Computer-assisted Implant Placement. A Case Report: Treatment of the Mandible

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The authors present a case of immediate loading of mandibular implants using a 5-step procedure. The first step consists of building a scannographic template, the second step consists of taking a computerized tomographic (CT) scan, and the third step consists of implant planning using SurgiCase software. The final 2 steps consist of implant placement using a drill guide created by stereolithography and placement of the prosthesis. Using a CT scan–based planning system, the surgeon is able to select the optimal locations for implant placement. By incorporating the prosthetic planning using a scannographic template, the treatment is optimized from a prosthetic point of view. Furthermore, the use of a stereolithographic drill guide allows a physical transfer of the implant planning to the patient's mouth. The scannographic template is designed so that it can be transformed into a temporary fixed prosthesis for immediate loading, and the definitive restoration is placed 3 months later. (INT J ORAL MAXILLOFAC IMPLANTS 2003;18:599–604)

Key words: *computer-assisted surgery, dental implants, drill guide, endosseous dental implantation, stereolithography, surgical guide*

Over the last few years, many different implant planning programs[1–5] have been developed to help in the planning and positioning of oral implants. There is agreement that the prosthesis should guide the surgical positioning of implants. Several systems have been designed to allow for a real transfer of planned data from the computer to the mouth of the patient at the time of implant placement.[6–9] Within the framework of the European Personalized Implants and Surgical Aids (PISA) project, several industrial companies and universities (Materialise, Philips Medical, Ceka, OBL, DuPuy International, Katholieke Universiteit Leuven, University of Leeds) pooled their knowledge between 1997 and the beginning of 2001. This led to computer programs for the planning of implants and the design of custom-made stereolithographic drill guides. This research was not limited to implant dentistry. Other implant approaches have also been developed: C1–C2 transarticular screw fixation, transcutaneous stabilization screws for treatment of ankle fractures, individualized implants for reconstruction of skull bone and maxillofacial bone defects, and 3-dimensional (3D) bone and soft tissue modeling of bone distractions.

With the tools designed by Materialise (Leuven, Belgium), a new therapeutic protocol was developed that included not only case planning based on 2D and 3D scanner data, but also the transfer of

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Fig 1 Photograph before treatment, with a highly and very unevenly resorbed mandible.

Fig 2 Scannographic template.

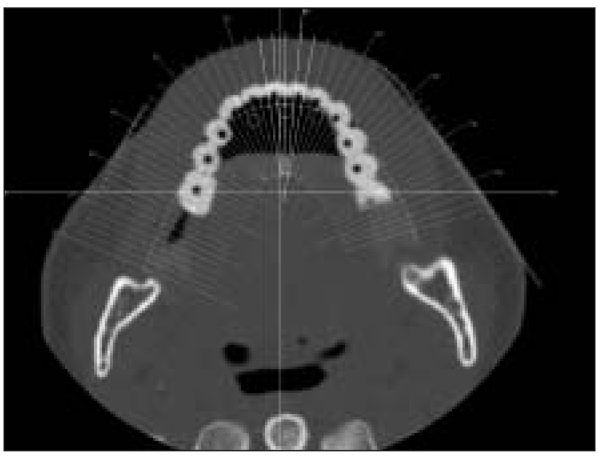


Fig 3 2D axial view with the image of the scannographic template.

implant planning into the mouth of the patient through the use of custom-made stereolithographic drill guides. This format was validated on cadavers and has been developed for human clinical applications. The following clinical problems have been tested with this treatment modality: partial or total rehabilitation in the maxilla or mandible, vertical-insertion or lateral-insertion implants, implants in extensive bone grafts,[10,11] classic (ie, delayed) loading (1 or 2 surgical stages), immediate loading, zygomatic and pterygoid implants,[12,13] and transmucosal implant placement.[14] To date, 4,800 implants have been placed using this procedure; the authors have placed more than 1,000 implants using this system.[15] To fully utilize the possibilities of this treatment modality, 5 steps have been proposed for implant treatment, as described below in the treatment of an edentulous mandible.

STEP 1: THE SCANNOGRAPHIC TEMPLATE

The scannographic template is the key to the system, since it allows the transfer of the predetermined prosthetic setup to the actual implant planning. The scanning template is an exact replica of the desired prosthetic end result. Incorporation of the scanning template into the computerized tomographic (CT) scanning data allows the surgeon to base implant planning on the desired prosthetic outcome. The treatment plan is thus driven by the prosthetic end result, rather than conversely.[11,12]

According to the literature, scannographic templates can be made of 15% by weight barium sulfate in resin powder, or by means of other radiopaque substances.[16,17] However, a variety of mixtures of barium sulfate ranging between 5% and 35% by weight have been used. Experimentation has revealed that the percentage should vary with respect to the surrounding elements (metal crowns or natural teeth) and also as a function of the opacity gradient that one wants to obtain within the same template containing several different radiopaque layers.

