Clinical update

Application of CT imaging for dental implant simulation

Yoshiyuki Hagiwara, Masayuki Koizumi and Takayoshi Igarashi

Department of Crown and Bridge Prosthodontics, Nihon University School of Dentistry, Tokyo 101-8310

(Received 10 August and accepted 1 November 1999)

Abstract: Accurate diagnosis and exact treatment planning are very important for successful implant treatment. Pretreatment examination and simulations using CT can be especially effective information sources, and diagnosis by CT imaging before treatment substantially enhances the security and safety of the treatment plan. New interactive CT software (SIM/Plant™) which enables diagnosis of bone morphology and quality, and also implant simulation on a personal computer through multiplanar reformation of CT images, has been developed. Stereolithography-models (SLMs) are reproduced anatomical morphological models of an individual patient’s bone structure from the information obtained by the CT scan, and is fabricated out of light cure resin. In this article, SLMs and SIM/Plant™ for simulation of various examinations and diagnosis incorporating CT information are described, and their features are introduced. (J. Oral Sci. 41, 157-161, 1999)

Key words: osseointegrated implant; CT; SIM/Plant™; stereolithography-model; simulation.

Introduction

The use of osseointegrated implants for the restoration of oral function and form of totally and partially edentulous patients is widely accepted and scientifically supported. The evolution of dental implantology has been swift and comprehensive in the past 10 to 15 years (1-10). This is not only due to new technological developments and improvements made in the areas of implant systems and guided bone regeneration (GBR), but also because of improvements in diagnosis and diagnostic apparatus. In particular, for complicate cases, diagnosis by CT imaging before treatment substantially enhances the security and safety of the treatment plan (11-16). Recently, an interactive CT software named SIM/Plant™ (Columbia Scientific Inc., Columbia, Maryland, USA) was developed and its clinical uses are being examined and discussed (17,18). This software enables clinicians to conduct a simulation procedure for diagnosis of bone morphology and quality and also perform implant simulation on a personal computer through multiplanar reformation of CT images. In addition to the above, the authors are studying the use of Stereolithography models (SLMs), which incorporate CT information in simulation of dental implants (19). SLMs reproduce the anatomical morphology from an individual patient using the information obtained by the CT scan, and this information is used to fabricate a model out of a light cure resin. Also SLMs differ from CAD/CAM models in that they can, to a certain extent, reproduce cortical and sponge bone, airway space such as a sinus and mandibular canal as well as the external morphology of the jaw bone (19,20). This model leads to accurate examination, diagnosis and determination of the treatment plan for dental implants. Further, it also makes possible pretreatment simulation on a model derived from the actual patient, and thereby is quite effective in implant education.

Clinical Applications of the Stereolithography Models and SIM/Plant: A Case Report

In this article, a clinical case is presented of the application of the SLM and SIM/Plant for a simulation of various examinations and diagnoses.

The patient was a 57 year woman who had been wearing a overdenture for about 10 years. This patient had an imbalance of right and left mandibular ridges that could be observed as a transition from the non-vertical stop occlusion (Fig. 1). CT was taken before the treatment, and based on that information, a SLM was fabricated (Fig. 2, Fig. 3 and Table1). The improved SLM was effective for not only implant placement, but also...
for soft tissue management simulation and for implant education. Therefore, to furnish the conventional SLM adhesion to pseudo-soft tissue which is made out of urethane coated with a latex, for achieve the similar periosteal elevation force which was based on the data from the long bone of monkeys (21) to that of vital one’s (Fig. 4).

In this clinical case, CT was used for pretreatment simulation of the upcoming surgical procedures. Sufficient and practical simulation could be used in determination of the location of the incision line, feeling of the periosteal elevation, reduction to establish a platform and implant placement. This model could not only simulate working with hard tissue but also soft tissue (Fig. 5).

---

Table 1 Features of Stereolithographic model

1. Reproduces anatomical morphology of an individual patient based on the CT data with light cure resin (Acrylic resin: SOMOS-3100)

2. Differs from CAD/CAM model in that it can reproduce to a certain cortical and sponge bone, airway space such as sinus and mandibular canal as well as jaw bone external morphology.

3. Easy to duplicate from stored CT data.

4. Leads to correct examination, diagnosis and determination of treatment planning in dental implant.

5. Could be used as educational phantom models with the simultaneous use of live surgery video and clinical procedure slides.

