An Image-Guided System Based on Custom Templates: Case Reports

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ABSTRACT

Background: With the use of computer-assisted surgery and other modern imaging technologies, the surgeon's procedures have been modified.

Purpose: The purpose of these case reports is to show the clinical predictability of dental implant placement using an image-guided system.

Material and Methods: An acrylic template is made on the patient model. After computed tomographic examination, a treatment plan is established with appropriate software. To fabricate the surgical template, it is necessary to use a dedicated drilling machine. The first osteotomy is achieved through the template with a 2 mm twist drill. The template is then removed, and the osteotomy is completed, followed by implant placement with standard clinical procedures.

Results: An excellent predictability was observed between the planned implants and those placed in the two maxillary cases presented: a full upper screw-retained bridge and two single units.

Conclusions: This new technology improves the treatment outcome and optimizes the surgical procedure.

KEY WORDS: computer-assisted surgery, dental implants, ideal placement, image-guided system, prosthetic axis, surgical template

Recently it has been proposed that medical imaging technology be used to fabricate a permanent carbon fiber-reinforced bridge cemented to the abutment at the time of surgery.[1] The objectives of medical imaging technology are to reduce the inherent invasiveness of surgical procedures and to improve localization and targeting by pre- and intra-operative imaging.[2,3] Currently, guidance systems consist of an imaging workstation for planning surgery and a technologic tool for transferring the planned surgery to the surgical site. For oral implant placement, several different approaches to transferring the planned position to the surgical field have been proposed; these include navigating with an optical tracking system[2,4] or a magnetic tracking system,[5] using a template adapted on soft tissue as a drill guide on the surgical site,[6–8] and using a robot with a mechanical arm.[9] A more invasive procedure has also been proposed along with the use of a template directly in contact with the bone.[10] Van Steenberghe and colleagues[1] propose to use this technology to make a three-dimensional computer copy of the patient's arches in order to build a cast and fabricate the prosthesis prior to surgery.

This paper describes an image-guided system based on a mechanical device connected with a custom template. Two patients have been treated with this procedure.

MATERIAL AND METHODS

Patient 1

Clinical and Radiologic Examination. This patient was a 50-year-old female in good medical health. A dental and periodontal examination was performed. Periodontal evaluation revealed probing depths of 5 to 8 mm and fair oral hygiene (Figure 1A). Occlusal evaluation revealed flaring of the maxillary anterior teeth, with diastema between the maxillary central and lateral incisors. Radiographic evaluation of a pantomogram demonstrated horizontal bone loss in the maxillary and mandibular arches (Figure 1B). The

