Surgical Planning and Prosthesis Construction Using Computer Technology and Medical Imaging for Immediate Loading of Implants in the Pterygomaxillary Region

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This report describes a protocol that uses computerized tomography (CT), computer-aided design/computer-assisted manufacture (CAD/CAM) technology, and the Internet to plan placement of anterior and posterior dental implants and construct a precise surgical template and definitive prosthesis, which is connected at the time of implant placement. This procedure drastically reduces surgical treatment time and the recovery period. Patients with an edentulous arch had a denture with radiopaque markers constructed for CT scans of the appropriate jaw. The CT images, with acquisition slices of 0.5 mm, were transferred into a three-dimensional image-based program for planning and strategic placement of dental implants. After implants were virtually placed on the computer, the surgical treatment plan was sent to a manufacturing facility for construction of a surgical template and the prosthesis. Special surgical guide components were also manufactured for placement of implants in the pterygomaxillary region. The manufactured surgical components, surgical template, and definitive prosthesis were then delivered to the clinical site. Implant placement surgery was performed using the surgical template, without a flap, and the prosthesis was delivered, achieving immediate functional loading. Minor occlusal adjustments were made. The total surgical treatment time required was less than 60 minutes. Postoperative symptoms, such as pain, swelling, and inflammation, were minimal. Identification of the bone in relationship to the tooth position via three-dimensional CT prior to surgery allows precise placement of implants. CAD/CAM technology using the three-dimensional images allows for fabrication of the surgical guide and final prosthesis. This is a significant advancement in implant dentistry and prosthodontics. (Int J Periodontics Restorative Dent 2006;26:239–247.)

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The placement of dental implants for oral reconstruction originally required a two-stage process: implant placement itself, with abutment connection months later.[1] Recently, many studies have shown comparable success rates with immediate loading of implants,[2–27] with treatment time sometimes minimized to a single visit.[9–12,14,18,19] With the use of computerized tomography (CT), computer-aided design/computer-assisted manufacture (CAD/CAM) technology, and the Internet, implant dentistry is now evolving, where surgical treatment time can be cut to just 1 hour.

Planning of treatment with dental implants is typically done with the use of periapical and panoramic radiographs. Although these imaging techniques often provide sufficient information for successful planning, they provide no precise plan for the placement of the implants.[28] CT is a medical imaging technique in which images are digitally acquired in slices. These slices are then reformatted into virtually any two-dimensional (2D) or three-dimensional (3D) perspective.[29] The ability of computer software to reformat axial CT images into 2D and 3D

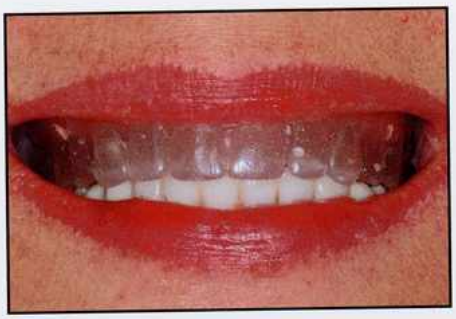


Fig 1 *Soft tissue fit and occlusion for the transparent scanning denture must be refined befor e CT imaging is performed.*

images with 1-to-1 replication allows more accurate planning for implant placement.[30]

One of the first computer software programs (SimPlant, Materialise) to use CT images was capable of planning and practicing surgery, but had no direct way to correlate computer images to the mouth. Other CT or CAD/CAM systems offer the ability to place implants with a developed drill guide; however, they do not provide for an immediate prosthesis.

The 3D computer-assisted technology is continually expanding. A 3D image-based program (Oralim, Medicim) for planning and placement of dental implants was recently introduced. This program allows the user to view a 3D image volume as a 3D scene in which the image-derived features can be rotated on all axes to provide any desired perspective. Virtual representations of the implants, abutments, and other surgical accessories can be inserted into the 3D scene and positioned at appropriate 3D coordinates. These virtual representations can then be rotated with the image-derived features. However, the original protocol only allows for the placement of implants in a completely edentulous jaw. Also, implants can only be placed anterior to the sinuses in the maxilla and anterior to the mental foramina in the mandible.

