Intraoperative Computerized Navigation for Flapless Implant Surgery and Immediate Loading in the Edentulous Mandible

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Computerized navigation surgery has evolved to facilitate minimally invasive procedures, the gold standard of surgery today. While flapless implant surgery may be clinically beneficial, it has generally been perceived as a blind procedure limited to straightforward cases that do not pose a risk of cortical plate perforation. The objective of this report is to describe a protocol for flapless implant placement in a completely edentulous mandible using computerized navigation surgery. The Image Guided Implantology system (IGI, DenX Advanced Dental Systems) is described. The IGI system provides real-time imaging of the dental drill and transforms flapless implant surgery into a fully monitored procedure. The highly accurate intraoperative navigation enables precise transfer of the detailed presurgical implant plan to the patient. This is particularly valuable in edentulous jaws lacking any indication of the dental arch. The accurate positioning of the implants, based on the presurgical digital plan, allows fabrication of a provisional fixed prosthesis before the implant surgery for immediate postoperative loading. This innovative protocol can enhance prosthodontic-driven placement of implants in a fully monitored flapless surgery. Int J Oral Maxillofac Implants 2005;20:92–98

Key words: *computer-assisted surgery, dental implants, edentulous mandible, flapless implant surgery, immediate loading, navigation surgery*

Flapless implant surgery has been associated with high success rates. The advantages of flapless procedures include reduction in intraoperative bleeding and decreased postoperative patient discomfort.[1,2] Immediate loading may follow the flapless implant procedure. However, flapless implant surgery has generally been perceived as a blind procedure because of the difficulty in evaluating alveolar bone shape and angulation, a problem that increases the risk of perforating the cortical plates. Therefore, this procedure has been limited to straightforward cases in which the width of the bone crest is favorable.

Computerized navigation surgery has evolved from neurosurgical procedures[3] and is being implemented in various surgical fields.[4] These developing technologies for intraoperative tracking and guidance of the surgical instruments enhance minimally invasive procedures. The use of intraoperative navigation in implant dentistry allows the surgeon to precisely transfer a detailed presurgical implant plan to the patient. During the procedure, the surgeon can rely on the computerized navigation to adjust the position and angulation of the dental drill in absolute agreement with the presurgical digital implant plan. The real-time imaging of the dental drill integrated with the cross-sectional view (Fig 1) continuously updates the surgeon on the progress of drilling to avoid critical anatomic structures (ie, the maxillary sinus, nasal cavity, inferior alveolar nerve, roots of

