CAD/CAM Fabrication of Occlusal Splints for Orthognathic Surgery

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Occlusal splints used for intermaxillary positioning after orthognathic surgery require accurate positioning, stabilization, and control of the mobilized segments.[1] Conventional fabrication of an occlusal splint is a complicated process that includes mounting the study cast on an articulator, cutting the cast, determining the position of the dental arch, and forming the splint with self-curing resin.[2] With bimaxillary surgery, the procedure is even more difficult.

Recently, a computer-aided design (CAD) program has been developed to assist in planning maxillofacial and craniofacial surgeries.[3,4] Bone implants and dental restorations have been fabricated by entering the CAD data into a computer-aided manufacturing (CAM) machine,[5,6] thus eliminating much of the conventional laboratory work associated with these procedures. In this article, we will describe the CAD/CAM technique for occlusal splint fabrication and discuss its advantages and current limitations.

*Surflaser 250R, UNISN, Inc., Osaka, Japan.

Fig. 1 Study cast mounted on 3D laser surface scanner.

CAD/CAM Procedure

We used the CAD/CAM method to design a splint for a patient with a typical mandibular hyperplasia. The procedure is as follows:

1. The study casts are mounted and scanned on a 3D laser surface scanner* (Fig. 1). The scanner provides digital data about the surface geometry of the casts; this data is then transferred to a personal computer to be converted into polygonal

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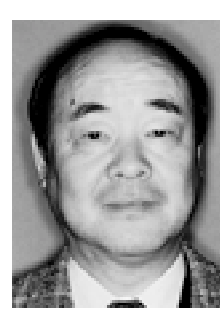

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Fig. 2 3D image of study casts on computer.

data and finally into a 3D image (Fig. 2). The morphology of the facial skeleton is represented in a 3D image using small triangular facets, which are formed by connecting the spatial coordinates of anatomical landmarks taken from conventional frontal and lateral cephalograms (Fig. 3). The two computer images are combined to form a 3D virtual image for surgical simulation (Fig. 4). Details of this technique have been reported elsewhere by the authors.[7]

2. The 3D virtual image is used to plan the amount and direction of bone displacement and the post-surgical occlusal relationship. In the present case, a simulated bilateral sagittal split ramus osteotomy of the mandible was performed (Fig. 5).

3. Using the simulation as a guide, the surgical splint is designed. The occlusal surface contact areas are drawn from the graphic image of the study cast (Fig. 6). The non-contact areas are filled in by the operator (Fig. 7).

4. The 3D graphic image of the surgical splint is transferred to a laser lithography unit** and pho-

**Sinterstation, DTM Corp., Austin, TX.

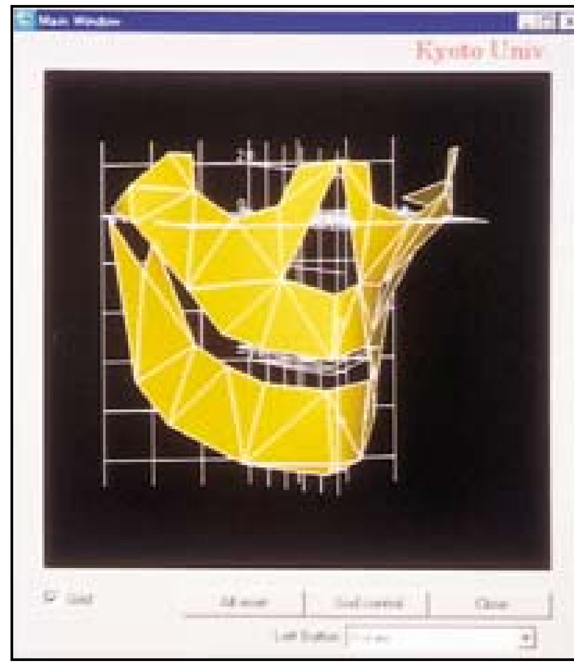

Fig. 3 3D facial skeleton constructed from cephalograms.

