CLINICAL REPORT

Use of Stereolithographic Templates for Surgical and Prosthodontic Implant Planning and Placement. Part II. A Clinical Report

Kunal Lal, DDS, MS;[1] George S. White, DDS;[2] Dennis N. Morea, DDS;[3] and Robert F. Wright, DDS[4]

Eight implants were placed in the posterior part of the mandible using computer-generated stereolithographic templates. Preoperative implant simulation was done on a 3D computer model created by reformatted computerized tomography data. The surgeon and the prosthodontist positioned the simulated implants in the most favorable position addressing all concerns with regard to anatomy, biomechanics, and esthetics. The length and diameter of each implant along with the angulation/collar of abutments required for a screw-retained prosthesis were determined.

Stereolithographic templates were then fabricated by incorporating the precise spatial position of the implants within the bone as previously planned during the computer simulation. The templates were fabricated to seat directly on the bone and were stable. The first template was used to complete osteotomies with a 2-mm twist drill followed by the second template for the 3-mm drill. Implants were placed and allowed to integrate for 4 months. After second-stage surgery, the definitive abutments were torqued into place followed by insertion of the definitive screw-retained prostheses. Dimensions of all implants and abutments were the same as planned during the computer simulation.

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INDEX WORDS: computerized tomography, stereolithography, computer-aided design, implantology, treatment planning, dental implants, surgical templates

A 66-YEAR-OLD male patient was referred to the postgraduate prosthodontic clinic at Columbia University School of Dental and Oral Surgery for a comprehensive diagnostic work-up.[1] The patient's medical history was noncontributory and there were no contraindications for treatment. The patient complained of pain and swelling in the mandibular posterior region.

Clinical and Radiographic Findings

Clinical examination (Fig 1) revealed defective amalgam restorations, extruded teeth in the maxillary arch, and bilateral, long-span, fixed partial dentures (FPDs) in the posterior part of the mandible. The FPDs were fabricated without correcting the unacceptable plane of occlusion resulting from the extruded maxillary teeth. There were

[1]Assistant Professor of Clinical Dentistry and Program Director, Graduate Prosthodontics, Columbia University, New York, NY.

[2]Associate Professor of Clinical Dentistry, Director, Department of Prosthodontics, Columbia University, College of Dental Medicine, New York, NY.

[3]Professor of Clinical Dentistry, Department of Prosthodontics, Columbia University, New York, NY.

[4]Associate Professor of Restorative Dentistry and Biomaterials Sciences and Director of Advanced Graduate Prosthodontics at Harvard School of Dental Medicine. Formerly, Professor of Clinical Dentistry (in Otolaryngology/Head and Neck Surgery), Director, Columbia University, Department of Prosthodontics, Columbia University, New York, NY.

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Correspondence to: Kunal Lal, DDS, MS, 630 W. 168th Street, PH 7-E, Rm 121-A, New York, NY 10032. E-mail: kl341@columbia.edu.

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Figure 1. Intraoral frontal view in maximum intercuspation.

working and nonworking side interferences in the molar region resulting in a restricted range of mandibular movement. The prostheses had open margins with resultant secondary caries in the abutment teeth. The porcelain had fractured off in several places resulting in the exposure of metal substructure and unacceptable occlusion. The periodontal tissue around the distal abutments was generally erythematous; periodontal charting revealed probing depths between 6 and 9 mm, and significant bleeding was observed on probing.

Radiographic examination revealed periapical lesions around all the abutment teeth with significant bone loss. Tooth no. 18 had a hemisected mesial root. Teeth nos. 21 and 28 had inadequate dowel-core restorations (Fig 2).

The diagnostic casts were articulated on a semi-adjustable articulator (Whip Mix 2240, Louisville, KY) with the help of a facebow transfer and a centric relation interocclusal record.

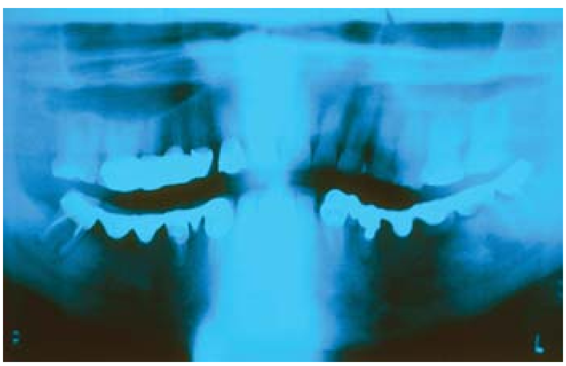

Figure 2. Preoperative panoramic radiograph.

A comprehensive treatment plan was presented to the patient based on clinical and radiographic findings, specialty consultations, articulated diagnostic casts, diagnostic wax-up, and, to some extent, the patient's desires.

