Digitally Designed Surgical Guides for Placing Implants in the Nasal Floor of Dentate Patients: A Series of Three Cases

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Purpose: Insight into the bone volume and position of natural teeth is essential when placing implants to retain nasal prostheses. This paper describes a series of three cases in which a new method was applied for implant placement in the nasal floor of dentate patients using digital planning techniques. ***Materials and Methods:*** With the aid of computer software, digital planning of implants in the nasal floor based on cone beam computed tomography was performed. Next, surgical guides for implant placement were digitally designed and fabricated using rapid prototyping. ***Results:*** In all three patients, implants could be placed and nasal prostheses could be manufactured as planned. All anterior teeth remained vital. Analysis of planning and post–implant placement cone beam computed tomography scans revealed high accuracy of implant placement. ***Conclusion:*** The applied method allows for reliable implant placement in close proximity to the preoperatively planned implant position. *Int J Prosthodont 2012;25:245–251.*

Midfacial defects (eg, nasal defects) can be caused by genetic disorders, trauma, and ablative tumor surgery. Patients with nasal defects can suffer from esthetic and psychologic problems.[1] Treatment options to rehabilitate such patients include surgical reconstruction with a radial forearm free flap, titanium mesh, or paramedian forehead flap. However, surgical reconstruction of a defect affecting the entire nasal cavity is a significant challenge to reconstructive surgeons and is currently only performed with good results in a few specialized medical centers worldwide.[2] For this reason, nasal defects are usually covered with maxillofacial prostheses made of silicone. These prostheses can be attached to the patient's skin with glue or be attached to glasses,[3] or the prosthodontist can try to find mechanical retention for the nasal prosthesis in the remaining nasal cavity.[4] The latter approach runs the risk of compromising normal nasal airflow. Because of limitations in all of these retention systems, dental implants are currently the preferred treatment modality to retain nasal prostheses.[5,6] Implant-retained nasal prostheses have been shown to be reliable, and from a patient's perspective, are a highly appreciated treatment option.[7–10]

Implants to retain nasal prostheses are usually placed in the nasal floor. An additional implant can be placed in the glabella region, but success rates for implants in the glabella region have been reported to be lower than those for implants placed in the nasal floor, probably resulting from poor blood supply and bone density in this region.[11,12] Planning and placement of implants in the nasal floor is often complicated when the patient has natural teeth in the anterior portion of the maxilla or when there is a deficiency in paranasal bone. For placement of intraoral implants in compromised areas, special software such as NobelGuide (Nobel Biocare) and Simplant (Materialise) is available to aid the surgeon and prosthodontist in digital planning. With this software, computed tomography (CT) or cone beam CT (CBCT) data are used to visualize the implant area and plan the desired implant position, after which a digitally designed surgical guide is fabricated. The surgical guide directs the surgeon to place the implants in the preoperatively planned and prosthodontically preferred positions, thereby avoiding damage to vital anatomical structures (eg, nerves, roots of the teeth) and attempting to safeguard a sufficient volume of bone at the implant site.

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Table 1 Patient Characteristics

Patient (M/F)	Year of amputation	Tumor	Radiotherapy (cumulative dose*)	Hyberbaric oxygen therapy†	Year of implant placement
1 (M)	1996	Adenoid carcinoma	Yes (66 Gy)	Yes	2010
2 (M)	2008	Adenoid carcinoma	Yes (66 Gy)	Yes	2010
3 (M)	2009	Vestibulum nasi carcinoma	Yes (66 Gy)	Yes	2010

M = male; F = female
*Cumulative dose received at the implant region in Gray.
†20 sessions before and 10 sessions after implant placement.

Since specific planning software for extraoral implants is not yet available commercially, the authors used an alternative method in three cases to digitally plan the placement of implants to retain nasal prostheses by using commercially available computer-aided design/computer-assisted manufacturing software, thereby avoiding implant placement too close to the patients' maxillary anterior teeth.