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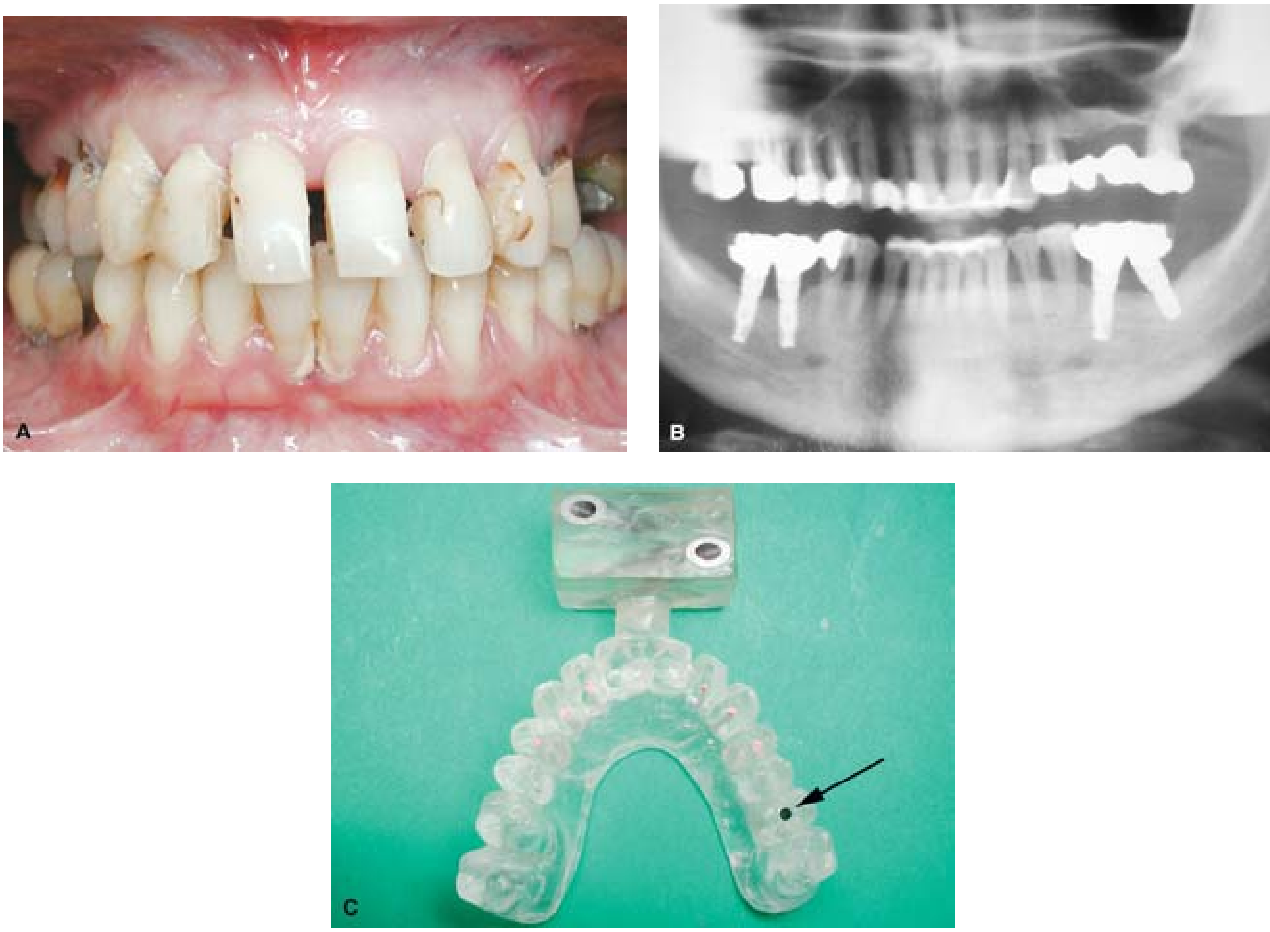

Figure 1 *A*, Preoperative view in patient 1. *B*, Pantomogram made before extractions (4–7, 10–13). *C*, Template with X-cube; note the gutta-percha pins and the pilot tube inserted into 14 (arrow).

patient was given several treatment options but declined sinus grafting.

Study casts were made for evaluation of her occlusion. The maxillary left first molar, first and second bicuspids bilaterally, maxillary lateral incisors, and maxillary canines were removed prior to fabrication of the maxillary wax-up. These teeth were removed on account of advanced periodontal disease. A provisional fixed restoration was made from the maxillary right first and second molars to the central incisors and was extended to the maxillary left second molar. Six weeks after removal of the teeth, a diagnostic wax-up was made to establish proper aesthetics and tooth form. The wax-up was duplicated in the dental laboratory and was used as a template during the scanning examination. Gutta-percha pins to be used as a radiopaque marker were inserted into teeth before computed tomography (CT) scanning (see Figure 1C). A prefabricated cube, called an X-cube (Praxim, La Tronche, France) was connected to the template prior to CT examination. The X-cube includes two titanium tubes accurately embedded in resin and in an orthogonal position. The X-cube protrudes anterior to the maxillary central incisors and displaces the upper lip. The X-cube was used to transfer the planned position of the implants to a drilling machine. To avoid radiologic failure, a pilot tube of 2 mm internal diameter was arbitrarily inserted into the occlusal aspect of one of the teeth (see Figure 1C). CT scan cuts were acquired with the template in the patient's mouth, and images were directly transferred to a personal computer with dedicated software (CADImplant®, Praxim, La Tronche, France).

