Interactive Imaging for Implant Planning, Placement, and Prosthesis Construction

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Purpose: This review describes a new interactive imaging program that allows computed tomography (CT) images to be used to virtually place dental implants and construct a precise guide splint and final prosthesis for delivery at the time of implant placement.

Materials and Methods: Patients with edentulous arches were recruited to participate in a trial program to assess the feasibility of using CT images in a 3-dimensional image-based program (Oralim; Medicine NV, Belgium) for planning and placing dental implants. Patients meeting the criteria received a CT of the appropriate arch using a denture with radiopaque markers indexed to the opposing arch. Acquisition slices of 0.6 mm or less was required. The software allowed precise planning for implant placement after which the planned case was sent to a manufacturing facility for splint and prosthesis construction.

Results: The guide splint and final prosthesis were returned to the clinical site for implant placement. An implant map was provided for each patient showing the diameter and length of the implant and abutments to be used in each predetermined implant site. The surgery was accomplished without a flap, and the prosthesis was delivered immediately. Occlusion required only minor adjustments in all cases, and immediate function was accomplished.

Conclusion: Interactive computer imaging can allow precise planning for implant position and the images can be used for guide splint and final prosthetic fabrication prior to surgery. This technology is powerful, easy to use, and is a significant advance in implant dentistry.

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Just as implants have revolutionized dental rehabilitation, interactive computer technology is doing the same for dental implant planning. Interactive computer technology incorporates data from computed tomography scans to precisely plan dental implant placement and construct guide splints for actual implant placement in these selected sites. The precision of this technology further allows a final prosthesis to be fabricated before implant placement that can then be delivered at the completion of the implantation procedure.

Background

Periapical, panoramic, and tomographic radiographs are routinely used in the planning for dental implant placement; however, these imaging techniques often do not provide adequate information for precise planning and placement. Computed tomography is a technique by which images are acquired digitally and subsequently reformatted into virtually any 2- or 3-dimensional (3D) perspectives subsequent to acquisition. After acquisition, the axial images are manipulated to produce multiple 2-dimensional (2D) images through a process called multiplaner reformating. Three-dimensional images or models may also be constructed. The application of computer software capable of reformating computerized axial tomograms into 2D and 3D image orientations with 1 to 1 replication allows more accurate planning for implant placement. Several proprietary computer programs for use in reformating dental implant cases are available. All of these programs typically provide an orientation axial image with a superimposed curve over the crest of the alveolar ridge, multiple cross-sectional images, and multiple panoramic-like curved linear images. Slice thickness and intervals are variable. The image is usually viewed in a bone window algorithm to evaluate morphology and localize anatomic structures, but it
can also be viewed with a soft tissue window algorithm.\textsuperscript{6,7} This technology is continually expanding and improving, as evidenced by a recently introduced product (Oralim, Medicine NV, Belgium), a 3D image-based program for planning and placing dental implants. This program is based on the concept of representing a 3D image volume as a 3D scene. This approach bridges the gap between the conventional (stack of) 2D radiographic images and the actual view of a patient in the dental chair. In these 3D scenes, image-derived features (eg, a delineated nerve, bone surface) as well as virtual representation of surgical accessories (eg, implants) are shown as distinct objects. Two salient characteristics of this 3D scene approach are 1) views on the scene can be composed dynamically by the clinical user and 2) the same object is consistently shown in multiple views.

**Method**

The technique described here for a surgical guide and prosthesis construction is based on the patient’s existing full upper or lower denture.\textsuperscript{8} These prostheses need to be correct for aesthetic display, centric and vertical position, and denture tooth

![Figure 1](image1.png)

**FIGURE 1.** A and B, Circular holes approximately 2 mm across and 2 mm deep are cut into the buccal flange bilaterally on the patient’s existing denture and are filled with gutta percha. These will serve as reference points during the reformatting process of the computed tomography scan and in the construction phase of the medical models. These sites should be staggered in a triangular pattern rather than in a linear arrangement. C, Two similar radiopaque markers are created in the palatal surface lingual to the center incisors.