After consultation with the endodontist and the periodontist, it was determined that the mandibular posterior teeth had a poor prognosis. The existing fixed partial dentures were removed and the teeth were extracted to eliminate the periodontal pathology.

For the purpose of this article, only treatment of the posterior part of the mandible with a screw-retained implant-supported prosthesis will be discussed.

Diagnostic Wax-Up/Radiographic Template

A diagnostic wax-up[2] was done, and a Broaderick occlusal plane analyzer was used to develop an ideal plane of occlusion.[3,4] The diagnostic wax-up was duplicated in the form of a radiographic template using orthodontic resin (Fig 3).

Gutta-percha markers were placed in the mesio-distal centers of the buccal aspect of the teeth in the resin template. Alternatively, it might have been better to have used barium sulphate denture teeth, such as Vivo TAC/Ortho TAC (Ivoclar Vivadent, Amherst, NY) for the radiographic template for more precise planning.[5] The barium teeth are a more accurate representation of the intended restoration as they appear

Figure 3. Radiographic template tried-in and checked for stability prior to the computed tomography scanning procedure. Gutta-percha markers were placed in the mesio-distal center of the buccal surfaces of the teeth.

on the reformatted CT data. This would preclude the possibility of deviating from the confines of the intended restoration while moving the simulated implants or using angulation correcting abutments. Denture teeth of molds identical to the barium teeth may then be used for fabricating a fixed or removable interim prosthesis using a vinylsiloxane index made from the radiographic template.

Scanning Procedure

The patient was sent for a spiral CT scan with 1 mm slice intervals and a 0° gantry tilt. The raw data were sent electronically to Materialise, Belgium for reformatting into a virtual 3D model along with parasagittal views of the bone.

3D Computer Simulation

The implant simulation was carried out using the Surgicase software (Materialise, Leuven, Belgium) with the 3D model and parasagittal views (Fig 4).

The surgeon finalized the length and diameter of each implant along with their optimal spatial positioning within the bone. On the right side, the two distal implants were kept shorter due to proximity to the inferior dental alveolar canal. The anterior-most implant had to be placed in the embrasure between nos. 28 and 29. Tooth no. 27 was facially inclined resulting in the apical part of the root directly below site no. 28. The location of the mental foramen prevented implant placement in site no. 29.

The abutments were also selected at this stage based on the angulations of the implant as they related to the 3D representations of the gutta-percha markers used in the radiographic template. On the left side, it was determined that the use of angulated abutments would not be necessary, as the long axes of the four implants appeared to be emerging from the center of the occlusal surface of the intended definitive restoration.

