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The aim of this article is to explain the use of a computer-aided three-dimensional planning protocol in combination with previously placed mini-implants and computer-aided design/computer-assisted manufacture (CAD/CAM) technology to restore a completely edentulous patient. Mini-implants were used to establish a setup for computerized tomographic imaging and a surgical template. The software and its three-dimensional simulation allowed the authors to plan ideal implant placement, digitally integrating the future prosthetic and anatomic situations to design the definitive superstructure. The CAD/CAM superstructure is produced digitally with a precise fit and occlusion and good esthetics, and is placed immediately after surgery. INT J ORAL MAXILLOFAC IMPLANTS 2009;24:541–546

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The introduction of computer-aided design/ computer-assisted manufacture (CAD/CAM) technology and computer planning based on images obtained using computerized tomography (CT) has been an important development in implant dentistry. These images can be converted to a virtual three-dimensional (3D) model of the treated jaws. This virtual 3D model gives the surgeon a realistic view of the anatomic bony morphology of the patient, allowing the surgeon to virtually execute the surgery in an ideal and precise manner.

This method, in addition to stereolithography, has been used to develop a new generation of precise surgical templates. Stereolithography is a technology that can produce physical models by selectively solidifying an ultraviolet-sensitive liquid acrylic resin using a laser beam, accurately reproducing, for instance, actual maxillary and mandibular anatomic dimensions. With these models, it is possible to fabricate surgical guides that can be used in vivo to place implants in the same sites and directions as in a planned computer simulation.1

With the planning software, the practitioner determines the implant position according to both the ideal position dictated by the definitive prosthesis and the available bone volume. The surgical template then dictates the actual implant positions at the surgical sites. The template can be used not only in critical anatomic situations but also to place the implant in an ideal position in the bone because it eliminates possible manual placement errors and matches planning to prosthetic requirements in a precise manner.2–7

With this case report the authors describe a modified concept in guided surgery based on the use of CT scan images and computer processing to create a digital and nonstereolithographic milled surgical guide using mini-implants as references to transfer the information from the computer to the patient. This 3D imaging protocol using templates attached to diagnostic transfer (mini-)implants enabled the authors to digitally plan the treatment of a patient and to design and fabricate a surgical guide and eventually the definitive superstructure, to be placed at the time of surgery.

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CASE REPORT

A 65-year-old completely edentulous male patient with moderate resorption (Cawood VI) caused by the long-term absence of his teeth was referred to a consulting session at the Oral Implantology Clinic at the University of Amsterdam, ACTA (Fig 1). Clinical and medical examinations confirmed his good health. Problems with his removable prostheses included lack of comfort and stability, inability to function and chew normally, and, most important, the psychologic impact and uncertainty about the idea of having removable dentures in the mouth. With this information, the panoramic radiograph, the articulator with the study models, and clinical observations, the authors advised treatment with fixed implant-retained restorations in both the mandible and the maxilla.

Six reference implants (three in each arch, 3 mm wide and 4 to 6 mm long; Straumann, Basel, Switzerland) were inserted transgingivally according to a flapless procedure 3 weeks prior to definitive implant surgery (Figs 2 and 3). The triangular distribution of the mini-implants, which were placed in positions that would not interfere with the future definitive implants, would ensure the stability of the CT setup and the future surgical template. The mini-implants were placed in the midline and tuberosities in the maxilla and in the midline and the retromolar regions in the mandible. These positions were set on the study model that was made during the patient's first visit. Impressions were made immediately after insertion of the mini-implants using impression copings and a polyether impression material. A master cast (stone) was fabricated using the mini-implant analogues (Fig 4).
The prosthetic procedures were undertaken in the following phases:

1. Maxillomandibular relationship record
2. Intraoral occlusal registration
3. Wax trial denture: esthetic and functional evaluation
4. Copying the ideal setup using a silicon wraparound