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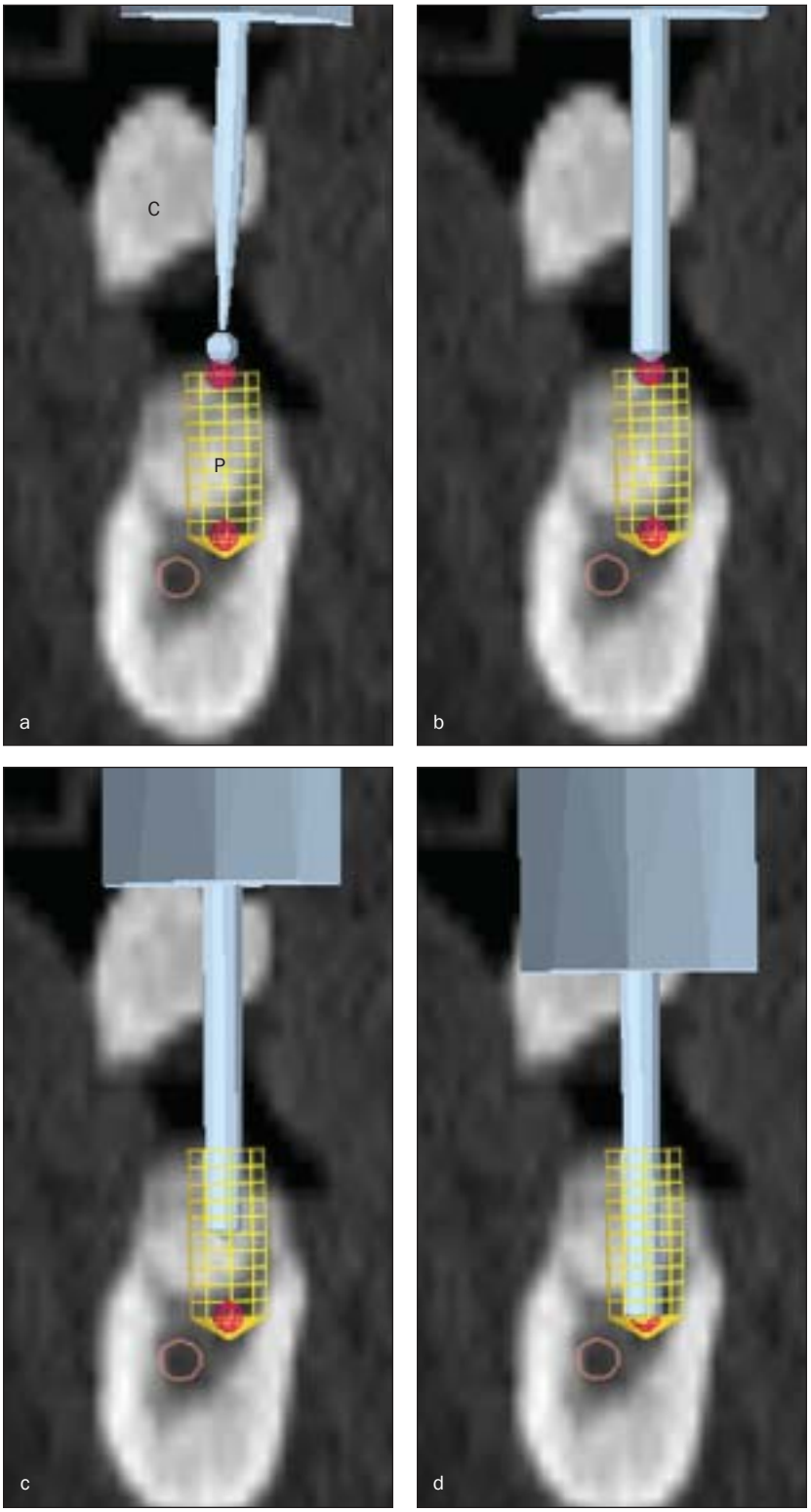


Fig 1 Real-time imaging of the dental drill integrated with the cross-sectional view *(a)* marking the implant's position with a round bur; *(b)* initiating drilling; *(c)* halfway through the drilling procedure; *(d)* in the final stage of drilling. P = the presurgical planned location of the implant; N = the inferior alveolar nerve; C = a trace image of the radiopaque crown.

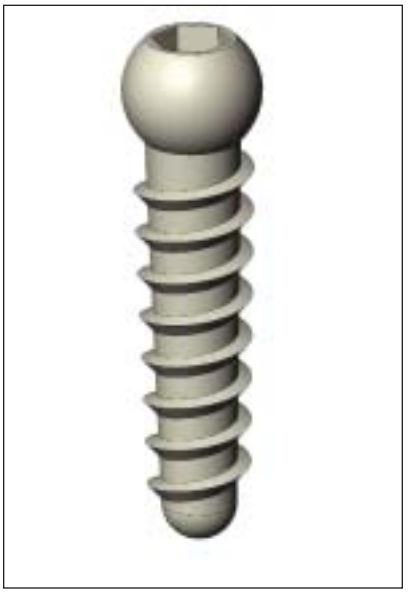


Fig 2a *(Left)* A 3D simulation of the short bone screws designed to support the acrylic resin template.

