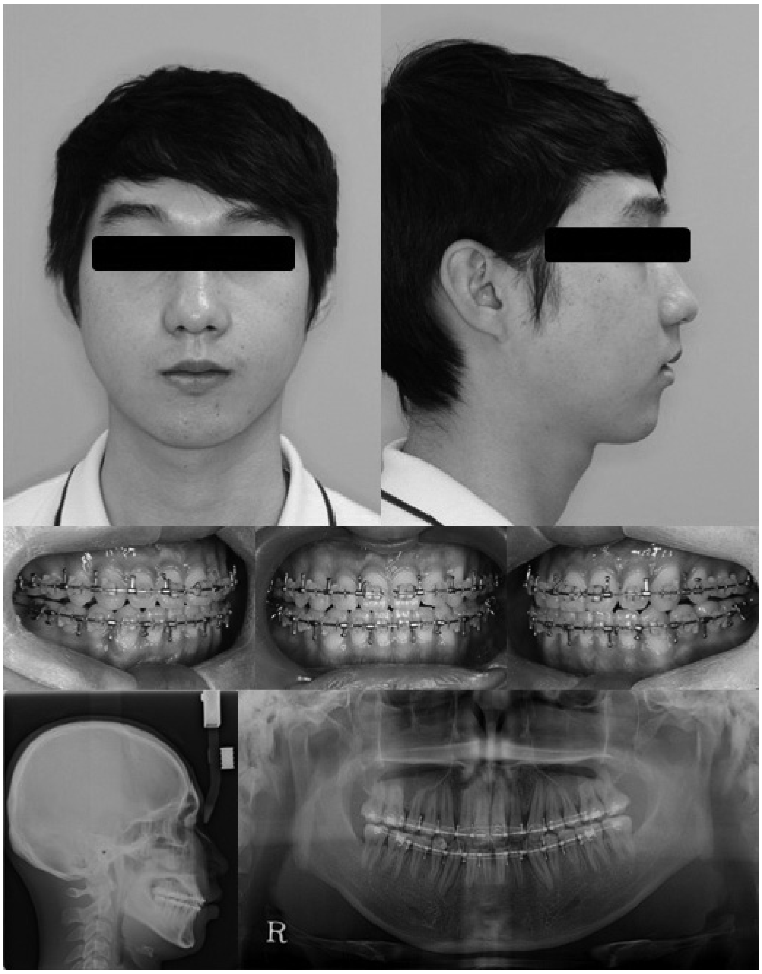

Fig. 3. Postoperative clinical photographs and radiographs. Mandibular prognathism and asymmetry were corrected.

Table 1. Comparison of the distance between reference planes and each point

		Vertical	AP	Trans
Mx. Rt.	Simulation(A)	51.43	22.23	30.15
	PostOp.(B)	49.44	23.81	31.04
	Δ B-A	−1.99	1.58	0.89
Mx. Lt.	Simulation	51.11	22.97	30.13
	PostOp	49.08	24.69	29.78
	Δ B-A	−2.03	1.72	−0.35
A point	Simulation	34.29	0.49	0.85
	PostOp	34.85	0.56	0.36
	Δ B-A	0.56	0.07	−0.49
Upper incisor	Simulation	56.91	4.5	0.96
	PostOp	58.56	2.88	0.96
	Δ B-A	1.65	−1.62	0

Mx. Rt. & Lt.: Mesio-buccal cusp tip of maxillary 1st molar, A point: A point of maxilla, Upper incisior: Mid-point of central incisiors ysis, segmentation and movement of maxilla was planned and performed in software (Fig. 2). Using CAD/CAM program with mandible and moved maxilla image, virtual intermediate splint was designed and fabricated with 3D printing to transfer 3D virtual treatment plan to patient.

Routine bimaxillary orthognathic surgery was carried out. After the operation, facial morphology and occlusion were improved (Fig. 3). Superimposition between preoperative virtual 3D simulation model and postoperative 3D model from CT data taken at 1 month after surgery was done and position of maxilla was analyzed. Reference planes(Mid-sagittal plane, Frankfort horizontal plane, Coronal plane) and points (maxillary 1st molar cusp tip, A point, maxillary dental midline point) were presented. Distance between each plane and point was measured to compare the result of 3D virtual simulation and actual operation. Maxilla was repositioned more superiorly and posteriorly than simulation surgery but discrepancy at each point was less than 2.0 mm except vertical change of left maxillary 1st molar. Especially, horizontal discrepancy was less than 1.0 mm (Table 1).

Discussion

The success of orthognathic surgery depends on the surgical technique and the accuracy of the surgical plan. Virtual planning combined with computer-aided surgery are rapidly emerging and increasingly important area of research (6). One of the important advantages of 3D virtual planning compared with traditional treatment planning of orthognathic surgery is that the clinician has more information on the patient's anatomy during planning. And 3D virtual planning helps clinicians to focus on 3D facial harmonization rather than on facial profile. It is a powerful tool for communication because clinicians can visualize the treatment plan of the patient with single anatomic model including hard and soft tissues and teeth (7).

In this case, the patient was diagnosed with 3D dimensional analysis and the intermediate splint was fabricated with 3D virtual simulation and CAD/CAM technique. Though it affects little in the point of function and esthetics, the discrepancy between 3D virtual simulation and result of actual surgery was more than 1 mm especially on canting correction and anteroposterior movement. The precision of imaging of the occlusal surfaces, streak artefacts by metal restorations, errors in the progress like fusion of images, reconstruction of 3D objects and surgical factors could be the reasons of discrepancy. The success criterion remains a difference of maximum 2 mm between the virtual planned surgery and the actual surgical outcome (8).

In cases of complicated surgery, conventional manual model surgery requires many laboratory based steps. These steps are time consuming and have possibility of errors in each step. Compared with conventional methods, 3D surgical planning and 3D fabrication of surgical splint have some advantages; splint can be made without plaster dental models and intermediate 3D surgical splints can incorporate more accurately the treatment plan. But, we need software to process CT DICOM files for virtual model, scanner for dentition, stereographic image, CAD/CAM software, and 3D printer for 3D virtual analysis (9). It is needed several new tools compared with conventional methods, so the cost has increased. Several studies have shown the accuracy of 3D virtual fabricated splint rather than conventional surgical splint (2, 4, 10, 11), but it can be still challenging to achieve precision intraoperatively when complex translation and rotational movements are performed in all three planes (12). And 3D surgical splints for segmental surgery are still very demanding in 3D virtual approach, because virtual occlusal definition of the segmented jaws is still very difficult (7).

As mentioned above, 3D based planning and fabrication of splint for maxillary segmental orthognathic surgery resulted in acceptable clinical outcome in this case, but still had shown discrepancy in detail movements. Virtual planning appears to be an accurate and reproducible method for treatment planning that can be reliably transferred to the patient by means of surgical splints. And for clinicians, it is possible to simulate virtual surgery several times. With more study and advancement in 3D software and careful surgical approach, virtual planning could be more accurate and reliable method even in maxillary segmental surgery.

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