Planning Software. Treatment was formulated with custom-designed CADImplant software (Figure 2). At the beginning of the planning procedure, the two reformatted planes were initialized with the gutta-percha axis. Each fixture position was visualized on the screen in three different planes; the axial cut and

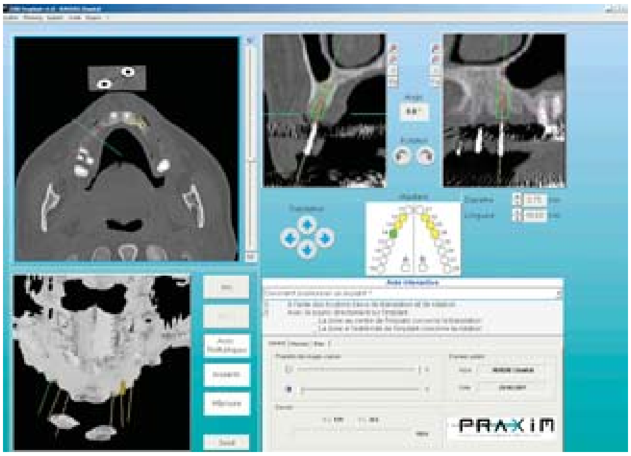

Figure 2 Treatment plan being designed with CADImplant software.

Figure 3 Surgical template with guiding sleeves (X-cube removed).

two reformatted views were evaluated. One of these reformatted views is perpendicular to the arch of the jaw, and the other is tangential to the jaw; both go through the fixture axis (not just intersecting with the axis) and are precisely located in three dimensions. Only the axial plane intersects the planned implant axis. According to the anatomic structures, the practitioner could interactively change the fixture position on each plane. Simulation was carried out in real time. Recalculation of the other planes was instantaneously performed so that cross-sectional cuts always went through the implant. When there were several implants, the practitioner worked on one implant and then proceeded to the next one, the images of the previously planned implants remaining on the axial cuts. If necessary, their position could be changed until all implants were in optimum position. To improve the relative position of implants in relation to one another, the clinician could also use the three-dimensional view showing the shape of the jaw, the ideal prosthetic axis, and the implant simulated cylinder.

Template Drilling. Once the final positions of the implants were defined, the template was drilled in the predetermined position. Thus, the template on its master cast was firmly connected to a drilling machine by placing the X-cube on a dedicated device on the drilling machine and by inserting two metal shafts through the two titanium tubes. The two titanium tubes embedded in the plastic cube were used as reference lines that made a predictable connection between the computer and the patient. These reference lines allowed the establishment of a mathematical link between the CT images and the drilling device. The preplanned implant position was then drilled through the template. The template and the plaster cast could be drilled at a different diameter. To evaluate the precision of the procedure prior to drilling the template, the 2 mm twist drill had to go across a pilot tube in the molar.

Surgery. The X-cube was then separated from the template, which became a surgical guide (Figure 3). Metal tubes were used as drilling sleeves and were inserted through the holes of the previously machined surgical guide.

The day before surgery the patient took 2 g of amoxicillin orally; she continued this medication for 6 days postoperatively. The surgical template was disinfected before surgery. In partially edentulous patients the template is supported by residual teeth. The patient was medicated intravenously for conscious sedation, and appropriate local anesthesia was provided. In fully edentulous cases the curvature of the drilling template and the close contact with the hard palate are insufficient to avoid template movement. Rigid fixation of the template on the underlying bone is achieved by means of osteosynthesis screws. To keep the same CT scanning position, the template is screwed into proper position with the patient in centric relation. The 2 mm twist drill (length, 13–20 mm) was inserted through the tube guide, creating the first osteotomy through the mucosa without flap reflection. The osteotomy was made under water irrigation. The diameter of this drill was 0.1 mm less than the internal diameter of the drilling sleeves. Drill penetration was determined according to the thickness of the mucosa and the length of the tubes. The template was then removed. A crestal incision was made, and flaps were minimally

