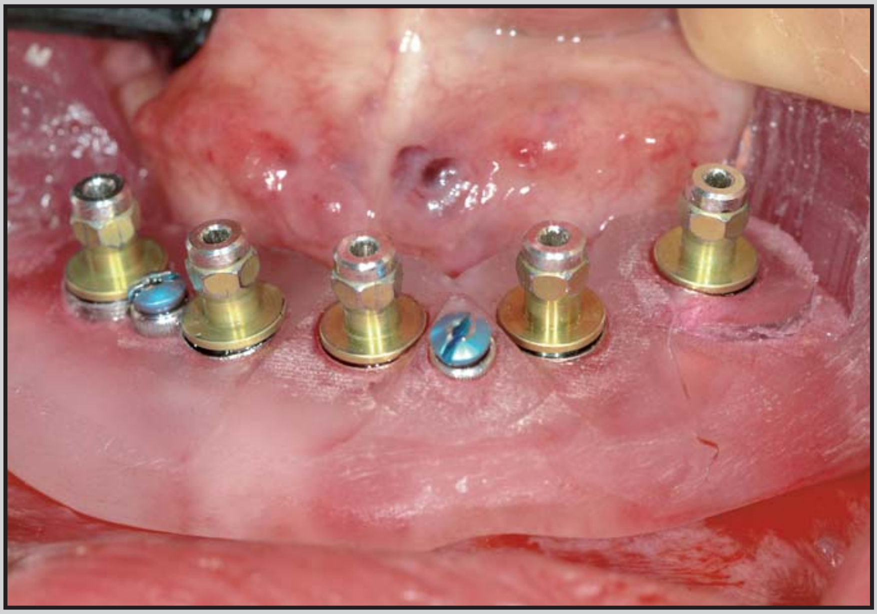

Prosthetically Directed Implant Placement Using Computer Software to Ensure Precise Placement and Predictable Prosthetic Outcomes. Part 3: Stereolithographic Drilling Guides That Do Not Require Bone Exposure and the Immediate Delivery of Teeth

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Previous publications have reviewed the concepts of implant diagnostics and computerized tomographic imaging used together to create an atmosphere of collaborative accountability. The use of SimPlant software in combination with stereolithographic medical modeling facilitates the fabrication of surgical drilling guides, which assist in precise placement of dental implants. In this article, the use of gradient density scanning appliances will be discussed. This type of scanning appliance allows tooth- or mucosa-supported surgical drilling guides to be fabricated and used for implant placement without bone exposure. The use of the SAFE System will be introduced, along with its application in simplifying the immediate-loading prosthesis concept, which can often bypass the need for traditional dental impressions. (Int J Periodontics Restorative Dent 2006;26:493–499.)

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In previous publications, the concept of prosthetically directed implant therapy was discussed extensively.[1,2] The management of diagnostic and clinical information using computer software has enabled the dental profession to use stereolithographic modeling to fabricate bone-supported surgical drilling guides, which facilitate more precise and efficient surgical treatment with less patient discomfort[3] (Tardieu PB, unpublished data, 1997–2001). The next application of stereolithography is in the placement of dental implants in partially and completely edentulous arches without bone exposure. The purpose of this paper is to discuss the use of *gradient density scanning appliances*, which make it possible to place prosthetically directed dental implants without bone exposure.

The authors have extensive clinical experience in the use of bone exposure surgical drilling guides. The logical clinical extension of the bone-supported concept is to place implants without bone exposure, based entirely on the use of a prosthetically directed scan-

Fig 1a (left) *Bone-supported SurgiGuide, which was created using the stereolithographic acrylic resin cast.*

Fig 1b (right) *Tooth-supported SurgiGuide on optically scanned hard stone mandibular cast.*

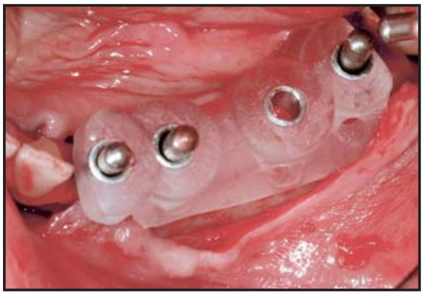


Fig 2a (left) *The bone-supported SurgiGuide is seated on the patient's mandibular bone; guide pins are in place to identify the prepared osteotomy sites.*