Case Series

Three patients, all with nasal amputation as part of ablative surgery (Table 1), had been provided previously with an adhesive-retained silicone nasal prosthesis but experienced discomfort. Cancer and prosthetic treatment had been performed at the Head and Neck Oncology Center of the University Medical Center Groningen, The Netherlands. Patients had not been provided with nasal implants to retain a nasal prosthesis because of the high risk of damaging the roots since no proper three-dimensional (3D) information was available regarding the volume of bone available for implant placement, thereby avoiding the roots of the maxillary anterior teeth.

All patients were scheduled for prosthodontic rehabilitation with an implant-retained nasal prosthesis applying a newly developed method. Patients were informed about the risk of damaging the roots of the teeth in the anterior portion of the maxilla. Vitality of the anterior teeth was tested before surgery, and an informed consent form was signed by the patients.

CBCT-Based Implant Planning and Surgical Guide Design

CBCT data (3D eXam, KaVo) were obtained for all three patients and converted to a surface model using Mimics software (Materialise) with an optimal threshold to depict bone, teeth, or skin. The CBCT machine was set to a voxel size of 0.3 mm, which results in a resolution that surpasses the 0.5-mm resolution prescribed for planning implants using NobelGuide or Simplant. In addition, digital registration of the dentition was done with the aid of the Lava COS intraoral scanner (3M ESPE). Three separate entities for the bone, skin, and teeth were imported into 3ds Max (Autodesk). Since the planning required a 3D model of the roots of the teeth (the CBCT dataset) and a precise 3D model of the crowns (the digital impression), the two models were combined in a separate software. The 3D model obtained from scanning of the dentition was imported into Geomagic Studio software (Geomagic 8.0, Geomagic) together with that of the teeth obtained from the CBCT. The two models of the dentition were aligned and registered with a manual registration algorithm available in the software. In this process, the coordinate system of the CBCT model was fixed to prevent movement of the CBCT model of the teeth. This procedure was introduced to ensure that the spatial coordinates of the scanned plaster cast coincided with those of the teeth in the CBCT model. The 3D model and its coordinates were exported as an stl file and imported into 3ds Max.

In the 3ds Max software, a library with a variety of dental implants was made with lengths and diameters corresponding to dental implants that are customarily employed extraorally to retain maxillofacial prostheses. Around the implants, a 3D cylinder was designed with a diameter of 6 mm, which was 2 mm larger than the implants (implant diameter: 3.75 mm). All components such as soft tissue, bone, and teeth can be made transparent so optimal virtual planning of the implants can be achieved (Fig 1a). This cylindric zone depicted the zone within which the implants could be placed safely and allowed the prosthodontist to fabricate the maxillofacial prosthesis as planned.

An experienced maxillofacial surgeon, an experienced maxillofacial prosthodontist, and an information technology specialist proficient with the aforementioned software planned the preferable implant positions while taking the prosthodontic and surgical needs and the implant characteristics and safety zone around the implants into consideration. The software provided the planning team with windows in which the amount of bone, the location and angulation of the roots of the teeth (Fig 1b), and the