![Figure 2](image2.png)

**FIGURE 2.** Computer-generated images of the edentulous maxilla showing an axial view of the maxillary alveolar ridge (left) and a cross-sectional image of the alveolar ridge (right), which corresponds with the center of the scaled line on the left.


![Figure 3](image3.png)

**FIGURE 3.** Computer image in axial and cross-sectional views of the maxilla after implants were virtually placed. Stabilizing screws are shown perpendicular to the alveolar ridge and dental implants (left). An implant is shown in relationship to the floor of the nose and cortical plates of the alveolar ridge (right).

arrangement. This is critical because the ultimate fixed prosthesis created from the imaging and rapid prototyping models will be a virtual duplicate of the denture in a fixed bridge configuration. The base must be processed hard resin because interim or long-term soft liners will not scan correctly. Before the scan procedure, the denture is prepared with radio opaque markers on the buccal flange in 3 sites per side (Figs 1A, B). These should be approximately 2 mm wide, and 1.5 to 2 mm deep in a staggered pattern. Similar markers are placed in the palatal surface just behind the central incisors (Fig 1C). Each preparation is filled with gutta percha for radiopacity. A silicone putty registration index in centric occlusion is also created at this initial appointment to help stabilize the denture(s) during the scan procedure for which the patient is now prepared.

A computed tomography scan of the patient provides the base information for this planning system. The data acquisition must be compatible and sufficiently powerful to acquire images of the jaws being treated. An acquisition slice of 0.6 mm or less is required. Oralim uses 2 viewing panels to view the preoperative image data (Fig 2). The left large panel embeds a 3D viewer that shows a general overview of the 3D scene. In particular, it is used to enable access of the imaged data in ways typical for oral implant planning. This kind of access is then visualized in the slice viewer embedded in the right panel. The curved line that appears on the alveolar bone and the scale is the means of selecting the

FIGURE 4. Computer image showing the maxillary skeleton with the virtual denture and implants.

FIGURE 5. The completed final maxillary restoration is prefabricated before the surgical appointment and has been constructed with screw connections at 8 implant sites.

FIGURE 6. The surgical guide is initially positioned through the use of an intraoral jaw registration index made of silicone. The vertical pressure applied in the centric position properly seats the surgical guide for horizontal pin stabilization.

FIGURE 7. A 1.5 mm twist drill is used to penetrate through tissue and bone horizontally in a predetermined direction and plane for pin stabilizers.
The exact position of the image on the right screen. The images can be taken from anywhere along this curved line to assess bony contours, landmarks, and defects. Once an area is selected for implant placement, the interactive software allows the operator to simply click on the implant and it appears on both the right and left screen (Fig 3). Once implant positions are chosen, the virtual prosthesis can be overlaid on the image to see the position of the implants in relationship to the prosthesis (Fig 4). This allows modification and adjustment for final implant placement. The final step is to plan the placement of 3 horizontal stabilizer pins through the labial denture flange into bone between the implant sites. The 3D images can be rotated 360° to view all aspects of the implants in the structures of the alveolus. It also allows visualization of the implants, abutments, and denture. Each component can also be viewed as individual objects. Therefore, Oralim adopts the concept of dual representation in the preoperative space and the image contains all available objects. The computer program has been easy to use and the techniques quickly learned even by a beginner.

The completed scan of implant and stabilizing pin placement is sent via modem to the manufacturing facility for prosthesis and splint construction (Fig 5). Once this phase of the process is completed, the patient can be scheduled for the second appointment which will be implant placement and prosthesis delivery.