Fig 2b (right) *Tooth-supported SurgiGuide in place, with the same guide pins in place that were used to identify osteotomy site positioning via the bone-supported SurgiGuide.*

ning appliance. The clinical question that needed to be answered was: Can a tooth-supported SurgiGuide (Materialise) be placed directly over guide pins inserted into osteotomy sites that were prepared with a bone-supported SurgiGuide? In other words, are SurgiGuides planned and manufactured so accurately as to make the tooth-/mucosa-supported guides interchangeable with the bone-supported guides? To test the clinical efficacy of implant placement without bone exposure, the authors decided to fabricate bone-supported and tooth-supported surgical drilling guides fabricated for use at the same surgical site based on a SimPlant (Materialise) software treatment plan. A stereolithographic bone-supported model was fabricated, and surgical drilling guides were constructed according to the treatment plan. In addition, an optically scanned cast of the teeth and jaw enabled fabrication of a tooth-supported surgical drilling guide (Figs 1a and 1b). The osteotomy preparations were completed using the bone exposure approach. With the guide pins in position, the tooth-supported guide was effortlessly inserted (Figs 2a and 2b). This clinical "moment of truth" was a breakthrough that facilitated the development of trust and confidence to attempt osteotomy preparations without bone exposure on a more consistent basis.

Surgical drilling guides for preparation of implant sites without bone exposure

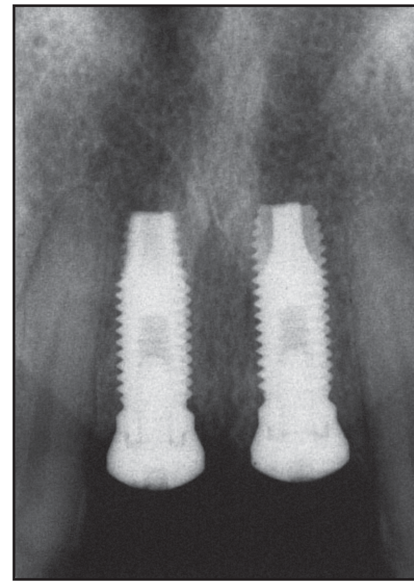
Tooth- or tooth/mucosa-supported surgical drilling guides

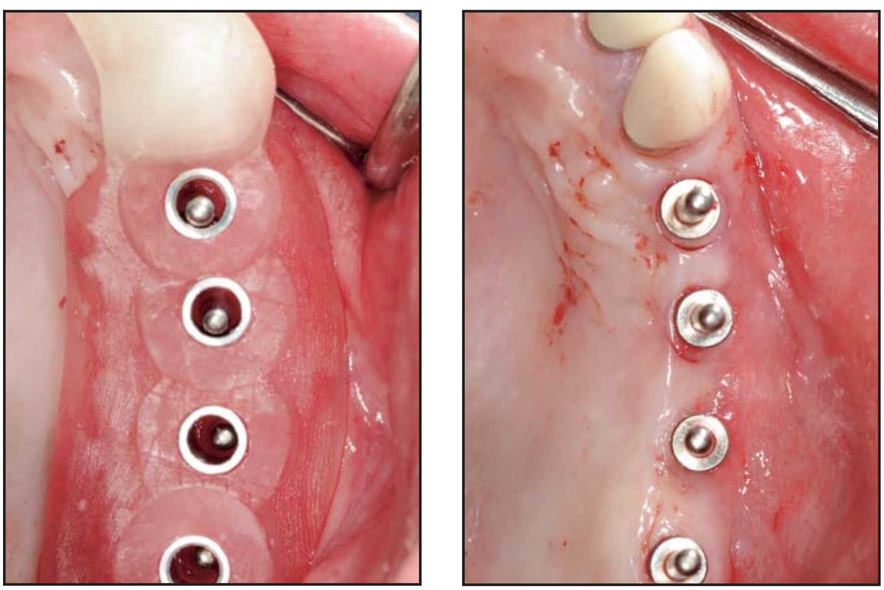
This drill guide design is applicable for the partially edentulous patient. The stereolithographic drill guide is designed to fit precisely on the dental structures. Although the development of a treatment plan varies little from that used with the bone-supported guide, several important points must be made. First, imaging artifacts may be created by any metal prostheses worn by the patient. This may interfere with triangulating a reproducible image plane and jeopardize the ability to build a stable tooth-supported SurgiGuide. Second, a high-quality impression and hard stone cast of the scanned arch must be made. The hard stone cast is optically scanned and the data superimposed over the computerized tomographic (CT) image to merge data from the computer-generated treatment plan and the tooth-supported guide. The natural dentition of a partially edentulous patient is helpful for guide stabilization and can allow for flapless surgery without requiring a large mucosal surface area to support the guide (Figs 3 and 4).