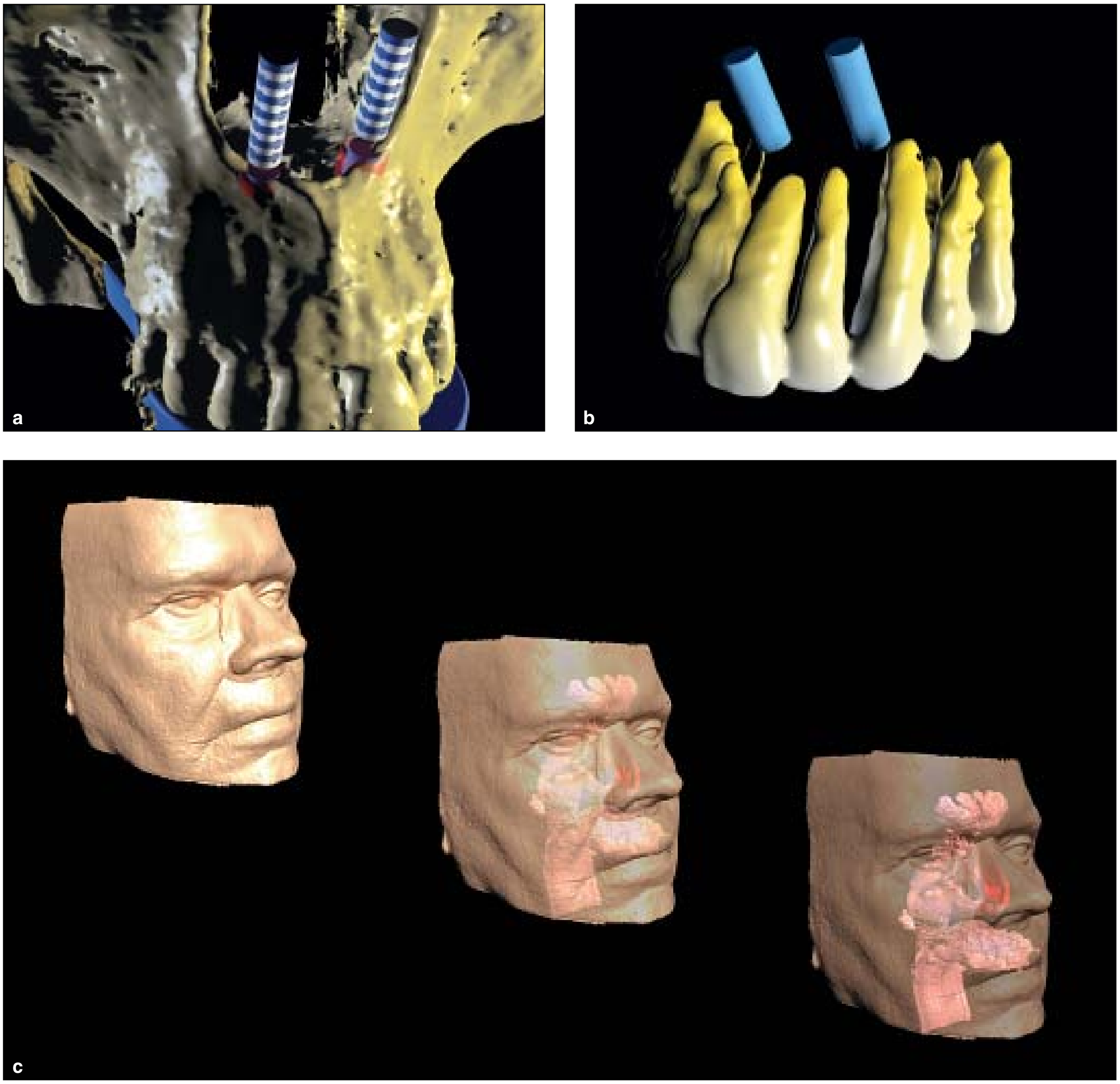
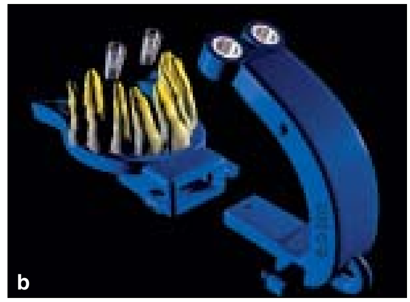


Fig 1a Implant planning in patient 1. The planned implants *(blue cylinder*, diameter: 4 mm) are in the center of the preferred implant position *(red circle,* diameter: 6 mm). Components such as soft tissue, bone, and teeth were made transparent so an optimal virtual planning of the implants could be achieved.

Fig 1b The planned position of the implants does not interfere with the roots of the maxillary anterior teeth. The software provides the clinician with a window in which the implant can be moved virtually in case the preferred implant position interferes with the available bone volume or position of the roots of the anterior teeth. This way, alternative implant positions can be viewed while still allowing for fabrication of an adequate suprastructure and nasal prosthesis. If no adequate position can be selected, this method helps the clinician decide whether it is suitable to perform reconstructive surgery before implant placement.