In the present clinical situation, the teeth were filled with 20% radiopaque mixture and the base was radio-transparent. Figure 1 shows the patient before treatment, with a highly and very unevenly resorbed edentulous mandible. The scannographic template was fabricated from a duplicate of the denture of the patient. On the scannographic template (Fig 2), the main axis of each tooth was marked by drilling a cylindric shaft in the tooth, centered on its occlusal side and emerging at the center of the cervical surface. On the scanning images, this cylindric shaft was easily visualized (Fig 3). In this clinical case, the teeth on the scannographic template were dyed, so that they could be used for the creation of an immediate temporary prosthesis.

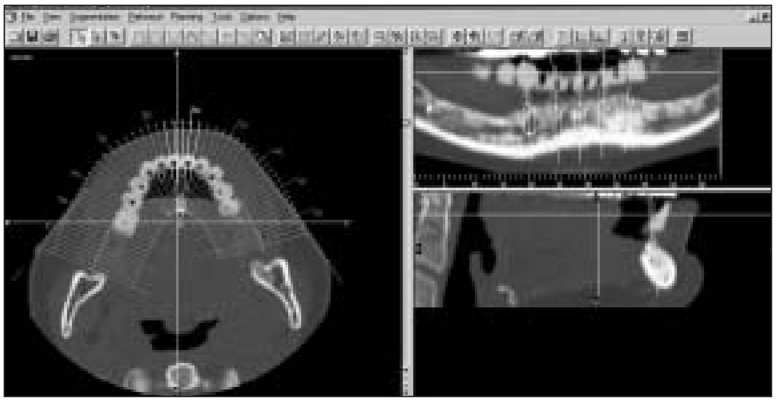


Fig 4 Window of the SurgiCase software showing different 2D sections.

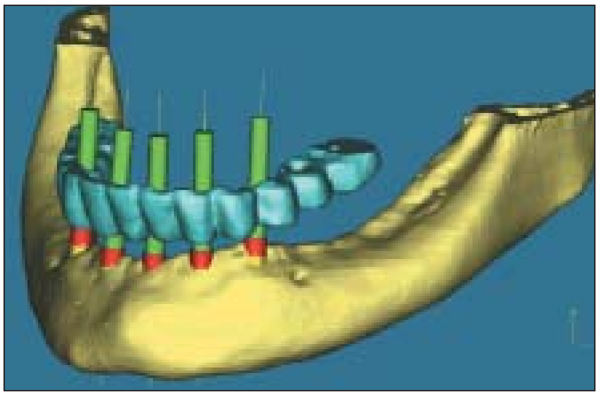
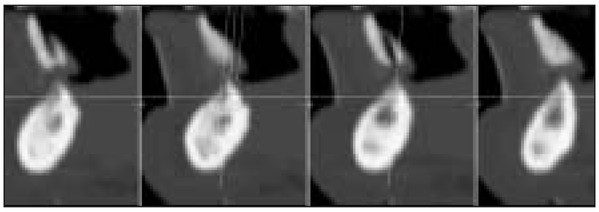


Fig 5 *(Left)* 3D reconstructions and implant planning.

Fig 6 *(Below)* Orthogonal frontal oblique reconstructions showing relationship between implant axis and tooth axis.



STEP 2: SCANNING, IMPORTING, AND PROCESSING OF THE IMAGES

The patient was sent to the radiologist with the scannographic template. The CT scan quality is of major importance, and the radiologist must pay particular attention to the following points. The axial plane must be determined parallel to the plane of occlusion, with the Gantry tilt at 0 degrees so as not to affect measurement accuracy. The CT scan must be taken without interarch contact, biting on cotton rolls, or a piece of wood, to avoid overlapping of the dental images of the opposite arch. The occlusal side of the arch must be clearly visible and should not have been cut off. The patient must be perfectly immobilized during the whole scanning procedure. When a scannographic template is used, its close adaptation with the underlying soft tissue must be verified before the scanning procedure starts.