This paper reports an expanded and improved interactive imaging technique for implant planning.[31] This technique takes full advantage of the pterygomaxillary region, which features compact bone,[32] to anchor implants in the posterior maxilla to provide support and retention for implant restorations and eliminate the need for posterior cantilevers in a complete-arch restoration.

Method and materials

The technique illustrated here for fabrication of a surgical template and prosthesis is dependent on the patient's existing full denture; the definitive fixed prosthesis created from the imaging and prototyping models is a virtual clone of the original denture in a fixed prosthesis configuration.[33] Therefore, the end esthetic result depends on an original denture that has correct centric and vertical positions and tooth arrangement.

A duplicate transparent denture dotted with radiopaque markers is constructed for CT scanning (Fig 1). Approximately 14 to 16 sites at different levels in relation to the occlusal plane are prepared in this denture, with each site about 1.5 mm in circumference. Each site is filled with gutta-percha for radiopacity. Vinyl polysiloxane bite registration paste (Regisil, Dentsply) is used to create a centric occlusion index to stabilize the denture and opposing dentition during scanning.

Data acquired from the CT scan must be compatible and adequately detailed (slices of about 0.5 mm). A scan of the transparent denture with radiopaque markers, oriented in the same manner as the patient wears it, is also performed.

The Oralim software uses two panels to view the image-derived features. The left panel is used to visualize an overview of the 3D scene, which can be rotated around all axes. The right panel is the slice viewer and can be altered by moving along the slice curve in the left panel in either direction (Figs 2a and 2b). The user can assess bony contours and defects by moving along the slice curves. Once an area is selected for implant placement, the user can virtually place implants into the 3D scene. The implant is visualized in both panels, which allows precise placement of the implant in a suitable area. Next, the appropriate abutment height is selected for each implant that will extend through the soft tissue but not through the virtual prosthesis. When all implants and abutments are virtually placed, the virtual prosthesis can be overlaid onto the image to evaluate the position of the implants in relationship to the prosthesis. Last, three horizontal anchor pins must be

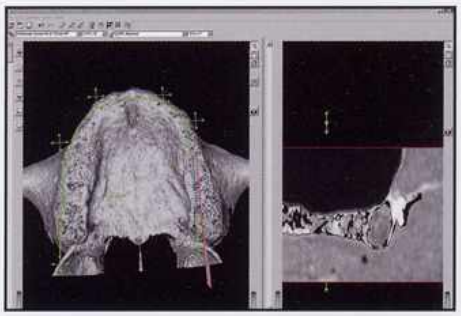


Fig 2a (left) *Initial viewing screen of the Medicim software. The software can generate 3D images of the edentulous maxilla. This screen provides an axial view of the maxillary alveolar ridge* (left) *and a cross-sectional image of the pterygomaxillary region* (right), *which corresponds to the slice viewer on the left-hand side of the screen.*

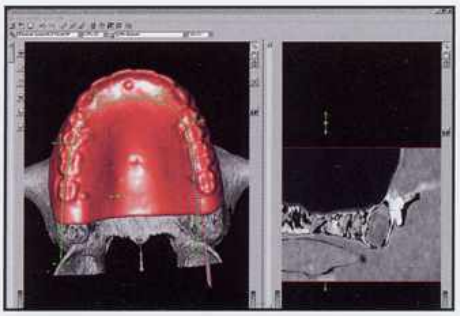


Fig 2b (right) *Computer-generated 3D images of the edentulous maxilla, with the prosthesis image superimposed over the 3D bone image.*

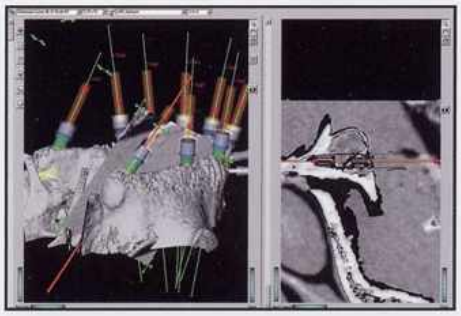


Fig 3 (left) *Computer-generated 3D images of the transmucosal abutments positioned on the implants.*