Fig 2b *(Right)* Intraoral postplacement image of 1 bone screw distal to the approximated mandibular left first molar. Note that the spherical head is 2 mm above the soft tissue to avoid coverage.

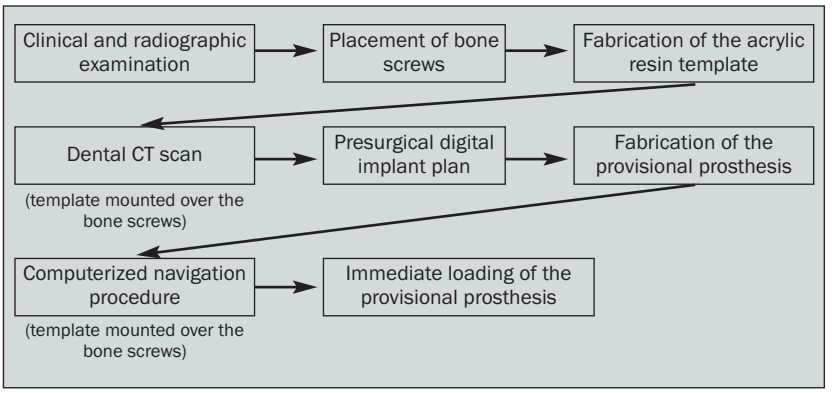


Fig 3 Treatment protocol flowchart.

adjacent teeth, and the cortical plates). Thus, the use of computerized navigation allows monitoring of the drilling procedure and minimizes the potential complications associated with flapless surgery.

The objective in the present report is to describe a protocol for flapless implant surgery and immediate loading in the edentulous mandible with the use of computerized navigation.

TREATMENT PROTOCOL

Background

The system used in the treatment protocol described herein is the Image Guided Implantology system (IGI, DenX Advanced Dental Systems, Moshav Ora, Israel). It was designed to transfer a digital presurgical implant plan to the patient by applying real-time computerized navigation of the dental drill.

The computerized navigation implant placement procedure requires a fixed interfacing template to be mounted in the patient's mouth for the duration of surgery. This template creates the interface between the real patient and related dental computerized tomography (CT) data, enabling the intraoperative navigation. In the partially edentulous patient, this template is supported by existing natural teeth.[5,6] In the treatment protocol portrayed herein, implementation of this technology for completely edentulous patients is described. The treatment protocol is based on a novel approach using short bone screws that are placed a few days before the implant surgery and support the essential interfacing template. The coronal pole of the bone screws is spherical (Fig 2) and allows mounting of the template by means of a simple ball attachment mechanism. Following fabrication of the template, the patient undergoes a standard dental CT scan with the template mounted. A digital implant plan, based on the reconstructed dental scan of the patient, is created before the surgical procedure. Consequently, during surgery, computerized navigation of the dental drill is provided in relation to this presurgical plan to facilitate drilling for the implants as planned (Fig 3).

Fig 4a Waxup of radiopaque teeth on the patient's cast.

Fig 4b Superior view of the radiopaque teeth attached to the acrylic resin template.

Fig 4c Inferior view of the radiopaque teeth attached to the acrylic resin template. Note the lingual acrylic resin bar and the ball attachment caps that are part of the template.

Fig 5 Hemiplate attached to the acrylic resin template. Note the fiducial marks (M) embedded in the hemiplate.

Clinical Examination

Patients requiring full-arch implant-based mandibular rehabilitation undergo clinical and radiographic examination to ensure the presence of adequate alveolar bone sufficient to accommodate dental implants. At this stage patients are also radiographically evaluated to ensure sufficient bone volume to allow safe placement of the short bone screws which will need to be placed initially.