The CT setup was delivered using an acrylic resin that contained barium sulfate (Vivotac/Orthotak, Ivoclar Vivadent, Schaan, Liechtenstein). This diagnostic CT setup represents the future definitive restoration. The fixed CT template allowed for accurate evaluation of esthetics, function, and occlusion. The CT template was then screwed onto the mini-implants during the CT recordings using a specially designed screw complex (Fig 5). The screw complex is used not only to stabilize the CT template but also to compensate for CT error. CT images are prone to metal-induced image distortion and errors within 0.5 to 1 mm. The screw complex has a determined and known dimension with radiopaque gutta percha marked on the top. This can be visualized on the CT images, allowing the clinicians to calibrate and adjust for errors and compensate for the distortion caused by the mini-implants during scanning. Before the CT scan was initiated, the template was connected to the mini-implants using the screw complex. The CT data were processed to create multiple cross-sectional and 3D images with the planning software (exe-plan software, Brussels, Belgium) (Figs 6a and 6b).

Twelve implants (six in each arch; Standard implants, Straumann, Basel, Switzerland) were virtually inserted, considering the available bone, the future definitive restoration, and the underlying anatomic structures. The planning data were exported to the CAD software program, where the surgical templates and the frameworks of the future superstructure were designed using the same data as the planning software (Figs 6 and 7). The designed structures were imported back to the planning software program, where the fit was checked virtually (Figs 7 and 8). The use of the same data for planning, surgery, and designing the surgical guide and the superstructure prevents errors that could occur when the data have to be translated or scanned.

After the planning and the design of the structure were approved, the data were sent to a milling company (ES Tooling, Beringen, Belgium). A simultaneous five-axis milling device fabricated the surgical templates (PEEK composite, ES Tooling) and the titanium frameworks. The dental lab (Van de Bijl TTL, Tilburg, The Netherlands) processed the titanium frameworks to the definitive restorations using the same master stone casts that were created at the beginning of treatment.
Treatment Day

The patient was locally anesthetized first in the maxilla using lidocaine (Alphacaine SP, Oral Hygiene Center, Zeist, The Netherlands). The surgical template was then connected to the mini-implants using gold screws (Straumann, Basel, Switzerland). The drilling guide was extremely stable because of the good internal connection of the mini-implants, which is similar to the connection of the Straumann Standard implants, and their triangular distribution.

The drilling sequence was executed for each implant starting with the punch and ending with the last drill through the template. Then the implants were inserted using the specified implant driver (Straumann) (Fig 9). The drilling sequence includes three different drill diameters, while the length increases by 2 mm per drill. In this way extreme movements are prevented during the osteotomy. The guiding segment of all the drills has the same diameter, which fits in the drilling guide in a very precise manner. The stop on each drill dictates the depth of the osteotomy (Figs 10a to 10c).

The other important improvement contributing to the higher precision of the implant placement is the so-called precision pin. This pin locks the insertion device when the implants are positioned exactly at the depth that had been determined during the planning phase (Fig 10).

The procedure was repeated for each implant in the maxilla (Figs 11a to 11c). After the placement of the last implant, the surgical template was removed by unscrewing the gold screws. The same procedure was then executed in the mandible.

Immediately after insertion of the implants, the definitive restorations were screwed directly at the implant level without interlocking any abutments (Figs 12a and 12b). The mini-implants were removed by reverse torquing. The fit was evaluated by panoramic radiography (Fig 13) and the occlusion was checked. Minor occlusal adjustments were carried out.

Evaluation and Follow-up

The patient was seen 2 weeks, 6 months, and 1 year after treatment. At 2 weeks, the patient reported no postoperative pain or discomfort and satisfactory esthetics and comfort. He was able to eat and chew. The occlusal screw access points were covered with composite. At 6 months, high satisfaction and an
**Figs 10a to 10d** Precision pin concept.

**Figs 11a and 11b** Surgery employing the position pin principle.

**Figs 12a and 12b** Definitive prosthetic restoration, in place immediately after surgery.

**Fig 11c** Insertion of implant through the surgical guide.

**Fig 13** Postinsertion radiography.
absence of discomfort continued. There was some minor chipping of the acrylic resin in the mandible. At 1 year, the superstructures were disconnected, and Ostell and probing depth measurements were executed. Implant stability quotients ranged between 70 and 80. The acrylic resin chippings were restored and the structures were reinserted.

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