Computer-aided design provisionalization and implant insertion combined with optical scanning of plaster casts and computed tomography data

Shingo Hara¹, Masaharu Mitsugi¹,², Takahiro Kanno³, Yukihiro Tatemoto¹

¹Department of Oral and Maxillofacial Surgery, Kochi Health Sciences Center, 2125-1 Ike, Kochi 781-8555, ²Takamatsu Oral and Maxillofacial Surgery Clinic, 11-16 Shioya-Machi, Takamatsu, Kagawa 760-0047, ³Department of Oral & Maxillofacial Surgery, Shimane University, Faculty of Medicine, 89-1 Enya-Cho, Izumo, Shimane 693-8501, Japan

Address for correspondence:
Dr. Shingo Hara, Department of Oral and Maxillofacial Surgery, Kochi Health Sciences Center, 2125-1 Ike, Kochi 781-8555, Japan. E-mail: shingo_hara_kochi@live.jp

ABSTRACT

The conventional implant prosthesis planning process currently involves confirmation of two-dimensional anatomical findings or the quantity and quality of bones using panoramic X-ray images. The introduction of computed tomography (CT) into the field has enabled the previously impossible confirmation of three-dimensional findings, making implant planning in precise locations possible. However, artifacts caused by the presence of metal prostheses can become problematic and can result in obstacles to diagnosis and implant planning. The most updated version of SimPlant® Pro has made it possible to integrate plaster cast images with CT data using optical scanning. Using this function, the obstacles created by metal prostheses are eliminated, facilitating implant planning at the actual intraoral location. Furthermore, a SurgiGuide® based on individual patient information can be created on plaster casts, resulting in easier and more precise implant insertion.

Keywords: Auto-Tooth Bone, computer-aided design/computer-aided manufacturing, implant dentistry, SimPlant® Pro

INTRODUCTION

Conventional implant prosthesis planning, whether it is a bottom-up or a top-down treatment, currently involves confirmation of two-dimensional anatomical findings or the quantity and quality of bones using panoramic X-ray images coupled with the experience and intuition of a surgeon who is skilled in implant insertion. Due to this dependence on experience, it is difficult for less-experienced surgeons or dentists who have no experience in actual mandibular dissection to accomplish this task.

Since clinicians have begun to use computed tomography (CT), which enables confirmation of three-dimensional findings, it is possible to plan implant placement in precise locations.

In addition, planning software such as SurgiGuide® by Materialise Dental[1-3] and NobelGuide® by Nobel Biocare[4-6] allows easier, safer and more precise placement of implants, making these treatments more accessible for dentists and their patients. However, artifacts caused by metal prostheses during CT imaging are problematic and result in obstacles to diagnosis and procedure planning.

The most recent version of SimPlant® Pro has made it possible to integrate plaster cast images with CT data using optical scanning. Therefore, obstacles created by metal prostheses are eliminated and implant planning at the actual intraoral location becomes possible. Furthermore, a SurgiGuide® based on individual patient information can be created on plaster casts, resulting in easier and more precise implant insertion.

MATERIALS AND METHODS

Data collection
Before tooth extraction, we initiated CT, either helical or cone-
beam, of the middle and lower sections of the face. CT imaging was conducted in accordance with the conditions specified by Materialize Dental. Imaging should also incorporate the mandibular canal of the upper and lower jaws as well as the maxillary sinus floor; these images were axial slices spaced 0.5 mm apart. To avoid issues with occlusion, the patient bit down on a radio-transparent silicon guard without opening his/her mouth. The thickness was adjusted such that the upper and lower teeth did not touch. Any artificial teeth present were also not removed during imaging. The imaging side was set parallel to the occlusal surface so that artifacts did not infiltrate the maxilla. The image data were then saved in DICOM format files.

**Laser scanning of plaster casts**
Next, we prepared a plaster cast for optical scanning. When tooth extraction was performed during or prior to surgery, a cast without the extracted tooth was prepared. The optical scanning data were then converted to a standard triangulated language (STL) file at Materialize Dental Japan.

**Data incorporation**
After segmenting the CT data into the upper and lower jaws (if necessary, by dividing the maxilla and the teeth), the CT and plaster cast data were combined in compliance with the optical scan wizard of SimPlant® Pro. A mucosal surface such as the palate or orthodontic anchor screws were used as the index, even if there were many tooth artifacts [Figure 1].