**Surgical Procedures**

Following adequate local anesthesia and any necessary sedation, the surgical guide is positioned using an...
intraoral silicone stabilizer (Fig 6). The horizontal stabilizing tubes are used to guide a 1.5 mm twist drill, which creates sites for the horizontal stabilizing pins (Figs 7, 8). Once the pins are in position, the silicone stabilizer is removed and implant site preparation is initiated.

The first drill is designed to remove soft tissue over the eventual implant site with depth control. It has a spade-like design that effectively clears the path for the osteotomy drills (Figs 9, 10). Twist drills are then used with a precise hand-held drill guide in sequence until the desired depth and width of the osteotomy is attained in 2 positions on the arch (Fig 11). The exact dimensions of each site as determined by the virtual preplanning on the computer and depicted on a “map” provided for each patient are part of the material included in the surgical/prosthetic kit (Fig 12).

The implants are then placed in the 2 initially prepared sites using a depth-limited fixture mount and a drill guide (Figs 13, 14) specific for the diameter of the implant. The implants are rough surfaced and have external hex head connections (Mark III TiUnite implants; Nobel BioCare USA, Yorba Linda, CA). A specifically designed abutment with expanding side-walls is connected to the first 2 implants to further stabilize the surgical guide while the additional sites are prepared (Fig 15). As each implant is placed, the mounts and guide are removed and the mount is replaced on the implant to maintain soft tissue patency (Fig 16). After all implants have been seated and the fixture implant mounts have been removed, the implanted arch can then be visualized (Fig 17). The flapless approach creates less trauma, which reduces postop-
erative pain, swelling, and enhances patient healing and postoperative comfort.

Prosthesis delivery is performed quickly, after removal of the surgical guide to prevent soft-tissue collapse. The individual abutments, which come in 2 lengths (3.7 and 5.0 mm) are positioned in the prosthesis based on the site designations depicted on the abutment map (Figs 18, 19). As soon as complete seating of the abutments on each implant is verified, the screws are tightened sequentially using a patterned “lug nut” approach (Fig 20). Any necessary occlusal adjustments are then carried out using appropriate burs, and screw access sites are sealed provisionally. Postoperative instructions regarding care and function are given to the patient before leaving the clinic.

The completed restoration should have intimate metal-to-metal contact at the implant abutment surface, and the implants should have ideal position as seen radiologically (Fig 21). The prosthesis should also have an aesthetic presentation very similar to that which existed preoperatively with the patient’s denture (Figs 22, 23).

Interactive computer imaging now allows the implant team to plan dental implant placement in virtual reality. This technology is a significant advancement over conventional computed tomography data alone. Although

FIGURE 16. It is important to replace the fixture mounts on the implants as they are delivered to keep the soft tissue from collapsing. Once all implants have been placed, the surgical guide can be removed and the patient is ready to receive the fixed bridge.


FIGURE 17. Immediately after removal of the surgical guide, the implants can be visualized in their subgingival positions around the arch. The fixed restoration should be delivered immediately after guide removal to take advantage of the patency of the soft tissue openings as they presently exist.


FIGURE 18. An abutment map is also included with the prosthetic kit which indicates the exact location and length of each of the self-adjusting abutments to be used with the definitive fixed restoration. The abutments come in 2 lengths (3.5 mm and 5.0 mm) and must be used in the exact positions indicated to achieve a passive fit of the prosthesis.


FIGURE 19. The self-adjusting abutments have been loaded into their appropriate cylinders, being careful to seat each one completely to metal contact against the cylinder base. The bridge is then quickly delivered to the patient to prevent soft tissue collapse.

the acquisition of the imaging requires more time than conventional technology, these data can be used to plan implant placement exactly and in relationship to not only the anatomic structure but to the final prosthesis. These data are then used to construct a precision guide splint and the final prosthesis, presurgically, which can be delivered immediately after implant placement. This technology allows significant shortening of the operating time, while minimizing the surgical trauma, postoperative recovery period, and pain. The technology is powerful, easy to use, and presents a significant advancement in implant dentistry.

References