Fig 3a *Osteotomy site preparation with tooth-supported SurgiGuide in place.*

Fig 3b (above) *Immediate postoperative view of flapless implant placement using a tooth-supported SurgiGuide. (Healing abutments are in place.)*

Fig 3c (right) *Postoperative radiograph verifying precise implant positioning.*





Figs 4a and 4b *Patient with unilateral maxillary posterior partial edentulism. Sinus bone grafting had been performed 9 months earlier. Prosthetically directed CT implant treatment planning was performed. A tooth/mucosa-supported SurgiGuide was in place for osteotomy site preparation in the region from the left first premolar to the left second molar. The guide pins are shown in the prepared osteotomy positions with* (a, left) *and without* (b, right) *the SurgiGuide in place.*

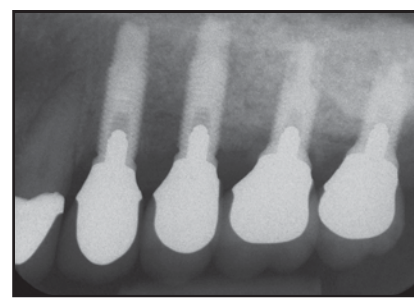


Fig 4c *Postoperative radiograph demonstrating precise, prosthetically directed implant positioning outcome.*

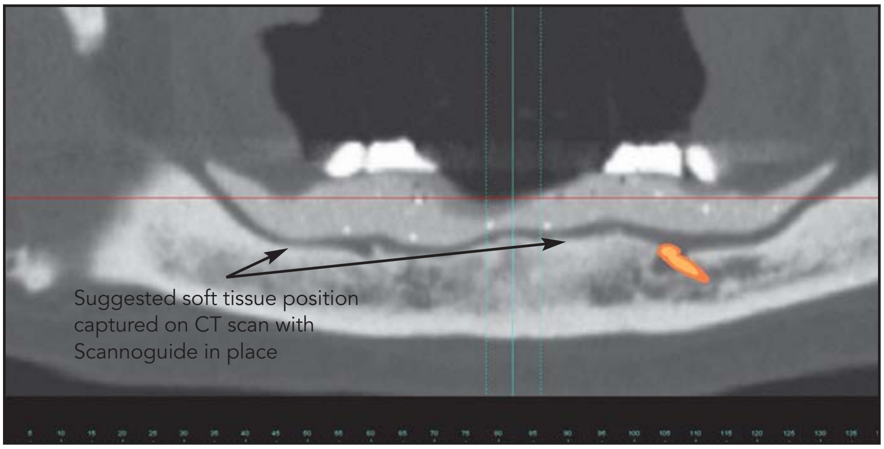


Fig 5 *Panoramic view of SimPlant analysis of patient's mandibular CT scan. The Scannoguide is in place, demonstrating a differential barium concentration gradient in the denture base versus the teeth. Note the absence of air pockets between the denture base and the mandibular jawbone, which suggests accurate adaptation of the Scannoguide to the mucosa.*

Mucosa-supported surgical drilling guides

Mucosa-supported drilling guides are designed to intimately fit on the soft tissue surface of the completely edentulous patient. The soft tissue surface can be identified by the use of a Scannoguide (Materialise) (Fig 5).[1] The Scannoguide is a unique scanning appliance that incorporates differing concentrations of barium in the denture base and teeth.[1] The Scannoguide, which represents the final prosthetic outcome relative to tooth position, esthetics, phonetics, oral muscular support, and other prosthetic parameters, becomes the basis for prosthetically directed surgical treatment planning.