After completion of the scan, the radiologist sent the data to a "data processing center." There, a computer engineer edited the images by removing scattered and useless parasite images (eg, spinal column, antagonist teeth, projection of the upper extremities of the mandible for maxillary analysis). The scanning template can easily be identified in axial sections. Different anatomic structures, such as the maxilla and mandible and the scannographic template, are separated in different masks. Each of these masks can be toggled on or off to allow separate visualization and interpretation. After calculation of the corresponding 3D models, the patient data were sent back to the surgeon on a CD-ROM so that the implant treatment plan could be started.

STEP 3: TREATMENT PLANNING

The SurgiCase Dental program (Materialise) that was used in this clinical case provides 4 views in which it is possible to modify the outline and display resolution at one's convenience (Fig 4). Each of these views displays either the sections in gray or 3D color reconstructions. The practitioner is able to view the predicted 3D color reconstructions and maneuver each element of the reconstruction (teeth, bone, nerve, implant), which the authors refer to as masks (Fig 5). When planning an implant in a cross-sectional image (Fig 6), the program automatically selects the length and diameter of the

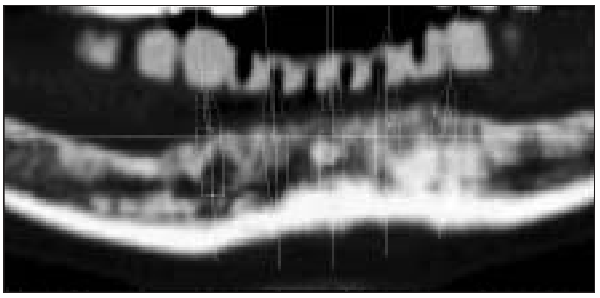


Fig 7 Panoramic reconstruction in 2D showing implant positions.

implants according to the existing dimensions of the brand of implant used. The position of the implant can then be fine-tuned by shifting, tilting, or adaptation of its dimensions in a panoramic reconstruction plane (Fig 7). Each implant may be assigned a "label." In planning for 8, 10, or more implants, the corresponding tooth number is generally selected to facilitate identification of the implants.

The software also has some semiautomatic functions to assist the surgeon in placing a newly planned implant between 2 other previously placed implants; another function facilitates translation of an implant over a certain amount of space along a predefined curve. Furthermore, there is a function that simulates the presence of angulated abutments. This is especially useful when dealing with implants that are planned with considerable angulation compared to the "normal" position. Using this angulated abutment simulation, it is possible to determine whether the implant will correspond with the original prosthetic plan. The remarkable versatility of the software in manipulation of the implants thus permits the selection of optimal locations for the implants according to a complex set of prerequisites, including correspondence with the initial prosthetic plan, visual check that the implant is encased in bone in all directions, and optimal position so that the implant is in a zone with the highest possible Hounsfield value.

STEP 4: CUSTOM-MADE STEREOLITHOGRAPHIC DRILL GUIDE

The finalized treatment plan is then used for fabrication of a surgical drill guide with bone support. The aim is to have an individualized drill guide that fits exactly on the bone crest of the patient. A CAD/CAM program uses the shape of the scanning template and the 3D information of the planned drill paths to design the drill guide. The drill guide is then produced by stereolithography. It has a special design consisting of a resin (USP Class 6 approved) backbone with cylindric openings into which stainless steel tubes are glued (Fig 8). The position and direction of the cylinders correspond exactly to the position and direction of the planned implants. A variety of drill guides can be used, and they may lay on bone, teeth, or mucosa.

In the clinical case presented, after incision and careful exposure of the bone, the drill guide was directly stabilized by several osteosynthesis screws (OBL, Chatillon, France) so that it did not move during drilling. Five-millimeter-high cylinders were used to guide the drills with precise tactile sensation during the drilling. This is appreciated particularly during tangential drilling on thin alveolar ridges or when one wants to modify a drilling axis in a fresh extraction alveolus. Drilling in the bone was performed as a 2-step procedure using 2 drills with different diameters. Drills with a diameter of 2.0 and 3.0 mm have been used in a single 3.2-mm drill cylinder. If more precision is needed, one can use a set of 2 drill guides with drilling tubes of 2.2 and 3.2 mm in diameter. A 15-mm drill length should be used for preparation of a 10-mm implant. After drilling, the drill guide was removed, and 5 Osseotite implants (3i/Implant Innovations, Palm Beach Gardens, FL) were placed manually (Fig 9).