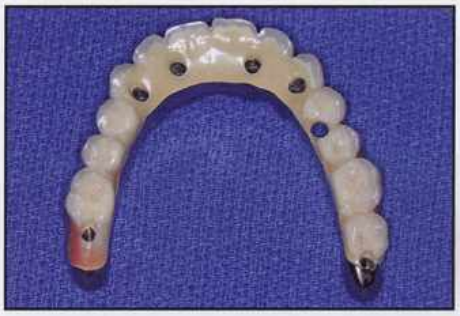


Fig 4 (right) *The definitive prosthesis is built presurgically on a Procera titanium framework.*

positioned to secure the correct location of the surgical drill guide during clinical implant placement (Fig 3). The inclination, depth, and distance from other virtual components of the anchor pins must be considered during virtual planning. After virtual planning is completed, the Oralim planning file is sent via e-mail to the manufacturing facility (ARK, Nobel Biocare) for construction of the prosthesis, drill guide, and surgical accessories.

The current surgical template is made of methyl methacrylate with metallic (stainless steel) sleeves for guiding drills. The definitive prosthesis is a Procera (Nobel Biocare) all-titanium milled frame with acrylic resin veneers that extends from second molar to second molar with a distal extension to the pterygomaxillary implant location (Fig 4).

Surgical procedure

The patient is prepared and anesthetized in the usual manner for dental implant surgery. The surgical template is positioned using an intraoral silicone occlusal index. Vertical pressure is applied in the centric position to seat the surgical template for horizontal pin insertion. With a 1.5-mm twist drill, the three sites for the horizontal stabilizing pins are created and the pins are inserted (Fig 5). The surgical template is now set in place with good initial stability, and the index can be removed.

To provide further stability, the surgical template is attached to four implants, which are strategically placed in the anterior sleeves. First, the tissue punch is used in one of the sleeves. This spade-like drill is designed to remove the soft tissue over the eventual implant site and clears the path for the osteotomy drills. Twist drills are then used in conjunction with a precise hand-held drill guide until the desired depth and width of the osteotomy are attained. The exact dimensions of each site have been determined during virtual planning on the computer and are illustrated on a printed map (Fig 6) that is provided for each patient. Implants of predetermined size can then be placed into the prepared osteotomy sites using a depth-controlling implant mount and

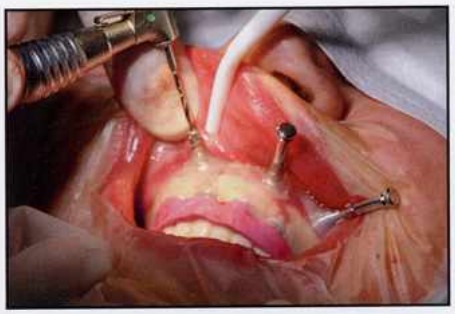


Fig 5 (above) *A 1.5-mm-diameter twist drill is used to prepare the bone for horizontal stabilizing pins.*