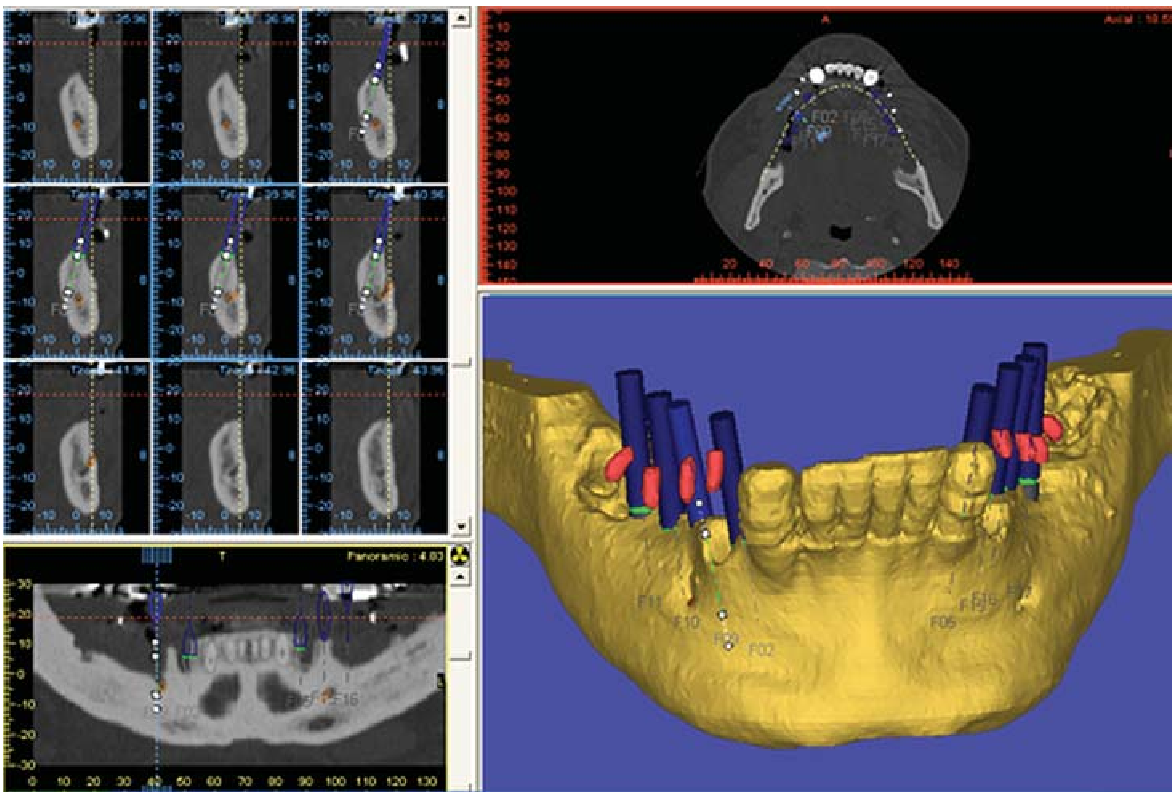

Figure 4. Reformatted CT data using Surgicase software showing cross-sectional, panoramic, axial, and 3D views. Note the gutta-percha markers on the 3D model allowing easy and accurate planning of fixture position.

Recent extraction sockets and inadequate bone prevented the placement of a fifth implant in the no. 18 site. For this reason the unopposed no. 15 was splinted to no. 14 to prevent supraeruption.

On the right side, however, due to the remodeling of the alveolar ridge under the pontic area of the previously fixed partial denture, the implant simulation resulted in a more buccal inclination of the long axes as related to the radio-opaque markers. Use of a 30° angulated abutment for all four implants on the right side appeared to orient the future screw access hole in the desired position (Fig 5). It was noted at this point, that for the system being used (Nobel Biocare, Yorba Linda, CA), the smallest collar available with the 30° angulated abutment was 4 mm. Use of these abutments would result in a nonesthetic display of metal collar. The problem could probably have been overcome by use of custom abutments and a cement-retained prosthesis, but then there would have been no way of verifying if the abutments planned presurgically with regard to angulation were the same as those actually used postsurgically. The matter was discussed with the patient and since it was in a nonesthetic area, he did not raise any objections.

The finalized 3D simulation was electronically sent to Materialise, Belgium. The stereolithographic models and templates (Surgiguides) were sent back in 2 weeks (Fig 6).

Prior to surgery, a second set of templates were used to drill holes in the stereolithographic model

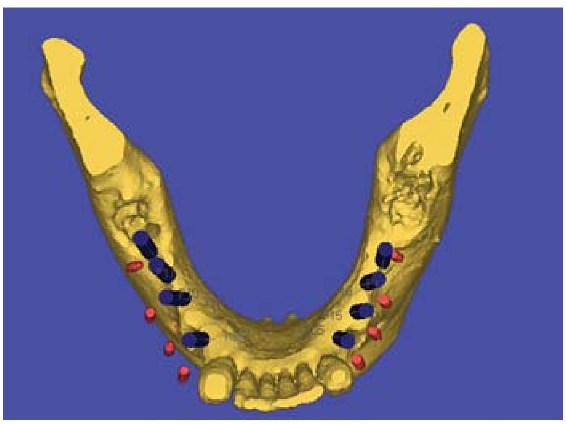

Figure 5. Three-dimensional model can be interactively rotated. This occlusal view allowed for planning of fixtures for tripodization and correcting abutment angulation, so screw access holes were in ideal location.

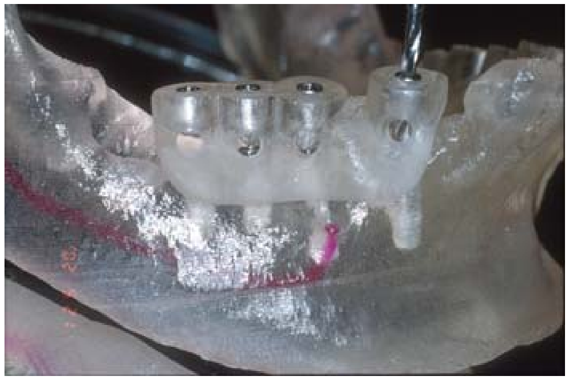

Figure 6. Stereolithographic model of the patient's mandible with S-L template. Metal sleeves of varying diameters guide the osteotomy drills. Windows on the buccal aspect allow access for external irrigation. Note the location of the mandibular nerve selectively colored in red giving the surgeon a preview of vital anatomical structures.

to familiarize the surgeon with the system. The mandibular nerve was selectively colored red and the remaining osseous structure of the mandible was made transparent in the stereolithographic model. Following the trial drilling on the model, it was reassuring to see that the drill sites were well away from the nerve and closely resembled the 3D model of the computer simulation. This model could be articulated with the cast of the opposing dentition and used to fabricate an interim/definitive prosthesis.

Surgical Procedure

Since it was the first time the system was being used by this team, implant placement was carried out separately for the right and left sides. A full-thickness mucoperiosteal flap was reflected and the first template corresponding to the 2-mm twist drill was seated. Care was taken to prevent the free ends of the flap from interfering with the seating of the template (Fig 7).