Fig 1c Besides bone, soft tissue, and teeth, the software also provides the clinician with a window in which the airways can be visualized.

airway (Fig 1c) could be visualized in 3D to ensure proper implant planning. The implant can be moved virtually within these windows to a preferred position or angulation. Based on the planning, a surgical guide was digitally designed in the 3ds Max software (Figs 2a to 2d). The guide used the dentition as a stable anatomical fixation. To allow proper placement, the guide was designed as two parts. The parts were designed to interlock and could be secured with a locking pin, thereby ensuring proper fit (Figs 2a to 2c).



Figs 2a to 2c Surgical guide to place implants in the nasal floor. Both parts interlock and can be secured with a locking pin. The natural dentition is used as a reference to stabilize the guide and to allow checking of its fit.

Fig 2d Fit of the surgical guide checked on the patient before surgery.

At the implant locations, the guide was designed to fit the bone surface with the aim of good fit and stability. At the site of the virtual implants, a hole was modeled in the surgical guide in which a metal tube with an inside diameter of 5 mm could be placed. This tube fit the metal insert that served as a guide for the first twist handpiece.

The surgical guide was made to fit to the bone surface by digitally subtracting the bone from the guide design, a so-called Boolean operation. A second Boolean operation was performed by subtracting the soft tissues from the guide design. The resulting guide would therefore fit the bone at the implant site and the soft tissues at the corresponding points. To ensure proper fit of the guide onto the teeth, a third Boolean operation was performed by subtracting the spatial properly positioned 3D scan of the plaster cast from the guide.

The digitally designed surgical guides were exported as stl files and sent to DSM Desotech, where they were converted to physical casts with the aid of a stereolithography (SLA) machine and a biocompatible SLA resin (BioSure, DSM Desotech). The fit of the guide was checked on the patient before surgery (Fig 2d).

Surgical Treatment

Implant placement was accomplished under general anesthesia using the digitally designed surgical guides. An incision was made through the nasal mucosa. Then, the skin and mucosa were elevated and the bone surface was exposed. The surgical guide was brought into place. The guides were easy to position and had good fit and stability. Implants were placed according to a two-stage procedure.[1,13,14] The implants (3.75-mm diameter, 12-mm length; Brånemark, Nobel Biocare) were placed in the digitally planned positions with the aid of the surgical guide. Next, the implants were covered with skin. Perioperatively, patients received broad-spectrum antibiotics.

The healing time was 4 months to ensure adequate osseointegration. Patients could wear their adhesive prosthesis in the meantime. Stage-two surgery was completed under local anesthesia and consisted of exposing the implants, thinning the subcutaneous tissue, and placing abutment cylinders of appropriate height (3 or 4 mm) and healing caps on the implants. After placing the healing caps on the abutments, gauze soaked in ointment (Terra-Cortril, Pfizer) was wrapped around the abutments to promote skin healing.

Prosthodontic Treatment

Fabrication of the implant-retained nasal prosthesis was started 2 to 3 weeks after abutment connection. The nasal prostheses were made of silicone elastomers (VST50 silicone, Technovent) and intrinsically pigmented with silicone paste and fabric fibers to achieve a good match to the skin (Fig 3a). Clips and magnets were used for retention (Figs 3b and 3c). Furthermore, the prostheses and bar suprastructures were designed and fabricated in such a way that adequate airflow during breathing was guaranteed (Fig 3d). Patients were instructed to clean the suprastructures and surrounding skin daily with either a very soft toothbrush and Super Floss (Oral B) or a small shoestring in combination with water and gentle soap.

Fig 3a A patient supplied with his implant-retained silicone nasal prosthesis.

Fig 3b Individually designed suprastructure to retain the nasal prosthesis. The suprastructure was placed directly on the implants.

Fig 3c In the nasal prosthesis itself, a metal clip and magnet were embedded to retain the nasal prosthesis onto the suprastructure.