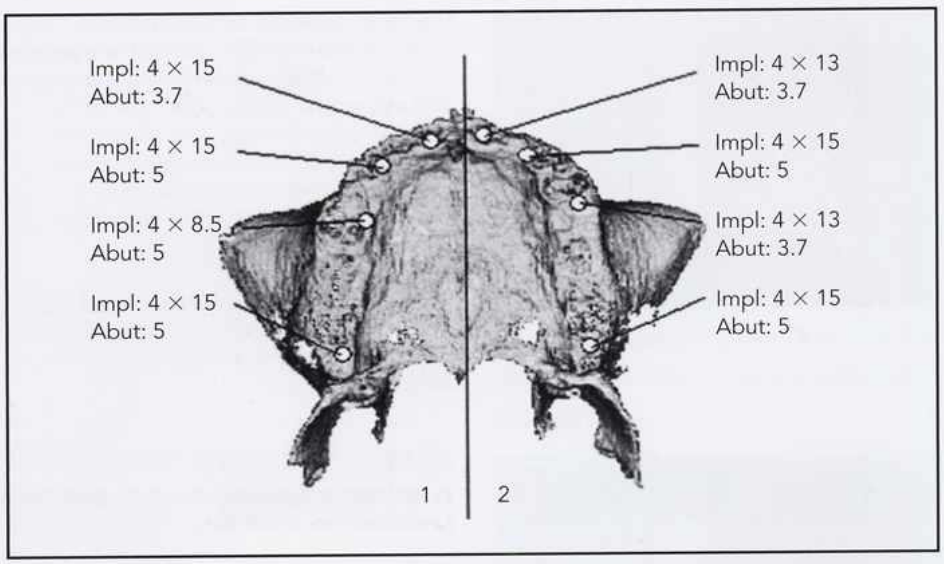


Fig 6 (right) *An operating map, used during surgery, illustrates the implant (impl) and abutment (abut) sizes (in mm) to be used at each implant site.*

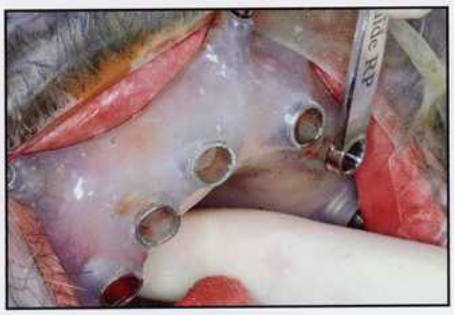


Fig 7 *The regular-platform implant guide is inserted into the surgical template to precisely position an Mk III 3.75-mm-diameter implant.*

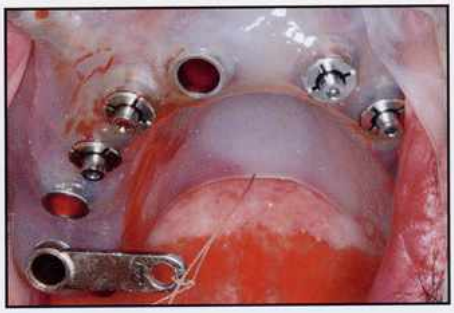


Fig 8 *The pterygomaxillary implant guide properly positioned in surgical template.*

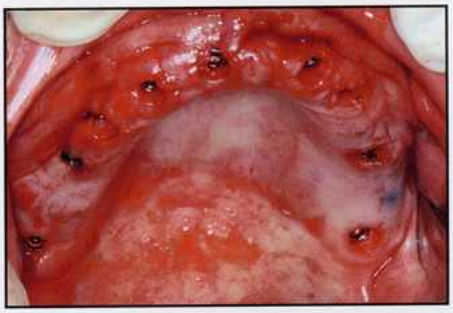


Fig 9 *The implants are visible after the surgical template is removed.*

implant guide that are specific for the diameter of the implant (Fig 7). The implants are rough surfaced and have external-hex head connections (Mk III and IV TiUnite regular platform, Nobel Biocare). It is crucial to avoid overtightening the implant at the time of placement; this may alter the position of the surgical template. The template abutment—specially designed with expanding side walls—is connected to stabilize the surgical template at this implant position while additional sites are prepared and implants placed. The other three strategically selected sites are prepared in the same manner.

Once the four template abutments are connected, the surgical template is firmly anchored. The two pterygomaxillary implant sites are prepared using a similar placement technique, and implants are placed using specially designed pterygomaxillary drill guides (Fig 8), with handles that are shorter than the double-ended anterior drill guides. Any remaining anterior implants are placed with the same technique as used with the other anterior implants that have the template abutments connected. After all implants have been seated and the template abutments have been

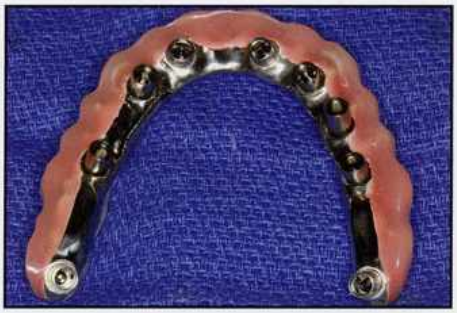


Fig 10 (above) *Expandable titanium abutments are positioned into the definitive prosthesis.*