**Data analysis and preliminary planning**
The rendering of the mandibular canal was first modified during imaging. When checking and modifying occlusion (confirming CO=CR), the jaw was rotated so that the head of the mandible was in its normal location. For treatment resulting in facial changes, photo mapping of the frontal face was performed for segmentation under the condition of the soft-tissues.

The tooth designated for extraction was eliminated, which was segmented above. Grinding of the plaster cast or virtual extraction was also performed as needed [Figure 2]. The minor tooth movement (MTM) was used to move and rotate the segmented tooth and the plaster cast tooth.

**Setup of a Virtual Tooth with SimPlant O&O version**
Prosthesis was created after the size and occlusion were determined according to the plaster cast tooth.

**Implant planning**
Using the virtual teeth, the desired manufacturer, type, thickness and length of the implant was selected from the implant library. It was necessary to include anchor pins in the design when the guide design was mucosa-borne and unstable. In addition, when teeth were extracted during surgery, the implant was inserted by replacement with the guide, by the placement of anchor pins in the guide before extraction, or by use of a plaster cast incorporating orthodontic anchor screws.

**Setup of an abutment**
The type and size of abutment were selected from the implant library in the same manner.

Additional procedures such as bone grafting, guided bone regeneration, sinus lift, or alveolar bone extension were selected as needed. If there was a large amount of bone loss, an alveolar bone extension was created. In general, insertion (drilling) was completed underneath the guide, while additional surgery was performed on removal of the guide [Figure 3].

**Preview output of the plan and purchase order of the guide**
After establishing the shape of the guide by selecting bone, tooth and mucosal support, the planned design was confirmed in the preview. If the plan was acceptable, the appropriate SurgiGuide® was ordered. The Nobel Compatible SAFE SurgiGuide®, a dedicated guide for NobelGuide® of SimPlant®, was used [Figure 4].

**Guide modification**
The virtual teeth and the Nobel Compatible SAFE SurgiGuide® were sent from Materialise Dental in approximately a couple of weeks after order placement. This guide was created by
Hara, et al.: CAD provisionalization combined with optical scanning

computer-aided design (CAD) and used for the preparation of each implant cavity for each diameter of implants by computer-aided manufacturing (CAM).

The number of implant cavities for the planned preparation, along with metal tubes corresponding to the diameter of the drill used for preparation was incorporated into each SurgiGuide®. The diameter of the metal tube was determined by the twist drill (each manufacturer has its own size) used at the time of preparation of the implant cavity. In general, the diameter was 0.03-0.1 mm larger than that of the drill.

In the case of the Nobel Compatible SAFE SurgiGuide®, the same guide used for the NobelGuide® was created.

Guide adjustment and provisionalization
The SurgiGuide® was designed to be slightly larger to allow for adjustment prior to surgery. Because the virtual teeth were created and sent with transparent or white laser lithography resin or in the form of ivory Immediate Smile Bridge by PMMA, it was sometimes necessary to modify the gum area and prepare an acrylic resin replacement. When many teeth were missing and occlusion required restructuring, technical work was required to return to the dental articulator by using a plaster cast and SurgiGuide® virtual teeth. In these cases, Nobel’s Guided Cylinder with Pin® was effective [Figures 5-8].

Surgery
The surgical kit for the NobelGuide® was used for surgery under local anesthesia (concomitant use with intravenous sedation), which was conducted in compliance with the surgical procedure of the NobelGuide®. One implant was inserted at a time so that the insertion direction did not shift. It was important to confirm the insertion depth with X-ray photos during surgery. On confirmation of a proper insertion, the provisional restoration was fixed. Provisionalization using Nobel Biocare: Quick Temp Abutment® was usually performed for cases with a small number of missing teeth, while that using Guided Abutment® was used for cases with a large number of missing teeth [Figures 9 and 10].

Postoperative management and Follow-up
Occlusion was examined every week following provisionalization and the provisional restoration was removed 3-6 months later. The 2nd provisional restoration was fixed after the confirmation test for the implant.

Figure 3: Bone graft in the sockets (upper). Implant planning in accordance with virtual teeth and sinus lift (lower)

Figure 5: An occlusal relationship between virtual teeth can also be set up from computed tomography imaging when the jaws are in proper occlusion

Figure 4: Planning of Nobel Compatible SAFE SurgiGuide® by SimPlant®

Figure 6: Provisionalization. (a) Recording the location of the virtual teeth by fabricating a design according to the guide pin length during abutment selection, (b) creation of the mucosal side of the virtual teeth in accordance with the plaster cast
Hara, et al.: CAD provisionalization combined with optical scanning

CASE REPORT

The present case report is about a 45-year-old female patient who presented with an almost collapsed bite with many unsalvageable teeth. Her chief complaint was impaired mastication and she requested implant prosthesis for the entire maxilla. The remaining teeth were extracted and implants inserted without raising a flap. Immediate provisionalization was planned, depending on the initial fixation.