The Scannoguide appliance allows for the segmentation of the different structural densities, which can be distinguished on the CT study.[1] This segmentation of differing radiodensities is the basis for developing visual masks. Examples of masks could include natural tooth crowns, the scanned arch (maxilla or mandible), roots of natural teeth, existing dental implants, denture teeth, and the denture base of the scanning appliance. These masks can be toggled on and off (ie, viewed or not viewed) in an effort to assess the impact of various structures in three dimensions using the SimPlant interactive software. Masks are created by the use of Materialise's SimPlant Master or Pro software and are based on defining objects by their differing densities.[4] This means that each segment or structure of interest can be visualized independently and interactively. A mucosal medical model of the patient's jaw can then be created by the stereolithographic rapid-prototyping process, and a mucosa-supported surgical guide can be fabricated from the model. To ensure accuracy, it is imperative that the Scannoguide is fully seated with minimal compression during the CT scanning process (Fig 5). Failure to achieve a fully seated scanning appliance will result in air pockets between the soft tissue and the denture base. This disruption will interfere with the accurate fabrication of a mucosa-supported drilling guide. The development of a prosthetically directed treatment plan is the same as mentioned in a previous publication on bone-supported SurgiGuides.[2] During surgery, it is necessary to stabilize the mucosa-supported guide. The major advantage of the mucosa-supported SurgiGuide is the flapless nature of the surgical procedure. The absence of sutures, reduction in pain and swelling, and decrease in surgical time are additional benefits.

The SAFE System

The next-generation surgical appliance is the SAFE System surgical drilling guide.[5] The acronym *SAFE* stands for secure, accurate, flexible, and ergonomic. In addition, the SAFE system is not specific to a single implant manufacturer. At the present time, delivery of implants with the SAFE System SurgiGuide is limited to standard diameter (typically 4.1-mm), external-hex-top implants. However, as soon as implant companies provide compatible carriers for their implants, the SAFE System will have universal applicability.

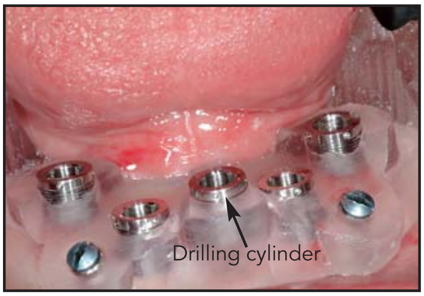


Fig 6a (left) *By varying the vertical position of the guiding components, a single drill length can be used. Note that the guide is fixed into position with pins, and the drilling cylinders have been inserted into the guiding cylinders.*

Fig 6b (right) *The drilling cylinders have been removed and implant placement performed through the guiding cylinders embedded in the SAFE System SurgiGuide using special mounts, which allow for precise vertical implant positioning.*

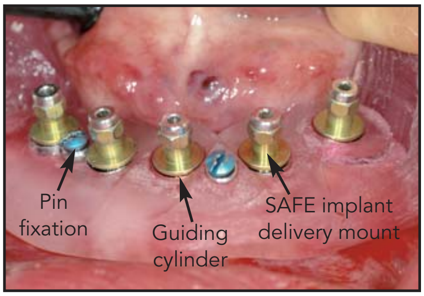


Fig 7a (left) *The flapless surgical procedure is complete. Abutments and temporary cylinders are attached to the implants.*

Fig 7b (right) *The denture, which was modified prior to surgery based on the mucosal stereolithographic medical model, is ready to be converted to an immediately loaded prosthesis.*

The procedure begins with the usual diagnostic workup, mentioned previously.[1] The first step involves the seating of the SAFE System guide and the assurance of fit and stability. In some instances, the guide can be further stabilized by bone fixation screws. Once the guide is stable, a trephine can be used to remove the overlying soft tissue, allowing bone exposure. This is accomplished through the guiding cylinder, which is embedded in the acrylic resin guide. Next, the drilling cylinders are inserted. The drilling cylinder allows for the introduction of the specifically designed pilot and twist drills (Fig 6a). Only two twist drills are used for osteotomy site preparation in the SAFE System: a pilot drill and a final drill. The SAFE System drill design provides precise tolerance with respect to the drilling tubes, thereby avoiding angulation errors and heat generation. The pilot drill is a stepped drill, beginning with a 2.0-mm cutting end and stepping up at the apical one third of the implant to 3.0 mm in diameter for the remaining portion of the twist drill. Physical stops on both the pilot and final twist drills provide for depth control. The same drill length is often used for all osteotomy sites.

The second and final twist drill finishes the drilling sequence through the same drilling tube. The final twist drill is 3.15 mm in diameter and is not stepped. Its design allows for the osteotomy site to be shaped completely, from the apical aspect of the osteotomy site to the bone crest. The total drill sequence may require only two drills of the same length. Drills of uniform length can be used because the depth is controlled at the time of manufacturing by adjusting the vertical position of the drilling cylinders on the guide.

After the drilling cylinders are removed, implant placement can be completed through the same guide (Fig 6b). Implant placement is done using the specially designed implant holders with low tolerance in diameter with respect to the guiding tubes. The physical stop on the implant holders precisely transfers the planned depth and orientation of the implant to the prepared osteotomy site.