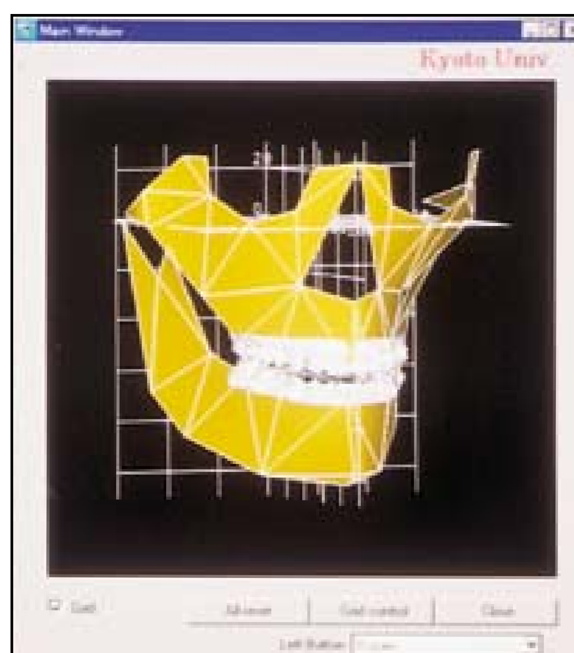

Fig. 4 Images of study casts and facial skeleton combined for simulation.

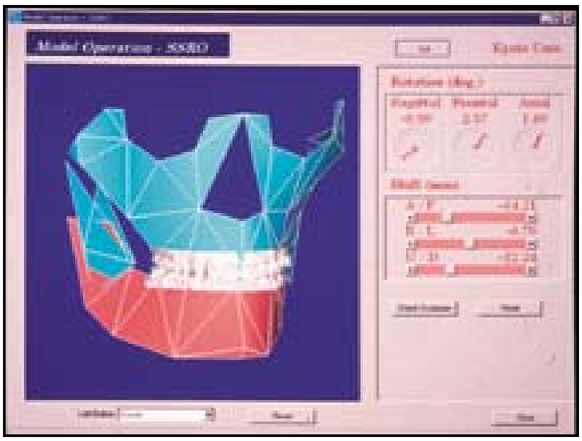

Fig. 5 Sagittal split ramus osteotomy simulated on 3D image.

Fig. 6 Contact areas of occlusal splint drawn from computer image of study cast.

Fig. 7 Finished 3D image of occlusal splint.

Fig. 8 Occlusal splint photopolymerized by laser lithography unit.

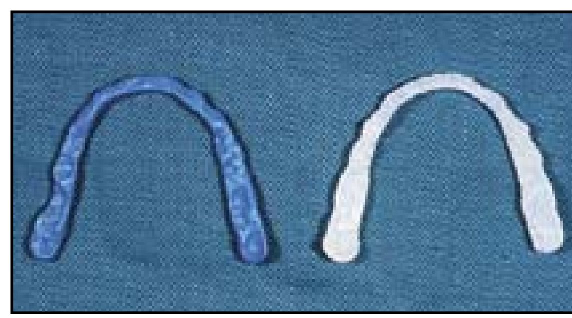

Fig. 9 Duplicate occlusal splints for verification of accuracy (left) and for patient treatment (right).

topolymerized (Fig. 8). To ensure biocompatibility, the occlusal splint is reproduced in dental resin, and the excess resin is trimmed away.

Patient Treatment

In this case, two occlusal splints were reproduced from the photopolymerized splint—one for evaluation of the accuracy of the CAD/CAM system, and the other for clinical use (Fig. 9). A conventional model surgery was performed on an articulator using the duplicate occlusal splint, which was found to be accurate enough for the surgery (Fig. 10).

After the split ramus osteotomy, the other occlusal splint was used for intermaxillary fixation as usual (Fig. 11).

Fig. 10 Model surgery using duplicate splint.

Discussion

Other procedures, such as prediction tracings of cephalograms and model operations on study casts, have been developed for surgical treatment planning,[2,8] but the computer-assisted technique offers several distinct advantages:

1. 3D virtual imaging of the facial skeleton and dental morphology allows the simultaneous evaluation of the skeleton and the dentition.
2. When surgery is simulated using the virtual image, the 3D data can be transferred directly into a laser lithography unit, eliminating all manual work except for the reproduction into dental resin.

In orthognathic surgery, especially bimaxillary surgery, the overall balance of skeletal proportions and occlusion must be taken into consideration. Computer simulation makes it possible to accurately estimate bone displacement by considering not only the cephalometric norms, but also the patient's occlusal harmony.

The simulations and CAD systems used to date in orthodontics and orthognathic surgery have been designed solely to develop treatment goals,[9,10] using predefined 3D CAD shapes.[11,12] The system described here combines treatment planning and complex clinical considerations. This method can also be used to fabricate orthodontic appliances such as activator plates.