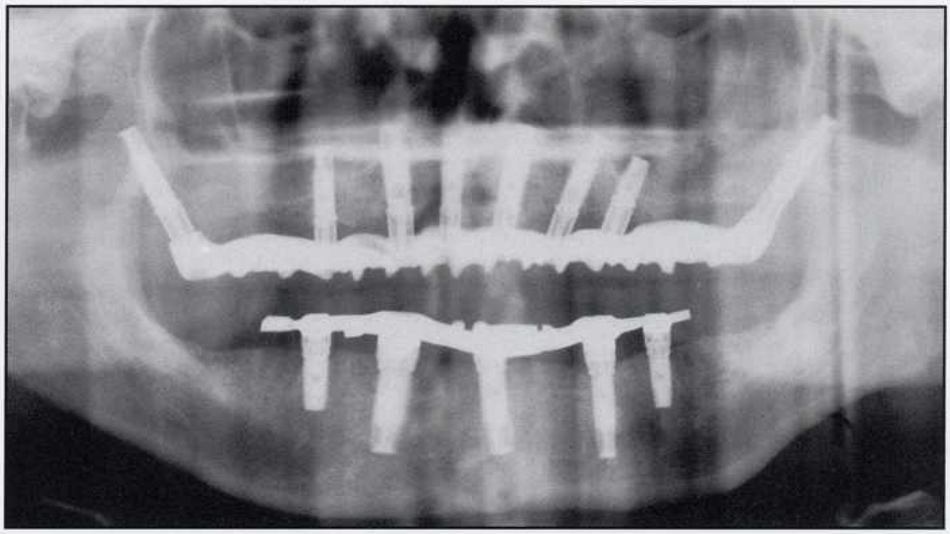


Fig 11 (right) *Panoramic radiograph demonstrates the precise fit of presurgically constructed definitive prosthesis.*

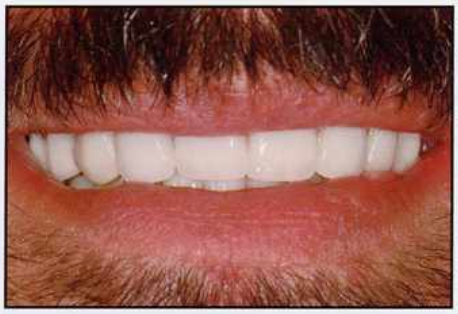
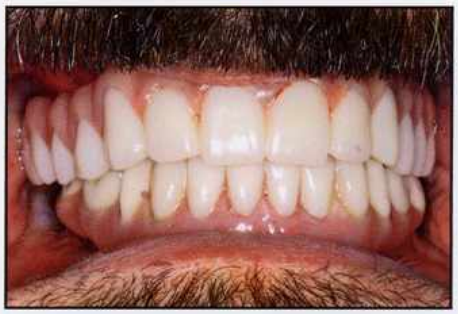


Fig 12a (left) *Presurgical view of maxillary removable denture with optimal esthetics.*

Fig 12b (right) *Definitive Procera titanium-framework maxillary prosthesis opposing a mandibular implant-supported prosthesis.*



removed, the horizontal anchoring pins and surgical template can also be removed.

The implants can be visualized in their submucosal positions around the arch (Fig 9). Prosthesis delivery is performed rapidly after removal of the surgical template to take advantage of the current patency of the soft tissue openings. The soft tissue openings are checked to ensure clear access to the implants. The screw-retained self-adjusting abutments, which are predetermined in the computer plan, are positioned into the appropriate cylinders of the prosthesis (Fig 10). The prosthesis is then delivered, with the abutments accurately seated on each implant, and the screws are tightened. Any necessary occlusal adjustments are made and screw-access holes are sealed.

The completed restoration should have a precise fit at the implant-abutment interface, as observed in a panoramic radiograph (Fig 11), and the prosthesis should have an appearance similar to that seen preoperatively (Figs 12a and 12b).