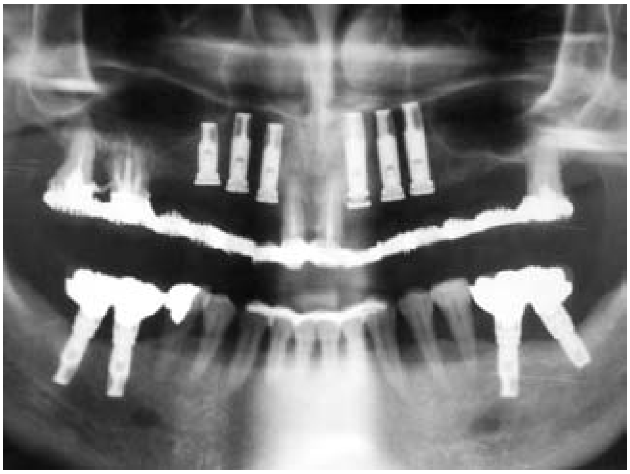

Figure 4 Implants in place under temporary bridge (Brånemark regular platform [RP]).

reflected. From this point on, recipient sites were prepared by following the standard protocol described by Brånemark. Six 3.75 mm machined screw-shaped implants (Nobel Biocare AB, Gothenburg, Sweden) were then inserted into the prepared osteotomies. All implants were stable after insertion. Cover screws were placed on the implants, and flaps were sutured with nonresorbable sutures. The provisional restoration was replaced on the abutments. Oral hygiene and postoperative instructions were given to the patient, along with analgesics to be taken orally in the event of discomfort. The sutures were removed 7 days after surgery, and oral hygiene instructions were reviewed.

Abutment Connection and Provisional Prosthesis. Control pantomography was performed 6 months after surgery (Figure 4). With the patient under local anesthesia, the surgical template was placed on the remaining molars and central incisors. The template provided the exact position of the implants. A periodontal probe was used to identify the top of the cover screws. Small incisions were made over the identified cover screws that were to be removed. Osseointegration was verified, radiography was performed, and healing abut-

Figure 5 *A*, Fixture-level impression; note scalloped tissue margin. *B*, Ceramic bridge (direct implant connection). *C*, Prosthesis, 1 year after placement.

ments were placed. The tissue side of the provisional restoration was relieved, and the bridge was temporarily cemented. Two weeks later the central incisors were removed while the patient was under local anesthesia. A fixture level impression was made, and the temporary bridge was modified in the dental laboratory. Within several hours, ovate pontics were created for the central incisors, and the fixture level bridge was reinserted onto the implants.

Definitive Prosthesis. Two months post-soft–tissue healing, another fixture level impression was made (Figure 5A). The definitive screw-retained prosthesis was made with a metal-framework, implant-supported, ceramic bridge (see Figure 5B). Radiography was performed to verify complete seating of the bridge, and occlusal contacts were adjusted. One month later tightening was verified with a torque driver, and occlusal holes were filled with composite. After one year the patient was recalled and the restoration was verified (see Figure 5C).

Patient 2

The patient, a 27-year-old male in good medical and periodontal health, had previously had orthodontic

Figure 6 *A*, Preoperative view in patient 2. *B*, Radiographs made before orthodontic widening of narrow interdental spaces (7 and 10).