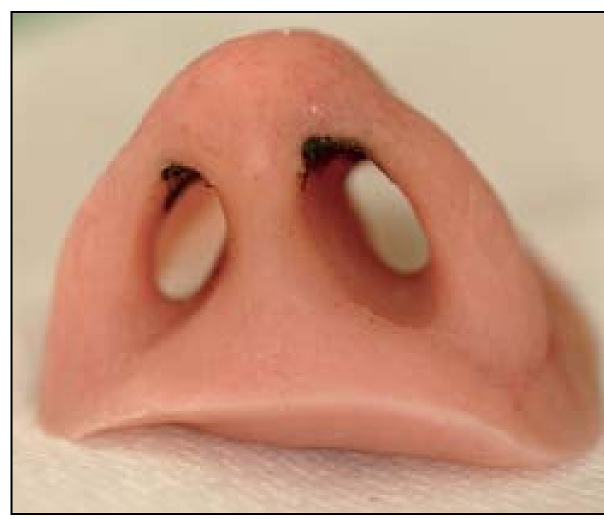


Fig 3d One patient, a smoker, reflected the uncompromised airflow by the presence of nicotine deposits on the inside of the prosthesis

Evaluating the Method

The surgical guides enabled the surgeon to place all implants at the preoperatively planned positions without damaging the roots of the teeth (Fig 4). No changes in vitality of the teeth occurred. The guides were easy to position and had good fit and stability. None of the implants were lost during the 6-month follow-up, and no inflammation of the skin around the implants occurred. All patients functioned well with their nasal prostheses (Figs 3a to 3d).

To assess the reliability of the developed method, a postoperative CBCT scan was taken of all three patients using the same CBCT machine as used for the preoperative planning scan. These scans were used to compare the actual implant position with the preoperatively planned implant position (Fig 4). Therefore, postoperative data were imported into Geomagic Studio software and matched with the preoperative planning data using an iterative closest-point registration algorithm. Linear measurements were made between the neck/tip of the planned implants and

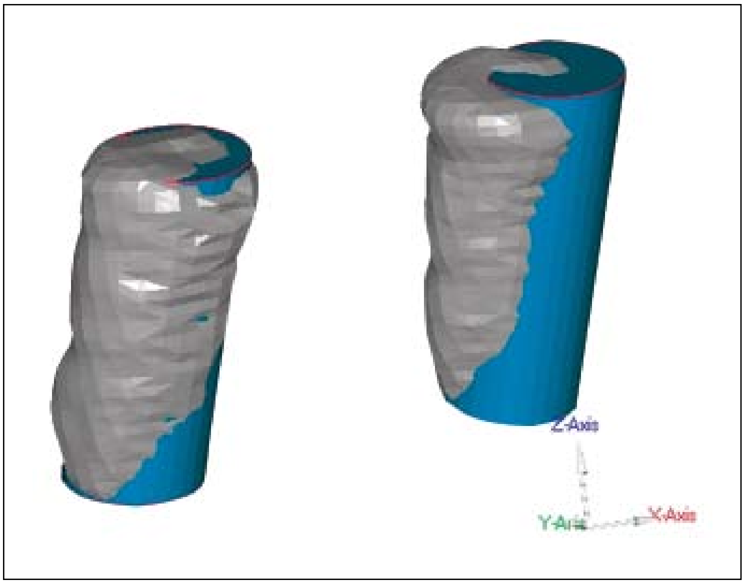


Fig 4 Comparison of planned and actual implant positions by superimposing preoperative and postoperative CBCT data. The planned implants *(blue cylinders)* could be placed as shown in close proximity with the preoperatively planned locations *(gray cylinders)*. The deviation of the neck and the tip of the implant as well as that of the angulation of the implant is depicted and was well within the limits as reported by Van Assche et al[15] and Schneider et al.[16] *(left)* Top: 0.496 mm, tip: 0.702mm, angle: 0.98 degrees. *(right)* Top: 1.924mm, tip: 0.9441 mm, angle: 4.66 degrees.

their actual postoperative positions. Lines were constructed through the center of the implants, and the angle between the planned and actual implant position was measured through angular measurement. Analysis of the differences between the actual and planned positions of each implant revealed that all implants were placed well within the limits needed for fabrication of an optimal prosthesis both from a surgical and prosthodontic perspective (Fig 4).