Discussion

CT and computer technology have raised expectations in implant dentistry. In a fast-paced world in which style and appearance are vital, the faster the "makeover" can be, the better. The described technique requires as few as three visits: *(1)* the initial exam, *(2)* the CT scan, and *(3)* the surgery, which takes less than 60 minutes. This protocol suits all those whose time is precious. This technique also results in a shorter postoperative recovery period because of the decreased surgical trauma. The use of flapless surgery decreases the amount of swelling and inflammation, which in turn leads to less discomfort and pain.

The reported technique illustrates the successful placement of implants posterior to the sinus in the maxilla, using a protocol that incorporates virtual surgery and planning. This technique and these components could also be incorporated posterior to the mental foramen in a mandible with adequate bone height. With this protocol, there is a decreased risk of paresthesia, since the positions of the implants are predetermined during virtual planning. Implants in the pterygomaxillary region have a distinct advantage, as they provide posterior anchorage without sinus augmentation, supplemental grafting, or the possibility and detrimental effects of cantilevered loading forces.[27] Engaging the cortical bone of the pterygoid plate with long implants can improve primary stability, thereby providing long-term success.[34,35] With this posterior support, the prosthesis can have a full complement of teeth in the posterior area, which is a distinct advantage for patients with broad and highly visible smiles.

Because accessibility of the pterygomaxillary region is limited,[36] the standard double-ended guides must be modified to place the implants accurately. The drill guides that are used for the placement of implants in the anterior arch are too long to use in the posterior regions of the mouth; therefore, smaller guides were constructed for use in these areas.

It is important to use care when constructing the transparent duplicate denture. If volumetric shrinking occurs, altering the length of the teeth in the transparent denture, the length of the teeth in the final restoration will be short. Therefore, several pours of the acrylic resin are recommended to decrease the amount of overall shrinkage.

The clinician must also use care with the original surgical template. The template extends into the posterior region, with a narrow and thin acrylic resin area that is susceptible to fracture if excessive forces are applied to it. The operating team must be careful to prevent the patient from closing down onto the surgical template, particularly during drilling or implant placement. A new design, in which the surgical template braces the entire posterior hard palate, seems to resolve this potential clinical complication.

Tissue thickness in the posterior maxilla has often been a problem during the development of this special surgical technique. Abutments are currently available in only two lengths: 3.7 mm and 5.0 mm. The surgical template must be fabricated to fit these abutment lengths; this often results in a difficult fit because of excessive soft

tissue in the posterior region. Either longer abutments need to be available for the virtual and clinical surgery or some of the soft tissue must be removed to accurately seat the template onto the alveolar ridge. Previously, prostheses were constructed of a carbon fiber–reinforced acrylic resin. The need for extensions through thicker soft tissue has resulted in the use of titanium Procera frameworks. To maintain a flapless protocol on the day of the surgical procedure, the patient can have the soft tissue thinned in the posterior region before scanning and fabrication of the surgical template. This method of treatment can eliminate difficult posterior suturing under the delivered prosthesis.

Conclusion

Identification of bone quantity and quality prior to surgery allows the clinician to place implants in areas where the implant-bone interface can be maximized. With the described technique, precise planning is possible so that implants can be optimally aligned. This is a tremendous advantage for both the patient and the clinician. The clinician can provide a treatment plan that minimizes operating time, surgical trauma, and the postoperative recovery period, while still yielding a result that is precise, stable, and biomechanically sound. The time saved with this revolutionary procedure is remarkable. No second-stage abutment connection surgery, no final impressions, and no additional clinical or laboratory procedures are necessary. Prosthodontic treatment is completed the day of implant surgery with delivery of the definitive prosthesis; only follow-up hygiene and normal maintenance are required. Patient time is minimal, with a single 1-hour surgical procedure versus numerous longer visits when using traditional implant protocols. This is a significant advancement in implant dentistry and prosthodontics.

Acknowledgments

The authors would like to thank the staff at Prosthodontics Intermedica for their kind and very gentle treatment of the patients; Robert Winkelman and the staff of dental technicians at Fort Washington Dental Lab; Filip Schutyser of Medicim; Dr Robert Gottlander, Dr Matts Andersson, Andreas Pettersson, Viktor Renenmark, Dr Ingvar Ericsson, Izidor Brajnovic, and the ARK team at Nobel Biocare.

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