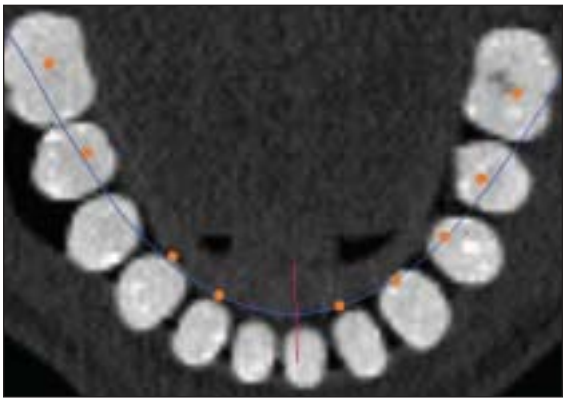
Acrylic Resin Template and Dental CT Scan

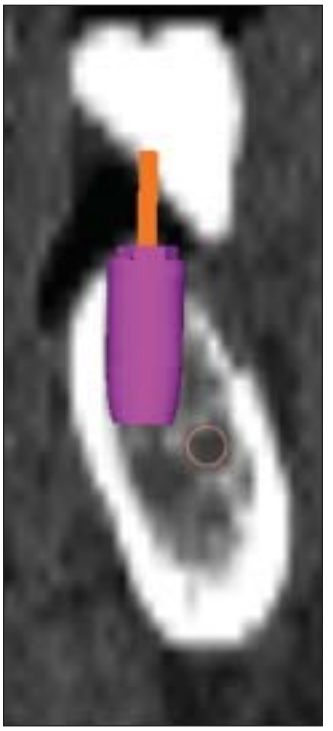
A few days before surgery, 3 short bone screws (1.8 mm diameter and 6 mm long; Alpha-Bio, Petach-Tikva, Israel) are placed transgingivally into the mandible. One bone screw is placed at the midline and the other 2 are placed distal to the approximated position of the mandibular left and right first molars. The bone screws are placed so that the spherical screw heads extend 2 mm above the soft tissue, to avoid coverage (Fig 2b).

A customized template is fabricated, consisting of a lingual acrylic resin bar attached to 3 ball attachment caps that correspond to the 3 bone screws. This template first acts in the CT scan as a radiographic template; later, in the surgical phase, it becomes an interfacing template. A full waxup of radiopaque teeth (Ivoclar Vivadent, Amherst, New York) arranged on the patient's cast is attached to the acrylic resin template (Fig 4). The template is further attached to a hemiplate consisting of special fiducial marks (Fig 5), which create the interface between the virtual patient, namely the imaging data, and the real patient. Following fabrication of the template, the patient undergoes a standard dental CT scan with the final template mounted on the bone screws.

Presurgical Implant Plan

A full digital presurgical implant plan is created from the patient's dental CT. The implant plan consists of between 6 and 8 implants that correspond to the anticipated crowns of the prosthesis (Fig 6a). The image of the radiopaque teeth, which are part of the acrylic resin template, guides the decision on the planned position and angulation of the implants. The clinician can view the cross-sectional cut of the anticipated crown next to the alveolar bone and determine the optimal position and angulation for the implants (Figs 6b and 6c). The apical border of





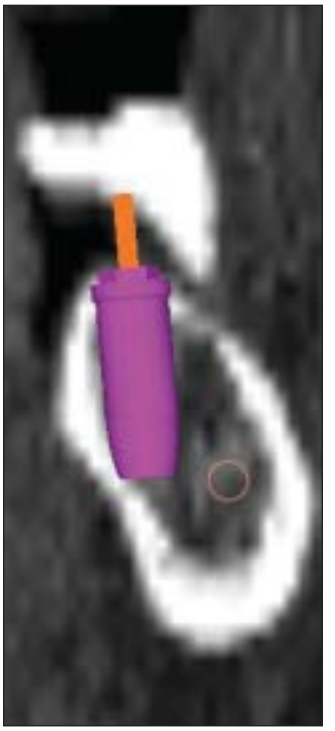


Fig 6a *(Above)* Occlusal view of a presurgical plan. Note that the orange dots representing the trajectory of the planned position of the implants correspond to the axial cut of the radiopaque teeth. The trajectory of the anterior implants falls outside the anticipated crowns because of the shape of the alveolar ridge in this region.