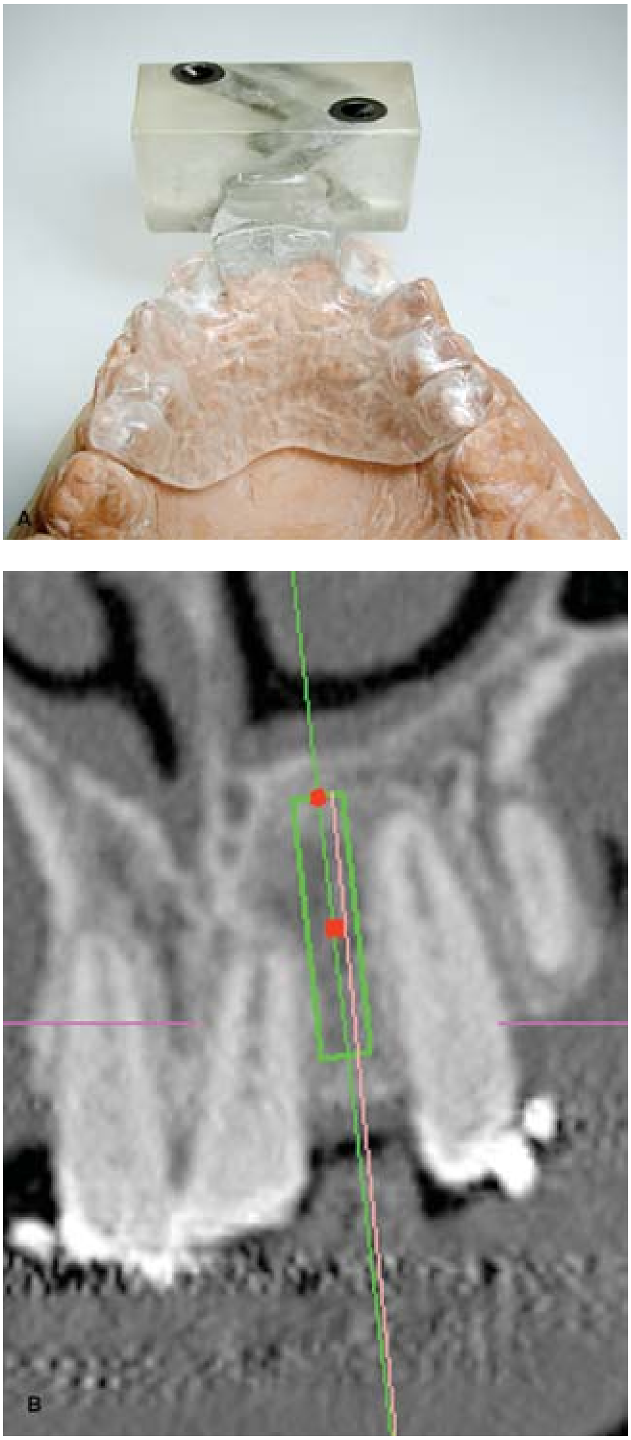

Figure 7 *A*, Template and X-cube before scanning, stabilized on the adjacent teeth. *B*, Tangential view of implant position plan (10).

treatment and was congenitally missing the maxillary lateral incisors (Figure 6A). Radiographs of the lateral incisor positions showed insufficient interdental spaces (see Figure 6B). The patient was referred back to the orthodontist, requesting widening of the interdental space in order to facilitate implant placement. This was achieved after 6 months. At this time there was a 6 mm space between the right canine and central teeth and a 5.5 mm space between the left central and canine teeth. The diagnostic procedures were performed in the same manner as for patient 1. Treatment was exactly the same as discussed previously (Figure 7). Due to space limitations, 3.3 mm Brånemark System® Mk III implants (Nobel Biocare AB, Gothenburg, Sweden) were inserted (Figure 8). After 6 months of healing the provisional screw-retained restorations were inserted. A fixture level impression was made after soft tissue healing (Figure 9A). In the laboratory, titanium