STEP 5: THE PROSTHESIS

In the present patient, a temporary screw-retained prosthesis was placed 24 hours after implant placement (Fig 10), and the definitive restoration was placed 3 months later (Fig 11). Depending on laboratory and office schedules, it is possible to use the scannographic template to fabricate the immediate temporary prosthesis and to place it in the mouth the same day of the surgery. The immediate loading approach has been well documented since the early 1990s.[18–22] The protocol that was used allowed the completion of implant treatment fully guided by the prosthetic design, without a loss of control over the precision of data transfer from the scannographic template to the definitive prosthesis.

SUMMARY

Progress in medical imaging and data processing is creating profound changes in the way that professional practice is perceived. Treatments are becoming more precise, faster, and safer for patients, and

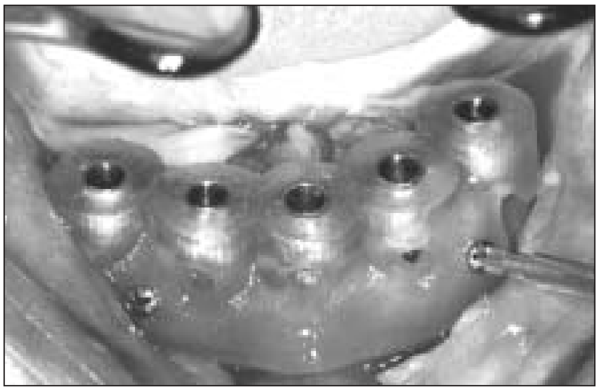


Fig 8 The drill guide is stabilized with osteosynthesis screws.

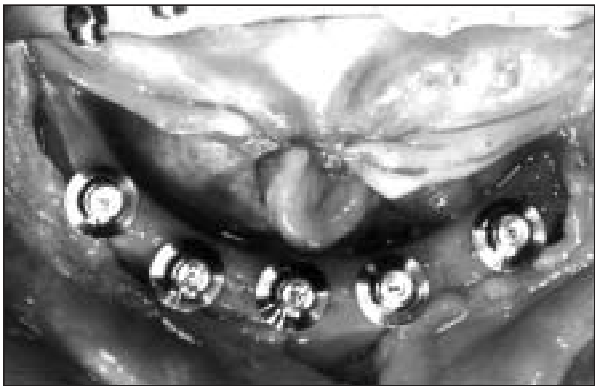


Fig 9 Implants are placed without the guide.

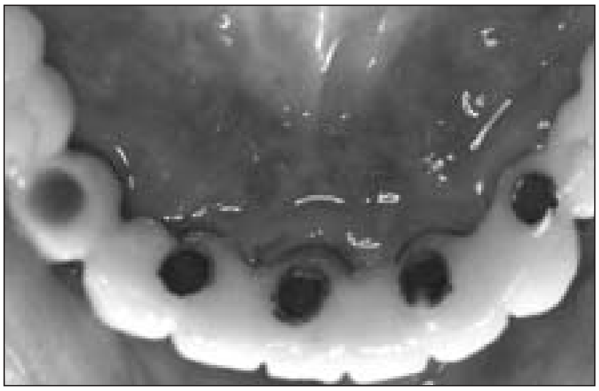


Fig 10 Placement of the temporary prosthesis 24 hours after implant surgery.

Fig 11 Definitive restoration placed 3 months subsequently.

surgeons are better able to control and carry them out. The precision of implant positioning also helps in reducing the cost of prosthetic restorations, avoiding the use of additional abutments to realign implants. Implant treatment with immediate loading using a bone-supported stereolithographic drill guide has been demonstrated in this treatment situation. This drill guide may be called the "missing link" in implant treatment.

The advantages of the described treatment protocol are apparent on 3 levels.

- With a CT scan–based planning system, the surgeon is able to select the optimal locations for implant placement, taking into account specific anatomic characteristics of the patient and using the optimal bone densities. The precision of the perpendicular reconstruction images along the axis of the arch (orthogonal frontal oblique sections) is 95%.[23,24] Thus, the precision of these reconstruction sections is amply sufficient for clinical application in implant therapy.
- Incorporation of the prosthetic planning using a scannographic template allows the treatment to be optimized from a prosthetic point of view.
- With the use of immediate loading, the temporary restoration can be placed only a few hours after implant placement.

Compared with other techniques (robotization or magnetic or infrared navigation of the position of the drills), the aforementioned drill guide has the advantage that it exists, and following experimentation, is appropriate for clinical use. The overall result is gratifying for the patient and the implant team as a whole.

More research is underway to test the accuracy of this system compared to conventional methods of implant placement. The next step in the evolution will be to improve accuracy, not only in guiding drills, but in guiding implant placement as well.

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