The patient is currently missing teeth #17-21 and #25. It was necessary to create bones or perform a sinus lift due to the alveolar bone resorption around the bilateral molars and the overhanging maxillary antrum floor. We anticipated the necessity for bone grafting in the socket and the surrounding area of the implant body for #26, where immediate insertion was planned on tooth extraction and #16, which was extracted 2 weeks prior [Figure 11].

Preparation
CT was performed under occlusion conditions at the initial consultation and an impression was obtained by insertion of the implant anchor into the region of #18 to determine the guide location for surgery. Intraoral CT data and the plaster cast for optical scanning were prepared for incorporation into SimPlant® Pro. Virtual tooth extraction was performed for #23 and #26 using the osteotomy function of the O&O version on the plaster cast. Guide restoration was planned at three sites, including the implant anchor placed in #28. The above mentioned fabricated bone was also added to the treatment plan and for bone grafting, we decided to use Auto-Tooth Bone® [5,6] granules from the naturally missing right molar. The Hounsfield value for the CT revealed a possibility of insufficient initial fixation. Therefore, treatment was planned such that a spare immediate provisional (IP) implant could be inserted into the bilateral maxillary tuberosity area. The SurgiGuide® was used and a provisional restoration fabricated according to these observations. No additional procedures such as tooth extraction were conducted until surgery [Figure 12].

Implant insertion
The following teeth were extracted under intravenous sedation: #23, #25 (dummy), #26 and #21 (remaining root). The SurgiGuide® was then fixed. The frontal implant was inserted as planned and socket lifting performed using Auto-Tooth Bone granules for #16 and #26 by incorporating the SCA kit (Neobiotech: Korea) into the guide, followed by implant insertion. Because sufficient initial fixture was not obtained for #14, the guide was removed and then the wide platform (WP) implant was

Figure 7: The occlusal relationship and virtual teeth can be returned to the dental articulator

Figure 8: Wax-up and provisionalization based on virtual teeth

Figure 9: Photos during surgery. Implant insertion in the exact planned location and depth is possible in a short duration of time

Figure 10: After extraction of the remaining canine tooth, install the immediate-loading provisionalization
replaced for #14. Furthermore, because the initial load for #16 and #26 did not reach 35 N, an IP implant was inserted in the maxillary tuberosity area after guide reinstallation. The surgical treatment was completed by hemostasis treatment after guide removal and remaining tooth extraction [Figure 13].

**Provisional prosthesis**

Subsequently, the reinserted provisional for part of #14 was modified in accordance with the temporary abutment and the provisional was trial-tested at 10 N with the guided abutment. After occlusion adjustment, it was finally fixed at 20 N. Treatment was completed by grafting granulates of auto-tooth bone in areas where the spaces between the socket and implant were large. The chair time for this case was 4 h, including additional bone grafting, re-insertion of an implant and modification of the corresponding provisionalization [Figure 14].

**DISCUSSION**

**Computer-guided implant planning**

The combination of analog and digital techniques to augment CT-guided implant treatment illustrates the potential of this technique. CT data were collected as follows. One CT image was obtained for each maxilla with the patient’s mouth open, attachment of a CT stent, enhancement with contrast media or Gutta-percha. The mainstream technique uses a plaster cast attached to the articulator in analog, with only the occlusion relationship created by the CT stent reflecting the surgical stent.
Double scans (NobelGuide®, etc.) are more advanced procedures, wherein CT is conducted separately for the CT stent and designed by superimposition on a PC as digital data. However, because the maxilla and mandible have to be imaged separately, a double scan must be conducted four times. Furthermore, the performance still requires separate performing planes, which in turn requires the patient to open his/her mouth, even though the procedure may be conducted while maintaining the occlusal relationship. Artifacts resulting from metal implants interfere with the recording of the occlusal relationship between the upper and lower jaws. Even if it was possible, segmentation (extracting the data) was not possible in the area where both occlusal surfaces of the metal crowns met.