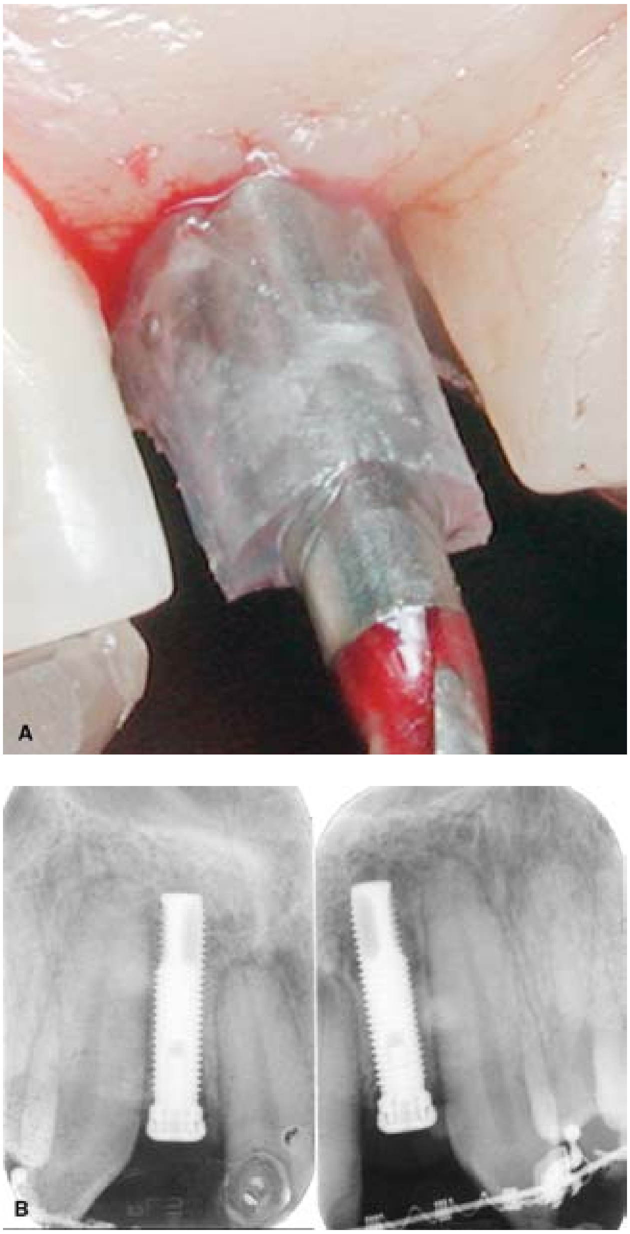

Figure 8 *A*, Transmucosal drilling with a 2 mm drill through the metal sleeve. *B*, 3.3 mm implants in place (7 and 10).

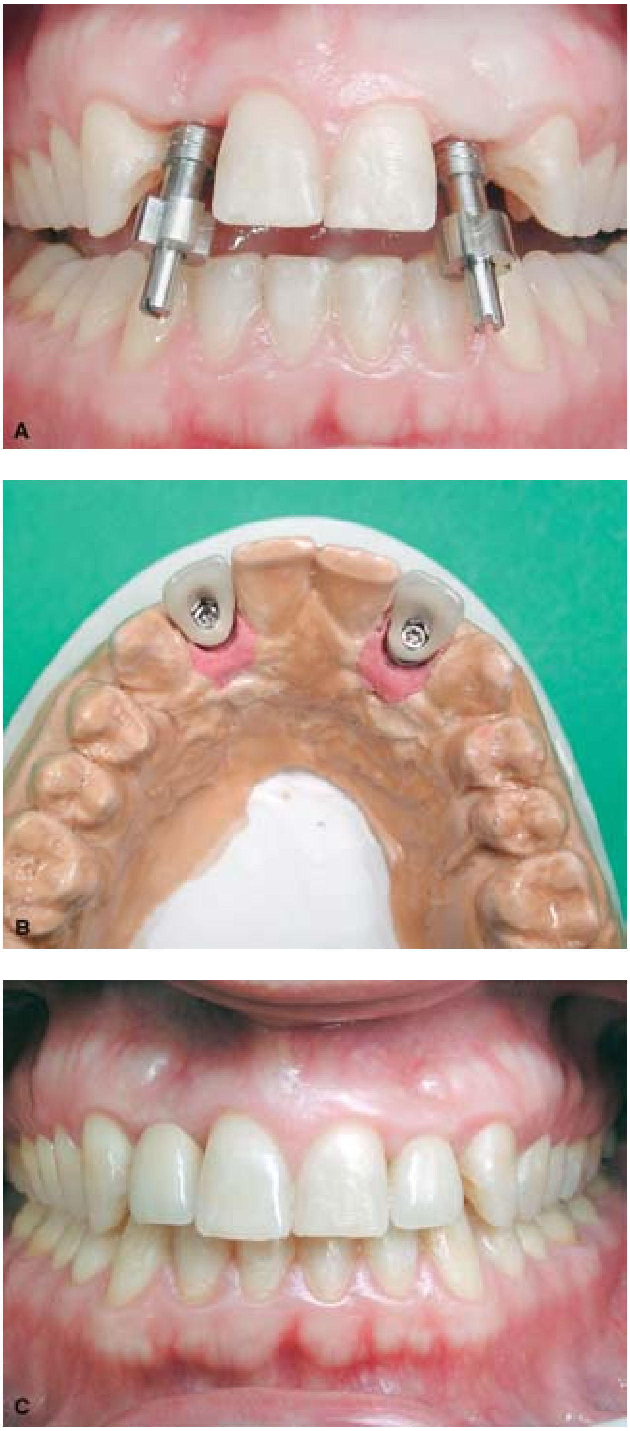

Figure 9 *A*, Transfer copings (Brånemark narrow platform [NP]). *B*, Screw-retained ceramic crowns (Procera system). *C*, Restoration 4 months after placement.