Osteotomies with the 2-mm drill were completed and then enlarged using the second template corresponding to the 3-mm twist drill. Implants were placed and conventional procedures were followed for the two-stage procedure. At this point, dimensions of all implants used during surgery were compared with those planned preoperatively; they were identical for all eight implants.

Figure 7. Stereolithographic template seated directly on the bone. The unique surface topography of the bone recorded by the CT scan and incorporated in the S-L template results in a precise fit without the need for external fixation.

Implants were allowed to integrate for a period of 4 months during which time the patient was wearing a removable partial interim prosthesis.

Prosthodontic Procedure

Following second-stage surgery, an implant-level impression was made using polyether impression material (Impregum, 3M, St. Paul, MN) along with a new centric relation record to articulate the master casts. The previously selected abutments were oriented appropriately on the cast using a clear vacuum-formed template of the initial wax-

Figure 8. Mandibular occlusal view of definitive screw-retained implant-supported prosthesis with screw access holes in a favorable location. Note the similarity in screw access hole in Figure 4.

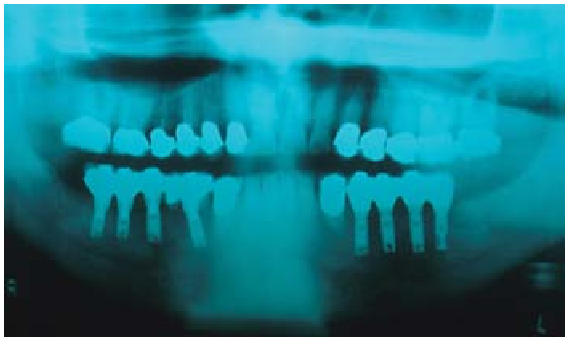

Figure 9. Postoperative panoramic radiograph.

up as a guide. The metal framework was then fabricated along with an interim fixed prosthesis at the abutment level. GC pattern resin (GC Corporation, Tokyo, Japan) was used to connect the abutments together in the form of an abutment transfer assembly to help transfer them intraorally.

The abutments were transferred to the implants and hand tightened. The metal framework was then tried in and radiographs were made to verify the seating of the abutments and framework.

The framework was removed, abutment screws torqued, and the interim prosthesis secured in place over the abutments. The ceramist proceeded with the porcelain application and returned the prostheses with the bisque bake. The Hobo twin-stage procedure was used to develop the occlusal scheme.[6] The prostheses were tried in the patient's mouth and functionally equilibrated.

Table 1. Preoperative and Postoperative Case Inventory, Recording Length and Diameter of Individual Implants Used and Angulation and Collar Height of Individual Abutments Used for the Definitive Prosthesis

Site	*Implant (Length/ Diameter)*	*Abutment (Angulation/ Collar)*	*Manufacturer*
19	13/3.75	0°/2 mm	Nobel Biocare
19	13/3.75	0°/2 mm	Nobel Biocare
20	13/3.75	0°/2 mm	Nobel Biocare
21	13/3.75	0°/2 mm	Nobel Biocare
28-29	13/3.75	30°/4 mm	Nobel Biocare
30	13/3.75	30°/4 mm	Nobel Biocare
30	10/3.75	30°/4 mm	Nobel Biocare
31	10/3.75	30°/4 mm	Nobel Biocare

All surgical and prosthetic components used were identical with those planned during the 3D simulation.

Figure 10. Postoperative lateral view of right side in maximum intercuspation.

Figure 11. Postoperative lateral view of left side in maximum intercuspation.

This was followed by the insertion of the definitive prosthesis. All the abutments used were identical to those planned and the resulting screw-retained definitive prosthesis displayed screw access holes oriented in the center of the occlusal surfaces of the teeth (Fig 8). A posttreatment panoramic radiograph was made (Fig 9).

Conclusion

The postoperative inventory list was compared with the preoperative list and dimensions of all implants as well as angulations of all abutments used were identical (Table 1). In addition, the screw access holes for all eight implants placed were predictably oriented near the center of the occlusal surface of the definitive prosthesis. At the 18-month postinsertion follow-up, probing depths were 3 to 4 mm and horizontal bitewing radiographs revealed stable bone levels corresponding to the first thread of all the implants.

The results from this clinical report are not only encouraging, but also indicative that near ideal surgical and prosthodontic implant placement can predictably be achieved using stereolithographic templates (Figs 10 and 11). The mucosally supported templates could make the procedure less invasive and significantly reduce the time required for comprehensive oral rehabilitation with dental implants. The task at hand now is to create an evidence base for this technique and make further assessment based on those results. Continued success using stereolithographic templates may make this procedure the standard of care for implant placement.

Acknowledgment

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