**Handling of metal artifacts on CT images**

The effects of metal prostheses on CT images is conventionally handled either by conducting CT after extraction or removal of metal crowns or by manually adjusting the photographed slices. However, extracting teeth to obtain a diagnosis and determine which teeth require extraction wastes the diagnostic value of CT. Furthermore, patients may not consent to metal crown removal; therefore, the ability to manually process the CT images may be limited and errors resulting from these shortcomings may inhibit CAD/CAM treatment planning. Optical scanning with a plaster cast not only solves this problem but also provides a novel option that can display the surface shape of the alveolar ridge, including the gums, which are features poorly described by CT.

**Advantages and important points of this method**

The greatest advantage of guided surgery is that the guide is fit and stabilized by orthodontic implants or anchor pins. A drill is easily inserted into the drilling tube, enabling insertion at the accurate location (direction and depth). Variations in treatments among surgeons can be decreased, enhancing consistency. In addition, the overall surgical duration can be decreased. However, guided surgery using CT images of patients with several metal crowns were combined with conventional work using analog techniques. This method enables treatment planning using CT data and the plaster cast. Although not recommended, insertion and loading immediately after tooth extraction may be possible. Patients do not have to use artificial teeth during the period between extraction and implant placement; this decreases the number of medical check-ups, with only one required before surgery and one required immediately after surgery.

**Advantages and importance of this method in terms of technique**

This method enables the elimination of planning errors due to incompatibility of the CT stent or errors caused by superimposition. Absolute return of the created SurgiGuide® to the optically scanned cast enables a significant decrease in the time spent on correction or adjustment. Furthermore, with the conventional method, the insertion location was largely controlled at the operating surgeon’s discretion, with esthetics and strength sacrificed for an easily modified provisional restoration created beforehand. This method also required more time to make chair side adjustments before immediate loading. Because of the possibility of minor errors in implant insertion, the provisional restoration may be installed without much modification, motivating technicians to create provisional restorations. Furthermore, with this creation method, virtual teeth are the effective index in transferring the virtual teeth on the PC to real teeth, facilitating simplified technical operations.

However, although implant insertion direction and depth are more accurate if a provisional restoration is prepared, the requirement of more precise and sufficient strength makes it more difficult to ignore the effect of errors associated with implant insertion caused by stent deflection and other issues. This compromises provisionalization and results in errors similar to those resulting from the conventional method. The author and colleagues often favor the application of the Guided Abutment® in order to solve these problems. The guided Abutment® allows a 20° relative angle of fixtures and resolution of the 0.4-mm perpendicular error. Dispersing the stent deflection evenly facilitates provisionalization with only a fastening screw after surgery.

The guide created on a PC must be moved from virtual to analog before actual surgery. The sleeve location has to be examined to see if any corrections are necessary because of production limitations of SurgiGuide® or any strength problems. If required, correction or enforcement of stents may be conducted after full consultation with the operating surgeon to ensure safety.

**CONCLUSION**

As shown in the case presented, if a metal prosthesis is present at the site of implant insertion, it is expected to cause shadows on CT. Because this results in obstacles for insertion simulation, we found that optical scanning of plaster casts combined with intraoral CT data is an effective measure for implant planning.

Creating a guide based on simulation by combining optically-scanned plaster cast and CT data has enabled more accurate, safe and easy implant insertion, which was previously performed according to experience and intuition. This method has resulted in dramatic advancements and outcome improvements for both surgeons and patients.

**REFERENCES**

1. Ruppin J, Popovic A, Strauss M, Spindrup E, Steiner A, Stoll C. Evaluation of the accuracy of three different computer-aided surgery systems in dental implantology: Optical tracking vs. stereolithographic splint systems. Clin Oral Implants Res 2008;19:709-16.
2. Tardieu PB, Vrielinck L, Escolano E, Henne M, Tardieu AL. Computer-assisted implant placement: Scan template, simplant, surgiguide, and SAFE system. Int J Periodontics Restorative Dent 2007;27:141-9.
3. Vasak C, Kohal RJ, Lettner S, Rohné D, Zechner W. Clinical and radiological evaluation of a template-guided (NobelGuide™) treatment concept. Clin Oral Implants Res 2014;25:116-23.
4. Abbond M, Wahl G, Guirado JL, Orentlicher G. Application and success of two stereolithographic surgical guide systems for implant placement with immediate loading. Int J Oral Maxillofac Implants 2012;27:634-43.
5. Kim YK, Kim SG, Byeon JH, Lee HJ, Min IU, Lim SC, et al. Development of a novel bone grafting material using autogenous teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2010;109:496-503.
6. Hara S, Mitsugi M, Kanno T, Tatemoto Y. Bone transport and bone graft using auto-tooth bone for alveolar cleft repair. J Craniofac Surg 2013;24:e65-8.