Fig 6b *(Center)* Cross-sectional view of an implant planned at the second premolar position. Note the correspondence of the trajectory of the implant *(orange line)* to the trace image of the radiopaque crown.

Fig 6c *(Right)* Cross-sectional view of an implant planned at the first molar position. Note the correspondence of the trajectory of the implant *(orange line)* to the trace image of the radiopaque crown.

each of the 3-dimensional (3D) planned posterior implants is evaluated in relation to a 3D reconstruction of the left and right inferior alveolar canals to ensure safe positioning.

Provisional Prosthesis

A full-arch fixed acrylic resin prosthesis is fabricated before implant placement surgery. The prosthesis is fabricated on the basis of the presurgical implant plan and corresponds to the waxup of the radiopaque teeth.

Computerized Navigation Flapless Procedure

Immediately before surgery, a registration procedure is performed using the fiducial marks on the template to interface between the virtual patient (the dental CT with the digital plan) and the real patient. Following registration, the hemiplate and the attached radiopaque teeth are detached from the template, leaving only the lingual acrylic resin bar with the attachment caps connected to an optical sensor unit that enables ongoing monitoring of the patient's position. Drilling is performed with the modified template mounted on the bone screws, allowing direct accessibility to the alveolar ridge. This template is not, in any way, like a conventional drill guide; rather, it interfaces between the patient and the precaptured imaging data, thus facilitating freehand computerized navigation of the drilling.

During the flapless procedure, the navigation system provides visual indications that guide the surgeon to drill in the exact planned position. The primary center position of the implants is marked on the gingiva, and a tissue punch incision is then made to remove the gingiva at this location. Real-time imaging of the dental drill is integrated with the anatomic structures and is constantly available to the surgeon with the updated progress of drilling (Fig 1). Throughout the drilling procedure, the surgeon must heed both the patient and the navigation screen to ensure the correct alignment of the drilling. Audiovisual signals alert the surgeon if drilling deviates from the planned position or angulation and when the final drilling depth has been reached.

Once the drilling is completed, the implants are placed. A minimal insertion torque of 40 Ncm must be achieved to allow immediate loading of the provisional prosthesis (Fig 7a).

Immediate Loading of the Provisional Prosthesis

Implants are immediately loaded with the preformed provisional prosthesis. The crown units of the provisional prosthesis that correspond to the positions of the placed implants are hollowed. The implants are mounted with the provisional abutments, and the prosthesis is relined and adapted to

Fig 7a Clinical photograph of 8 implants in place. One implant that was planned at the position of the mandibular right second premolar was not placed because of inadequate bone quality (compare with Fig 6a).

Fig 7b The provisional prosthesis adapted to the implants' final position. The position of the implants corresponds to the crown units of the prosthesis as planned. Anterior implants are outside of the prosthesis's crowns, as was anticipated in the presurgical plan. Note the accurate transfer of the presurgical plan to the patient (compare with the presurgical plan in Fig 6a).

capture the abutments. Finally, the prosthesis with the abutments is screwed to the implants (Fig 7b).

DISCUSSION

Flapless implant surgery is becoming accepted as an alternative protocol for placing dental implants. Flapless procedures have been reported to reduce postoperative swelling and patient discomfort.[1,2] Exclusion of the mucoperiosteal flap should prevent the potential postoperative bone resorption associated with full thickness periosteal flap procedures.[7] On the other hand, the flapless implant procedure requires an access incision, which eliminates much attached gingiva and may compromise soft tissue esthetics. Potential for contamination of the implant upon placement also increases in this procedure.