6. Pseudo-soft tissue model enables to simulate a sequence of soft tissue management.

---

Fig. 2 Fabrication of stereolithography-model.

Fig. 3 Stereolithographic model fabricated from the CT data of the patient.

Fig. 4 Modified Stereolithographic model adhered to urethane form as pseudo-soft tissue.

---

Fig. 5a Comparison of the anatomical shape between the SLM and patient mandible.

Fig. 5b Platform preparation on the mandible for implant site (SLM simulation and surgical phase).

Fig. 5c Simulation of implants placement (six implants placed between mental foramen).
The use of SLMs enables the study of placement location and directions, as well as actual placement exercise, even including soft tissue management up to suture with the model with pseudo-soft tissue attachments. This pseudo-soft tissue model has appropriate elasticity, and therefore allows even beginners to practice soft tissue management and suturing without breakage. The fabrication and use of SLMs is based on the important premise that CT must be taken, however, SLMs can also be effectively used with SIM/Plant as applied in the CT simulation (Fig. 6 and Table 2).

SIM/Plant was developed in the United States in 1993 as software to conduct simulation on a personal computer through multiplanar reformation of CT images for examination of jaw morphology, bone quality and implant placement (17,18,22,23). This software use has been increasing year by year (24,25). SIM/Plant consists of trans-axial, panoramic and cross-sectional images of selected areas and CT imaging of the jaw morphology is analyzed on the personal computer. SIM/Plant is a diagnostic simulation system which determines the size of implant to be actually used, as well as its number, position and angle of insertion (18,19,25). Figure 7 shows the central area of the mandibular bone of this patient. This area is sliced from the central solid line to the dotted line into nine sections. Using this image as a reference in between the mental foramen, six implants were placed by SIM/Plant simulation. As seen in this case, SIM/Plant can indicate advanced jaw morphology and dimensions, and therefore location and the number of implants were simulated, and the size of implants can be correctly determined. A panoramic radiograph, from which diagnostic and simulation procedures were followed by implant placement, and final prosthesis are presented (Figs. 8 and 9).

**Discussion**

**SLM**

It is imperative to acquire knowledge and new techniques for prosthodontics, oral surgery, periodontics and oral anatomy to lead to implant success, and therefore training for such are quite important (19-26). Since the SLM represents the specific jaw morphology of the patient who will receive implant treatment, it is ideal not only for pretreatment simulation, but also for the training for surgery of the hard tissue, including implant placement (19,28,29). Further, by storing CT image data, multiple model duplicates can be produced, which could be used as educational models with the simultaneous use of image diagnosis data including CT, and other teaching materials such as live surgery videos and clinical procedure slides.

**Adhesion to the pseudo-soft tissue**

The ability to simulate pseudo-soft tissue enables one to simulate a sequence of treatments from establishment of the...
incision line, to the implant placement and suturing. The similarity of periosteal elevation force of the pseudo-soft tissue to that of live periosteal is extremely useful for pretreatment education for beginners. A disadvantage of this model is that since it is difficult to reproduce teeth in the case of a partially edentulous patient, this model is not recommended for training of treatments such as periodontal surgery.

**SIM/Plant**

When using SIM/Plant in implant diagnosis, it is necessary to take CT at a medical facility. In order to download and store the data in a Optical Magnetic Disc (MO), limited types and models of CT equipment can be used. The data can be loaded onto a personal computer for simulation only after the data in the MO are reconstructed through multiplanar reformation (17,24) in the IMAGEMASTER-101™ (Columbia Scientific Inc., U.S.A). At present about 80 dental and medical facilities are equipped with SIM/Plant systems in the Japanese market, and this number is likely to increase (18,22,25). Furthermore, we found no reports on the measurement accuracy using these methods. Thus, studies should be conducted examining the accuracy and discrepancy between actual and image measurement values when these methods are used.

**Summary**

Proper examinations before treatment are needed in any implant case regardless of the degree of difficulty. It is particularly important in difficult cases to collect as much accurate information as possible. Pretreatment examinations and simulation using CT can be very important information sources. It was emphasized that prosthodontic factors including occlusion maintenance are important for the long-term success of implants. Restorations should not be made where an implant was placed, but implants should be placed at the optimize position for the restorations. CT information is indispensable in this regard.

**References**