Procera® (Nobel Biocare AB) abutments were fabricated and coated with low-fusing ceramic (see Figure 9B). Screw-retained ceramic crowns were placed and tightened (see Figure 9C).

DISCUSSION

The purpose of this article is to present reports of patients treated with the assistance of three-dimensional computer imaging software. This technology allows the clinician to design treatment plans for implant dentistry in real time and is an improvement over two-dimensional imaging software, which does not provide good predictability in regard to anatomic complications and implant sizes.[11] The three-dimensional approach outperforms planning practice based on two-dimensional images.[12,13] Passive systems, such as navigators, are more flexible than the semi-active system described in this article because modifications of the drilling procedure are always possible during surgery.[14] Passive systems require high-cost technologies such as optical sensors.[4] With an optical tracking system the overall accuracy is 0.96 $\pm$ 0.72 mm.[2,4] The position error can reach a maximum of 3.5 mm. Optical sensors depend on the image resolution. Furthermore, these systems are not easy to use since the surgeon has to integrate technologic constraints during the surgical procedure. In oral implant placement, the optical sensor coupled with the contra-angle must always be "seen" by the external sensor. The patient's head position must be tracked with fiducial markers implanted preoperatively (with the patient under local anesthesia) so that they are visible on CT examination.

Semi-active systems with templates should be easier to use than the navigator is and do not require a high-cost technology since the surgical template is drilled at a laboratory center outside the dental office. When using semiactive systems, the drill axis is predetermined, and no distortion can occur. Therefore, semiactive systems are considered to be more accurate. Because of the intact mucosa of the alveolar ridge, the template may be precisely positioned during surgery in the patient's mouth at the same position used during the CT examination. When compared with the template fitted on the jawbone,[1] the major advantages of this method are flapless surgery and no manual data processing. Treatment time is reduced, and a high rate of precision is achieved. The trajectory of the 2 mm twist drill (used for the two cases presented) through the template is very accurate. Precise calibration of the drilling machine provides accuracy of 0.2 mm in translation and 1.1° in rotation.[15–17] Subsequent drillings are not exactly in the same position. If more precision is required, different techniques might be used. A set of guided twist drills offers a good alternative, or a trephine drill could be guided over a pin guide as suggested by Miyamoto and colleagues[18] and later by Minoretti and colleagues.[19] The only way to transfer the exact position for each implant, as defined on the software, onto the surgical site is to keep a template in place during the surgical procedure, as is done with the Brånemark Novum technique.[20] The limits of the image-guided system (IGS) for oral implant placement can be seen in the use of CT as the radiologic modality providing three-dimensional information. CT requirements are described for several clinical situations.[21,22] Furthermore, the number of implants installed by practitioners of different experience levels is increasing. The use of an IGS thus may be of more importance to some clinicians than to others in terms of reaching a high success rate. One can also imagine that recent and future development of IGS applications, for both surgical and prosthetic protocols, will justify CT examination. Higher x-ray doses and higher costs, which are the main drawbacks of CT, can be significantly decreased by using the cone beam CT scanning technique.[23] Mozzo and colleagues[24] showed that x-rays from the cone beam CT scanner (NewTom®, QR Srl, Verona, Italy) decreased to 15% as compared with the output of "conventional" spiral CT scanners.

CONCLUSION

The image-guided system should be considered a definite improvement in implant surgery. It may be used for training before real target surgery, to get a view of the jawbone anatomy in relation to the ideal prosthetic implant axis. The transfer of the treatment plan to the surgical site might be accomplished with good predictability. This accurate technique, which is less time-consuming for the surgeon, decreases surgical invasiveness and improves implant positioning.

Further research is needed for this procedure to become a part of routine implant treatment.

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