The conventional techniques of the flapless procedure rely on the experience of the surgeon in predicting the shape of the alveolar bone at the implantation site. These generally blind procedures increase the risk of cortical bone perforation and are therefore limited to straightforward cases with favorable bone width. Alternative techniques that transfer a presurgical plan to the clinical setting have been suggested to be advantageous in flapless implant procedures,[8,9] but these techniques are still inherently blind and are based on drilling through a preformed drill guide. These drill guides do not permit intraoperative modification of the plan, and their accuracy cannot be verified during surgery.

Computerized navigation has evolved to facilitate minimally invasive procedures, the gold standard of modern surgery. Implementation of this technology in implant dentistry allows the accurate transfer of the presurgical implant plan in flapless implant surgery. The real-time imaging of the dental drill transforms the flapless surgery into a fully monitored procedure, with the surgeon constantly able to visualize the progress of the drilling. The accuracy of monitoring can be verified by positioning the tip of the drill on specific anatomic landmarks. Since the navigation procedure is accomplished in a freehand style by following the navigation screen, the surgeon has a direct view of the operating field, which allows intraoperative confirmation of the treatment plan. Any desired intraoperative modification of the plan can be easily accomplished in an interactive fashion using the established imaging interface.

Intraoperative computerized navigation in implant dentistry mandates that an interfacing template be firmly attached to the operated jaw throughout the surgery. In the partially edentulous patient, this is served by an acrylic resin splint that is mounted over the existing natural teeth.[5,6] In this report a novel approach is described for the implementation of this concept in a completely edentulous patient using short bone screws that are placed in the operated jaw and support the essential interfacing template. These short bone screws are placed in the preliminary stage without the aid of computerized navigation and prior to the CT scan. Therefore their placement is based on a panoramic radiograph evaluation that should ensure minimal alveolar bone volume to allow safe positioning of these short bone screws.

The edentulous jaw lacks any reference to the anticipated dental arch, complicating the ideal positioning of the implants. Also, stabilization of conventional surgical guides is difficult without tooth support. Presurgical digital planning allows the determination of the most favorable position for the

implants. With intraoperative navigation, the surgeon can accurately transfer the plan to the patient, ensuring proper positioning of the implants in relation to the restoration.

Immediate loading of full-arch mandibular fixed prosthesis is an accepted clinical procedure.[10] Different approaches have been described regarding the technique in which the immediate provisional fixed prosthesis is fabricated and adapted. Cooper and associates[11] reported the use of a mandibular denture that was hollowed and adapted to the implants' position and then converted to a fixed provisional prosthesis that was immediately loaded. Balshi and Wolfinger[12] reported the use of a complete mandibular denture that was relieved to allow its correct mounting over the placed implants. It was then used to capture the prosthesis cylinders, which indicated the final position of the implants. Thereafter, the denture was processed in the laboratory to adapt to the implants' position for immediate loading. Testori and colleagues[13,14] reported a similar procedure in which the prosthesis was relined over the provisional cylinders and immediately screwed onto the abutments.

In this report, use of the computerized navigation approach, which allows coordination of the availability of bone and the design of the immediate prosthesis, was described. Based on the digital treatment planning, the positions of the implants are planned, and the implants are subsequently accurately placed to accommodate the desired design of the prosthesis. In this sense, computerized navigation surgery allows precise planning of the implants for optimal accommodation of the prosthesis, rather than adaptation of the prosthesis to the position of the implants. When a discrepancy exists between the availability of bone and the ideal position of the prosthesis, it is easily noted, and the treatment plan (ie, number and position of implants, level of prosthesis extension distal to the mental foramen) can be modified accordingly. The final treatment plan consists of predetermined precise positions for the implants that correspond to the desired prosthesis. Based on these predetermined positions for the implants, the immediate prosthesis may be fabricated prior to the implant surgery and made ready for final adaptation once the implants have been placed.

CONCLUSION

Computerized navigation for flapless implant surgery can enhance this surgical procedure. The accurate positioning of implants according to the digital plan can permit the fabrication of a provisional prosthesis before the implant surgery. Patient treatment using this procedure has been described and illustrated.

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