Discussion

The digitally designed surgical guides facilitated placement of extraoral implants at the preferred implant positions in the nasal floor of dentate patients. A major advantage of digital planning is that the desired implant locations can be preoperatively visualized and the clinician can plan and place the implants in the most preferable position from a prosthodontic as well as surgical point of view (avoiding the roots of the teeth, minimizing invasive surgical treatment, guaranteeing an undisturbed airway, and confirming that there is enough bone volume for placing the implants).

This is a great achievement when comparing the present method with that applied by Guttal et al,[17] who, to the best of the authors' knowledge, described the only case reported in the literature of an implant-retained nasal prosthesis in a dentate patient. In that case, implant placement was accomplished without the help of special devices or tools to guide the surgeon to place the implants in the preferred position. The authors did not describe how they managed the risk of coincidentally damaging the roots of the maxillary anterior teeth, but they might have solved this problem by placing the implants deep into the nose, as is obvious when looking at the photographs accompanying their paper. This rather dorsal placement of implants can be an option for avoiding root damage but compromises both cleaning of the implants by the patients themselves and fabrication of the suprastructure. Furthermore, dorsal placement of the implants runs a higher risk that the suprastructure fabricated on these implants may interfere with nasal airlow.

Although all implants were placed in the prosthodontically and surgically preferred positions, the actual implant positions did not coincide 100% with their planned positions. This slight mismatch may be caused by several factors. One reason is system error, ie, a sum of all the errors present in the different phases. In the data acquisition phase, the resolution of the CBCT dataset should be taken into account. Since the voxel size is 0.3 mm, the accuracy of the system as a whole is unlikely to surpass 0.3 mm. Then, there is an error in the data acquisition of the dentition. The manufacturer of Lava COS claims an accuracy of 11 μm, but this value has not yet been validated externally. Furthermore, the 3D model of the dentition was registered with the dentition in the CBCT dataset to obtain a combined 3D model, which gives rise to registration errors. During the final stage of rapid prototyping, the SLA material will show a slight dimensional change during polymerization. In case the guide is not seated exactly as planned on the dentition, a small angulation of the final implant placement might occur, resulting in differences between the planned and final implant positions (see Fig 4).

The three cases showed that the applied digital method to place implants in the nasal floor to retain a nasal prosthesis is reliable, thereby avoiding the roots of maxillary anterior teeth when present and allowing for fabrication of a nasal prosthesis. Although the software for the aforementioned application can be quite costly if it cannot be purchased under an academic license, there are freeware applications for all of the necessary functions. Conversion of CT data can be performed with freeware such as Osirix, while the 3D visualization and design can be done in Blender, a free 3D modeling and software program. For digitization of the dentition, the authors used a Lava COS intraoral scanner, but a traditional impression that is poured in plaster can be used as an alternative since many dental laboratories offer the service of converting plaster casts to 3D digital models. This means that the software cost of the aforementioned method can be reduced to a minimum. However, since not all dentists have a special interest and skill in information technology, there might be a need to ask a specialist for help, which may bring some additional costs.

Notwithstanding the aforementioned limitations of this method with regard to potential costs, the method has a number of advantages. Traditionally, implants in the nasal floor to retain nasal prostheses are placed without any insight into the implant area. As mentioned previously, one risks damage of vital structures and loss of implants because of insufficient bone volume. Planning in 3D with all the necessary anatomical structures taken into account facilitates a predictable prosthetic end result. With the aid of a computer, every individual desired shape of a surgical guide can be made. Furthermore, printing of the designed surgical guide is not dependent on local facilities; the stl file can be sent to specialized centers all over the world for printing. The only limitation is that the clinician has to be interested in digital technology and have some skills in using computers.

Conclusion

Digitally designed surgical guides for placement of extraoral implants in the nasal floor are of great help in dentate patients to avoid the roots of the anterior teeth and place the implants in a preferred position from a prosthodontic point of view.

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