In designing the non-contact areas of the occlusal splint, there are numerous challenges to be overcome, including bracket positions and undercuts of the dentition. These areas were intentionally made slightly large in the present case to ensure stability during photopolymerization of the splint. More clinical experience will help determine standardized procedures.

Although many polymers and metals are currently available for laser lithography units, none of these materials is biocompatible, and reproduction in dental resin is the only present solution. Biocompatible materials may be available in the near future. In addition, continued improvements in the hardware and software used for this CAD/CAM technology should lead to widespread clinical application.

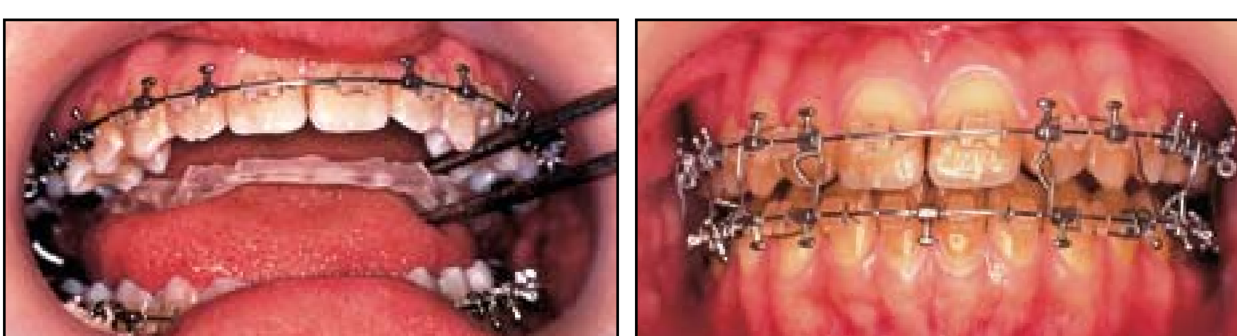

Fig. 11 Intermaxillary fixation with occlusal splint produced by CAD/CAM system.

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REFERENCES

1. Turvey, T. et al.: Surgical-orthodontic treatment planning for simultaneous mobilization of the maxilla and mandible in the correction of dentofacial deformities, Oral Surg. 54:491-498, 1982.
2. Erickson, K.L. et al.: Analytical model surgery, in *Modern Practice in Orthognathic and Reconstructive Surgery,* vol. 1, ed. W.H. Bell, W.B. Saunders Co., Philadelphia, 1992, p. 154.
3. David, E. et al.: Computer-assisted three-dimensional planning in craniofacial surgery, Plast. Reconstr. Surg. 92:576-585, 1993.
4. Ayoub, A.F.D. et al.: Three-dimensional modeling for modern diagnosis and planning in maxillofacial surgery, Int. J. Adult Orthod. Orthog. Surg. 11:225-233, 1996.
5. Eufinger, H. et al.: Reconstruction of craniofacial bone defects with individual alloplastic implants based on CAD/CAM-manipulated CT-data, J. Craniomaxillofac. Surg. 23:175-181, 1995.
6. Willer, J. et al.: Computer-assisted milling of dental restorations using a new CAD/CAM data acquisition system, J. Prosth. Dent. 80:346-353, 1998.
7. Okumura, H. et al.: 3D virtual imaging of facial skeleton and dental morphology for treatment planning in orthognathic surgery, Am. J. Orthod., in press.
8. Moshiri, F. et al.: Orthognathic and craniofacial surgical diagnosis and treatment planning: A visual approach, J. Clin. Orthod. 16:37-59, 1982.
9. Bhatia, S.N. and Sowray, J.H.: A computer-aided design for orthognathic surgery, Br. J. Oral Maxillofac. Surg. 22:237-253, 1984.
10. Cutting, C. et al.: Three-dimensional computer-assisted design of craniofacial surgical procedures: Optimization and interaction with cephalometric and CT-based models, Plast. Reconstr. Surg. 77:877-885, 1986.
11. Maeda, Y. et al.: A CAD/CAM system for removable denture, Part 1: Fabrication of complete dentures, Int. J. Prosthod. 7:17-21, 1994.
12. Mercuri, L.G. et al.: Custom CAD/CAM total temporomandibular joint reconstruction system: Preliminary multicenter report, J. Oral Maxillofac. Surg. 53:106-115, 1995.