The final step includes a decision to stage the procedure or proceed to an immediately loaded prosthesis. In the case of an immediately loaded prosthesis, preparation of the prosthesis can be simplified by completing a major portion of the fabrication presurgically (Figs 7a and 7b).

Discussion

Computer-guided implant placement represents a paradigm shift in the field of implant dentistry. The major benefit of this paradigm shift is the ability to determine the desired prosthetic outcome and surgical performance standards required to achieve this outcome prior to surgery. The available technology allows the restorative clinician to have direct involvement in surgical accountability and imposes a leadership role in the definitive outcome. Furthermore, the collaborative nature required during this process ensures that all of the participants involved in interdisciplinary care are accountable to the final outcome.[1] The accuracy and precision associated with computer-generated surgical guides dramatically supersedes that of "mental navigation."[3,6] Placement of implants with minimal invasiveness enhances both surgical efficiency and patient comfort.[7] Accurate presurgical treatment planning allows for interdisciplinary discussions, which would include the restorative clinician, implant surgeon, and laboratory technologist, so that a balanced and objective treatment plan can be developed. Perhaps the most underappreciated benefit of this technique is the ability to conduct the process of informed consent in an atmosphere of complete disclosure.

It should be stated that the use of CT scanning technology is not limited to so-called complex cases. Every implant case has unique nuances that may affect the treatment outcome. These might include bone density, regional anatomy, bone resorption patterns, root angulation, localized pathology, guided bone regeneration requirements, and the selection of site-specific implant designs. The ability to interpret CT radiographs is proportional to familiarity. As with any radiographic modality, its clinical application is related to experience.

Rapid prototyping and stereolithographic medical modeling applications have opened an entirely new approach to the field of implant dentistry. The fact that SurgiGuides have such universal applicability makes their use simple and efficient. In fact, reports have shown that laboratory cost overruns resulting from poor implant placement via traditional "mental navigation" are reduced by up to 30% when computer-guided implant placement is used.[8]

Conclusions

1. Interactive CT technology is the only diagnostic method available that allows for the incorporation of prosthetic information established by the restorative clinician to be imposed directly onto a CT study and analyzed three-dimensionally against a patient's existing regional anatomy before surgical intervention.
2. Collaborative accountability represents a leadership breakthrough for the restorative clinician.
3. The surgical performance standards required to achieve the desired prosthetic outcome can now be established presurgically.
4. Rapid-prototype medical modeling and the science of stereolithography have applications in implant dentistry.
5. The opportunity to offer patients the option of minimally invasive or flapless surgery is a desirable benefit. Also, the ability to deliver a prosthesis immediately after implant placement is greatly simplified with this technology.

References

1. Rosenfeld A, Mandelaris G, Tardieu P. Prosthetically directed implant computer software to ensure precise placement and predictable prosthetic outcomes. Part 1: Diagnostics, imaging, and collaborative accountability. Int J Periodontics Restorative Dent 2006;26:215–221.
2. Rosenfeld A, Mandelaris G, Tardieu P. Prosthetically directed implant computer software to insure precise placement and predictable prosthetic outcomes. Part 2: Rapid-prototype medical modeling and stereolithographic drilling guides requiring bone exposure. Int J Periodontics Restorative Dent 2006;26:347–353.
3. Sarment D, Sukovic P, Clinthorne N. Accuracy of implant placement with a stereolithographic surgical guide. Int J Oral Maxillofac Implants 2003;18:571–577.
4. Mimics 8.1 Reference Manual. Glen Burnie MD: Materialise, 2004.
5. Tardieu P, Vrielinck L, Implantologie assistée par ordinateur: Le programme SimPlantSurgiCaseTM et le SAFE System. Cas clinique: Mise en charge immédiate d'un bridge mandibulaire avec des implants transmuqueux. Implant 2003;19: 15–28.
6. Vrielinck L, Politis C, Schepers S, Pauwels M, Naert I. Image-based planning and clinical validation of zygoma and pterygoid implant placement in patients with severe bone atrophy using customized drill guides. Preliminary results from a prospective follow-up study. Int J Oral Maxillofac Surg 2003;32:7–14.
7. Campelo LD, Dominguez Camara JR. Flapless implant surgery: A 10-year clinical retrospective analysis. Int J Oral Maxillofac Implants 2002;17:271–276.
8. Beckers L. Positive effect of SurgiGuides on total cost. Materialise Headlines 2003;1:3.