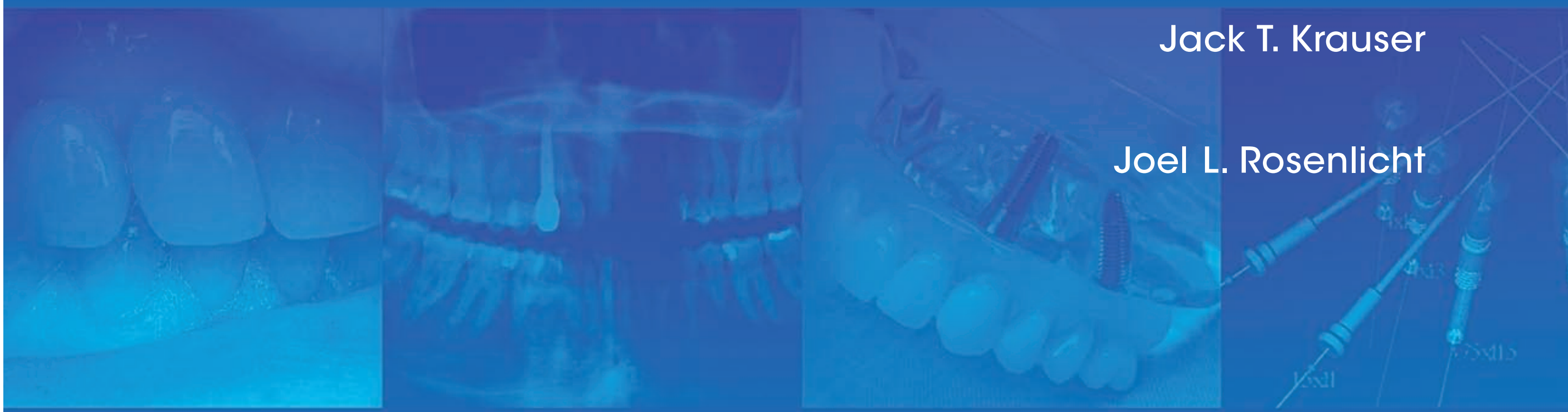

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CHAPTER 18

THE USE OF COMPUTERIZED TREATMENT PLANNING AND A CUSTOMIZED SURGICAL TEMPLATE TO ACHIEVE OPTIMAL IMPLANT PLACEMENT: AN INTRODUCTION TO GUIDED IMPLANT SURGERY

Successful prosthetic dental rehabilitation depends on detailed planning that takes into account both anatomical limitations and restorative goals. That planning must be accurately transferred to the surgical field. To facilitate that task, the use of surgical guides has become well established in implant dentistry.[1-7]

Over the years, a variety of approaches to implant surgical-guide fabrication have developed. Attention has focused on the results that can be achieved by combining computed tomography (CT) diagnostic scanning with computer-aided design and manufacturing (CAD/CAM) and rapid prototyping. Studies by Ganz[8-12] have suggested that the use of such technology can improve the outcome of implant placement by helping to ensure that the implant is placed in the best bone volume. The accuracy of these techniques has been confirmed by other research.[13,14]

Sophisticated three-dimensional (3-D) computer models of patients' oral structures can be generated from CT scan data. Implants can be virtually placed in those computer models (planning images), and the prosthetic result can be instantly assessed, with refinements in positioning made until the placement has been optimized. A surgical guide that allows for precise reproduction of that positioning can then be generated. The guided implant surgery concept takes this approach further by combining presurgical planning and computerized surgical-guide fabrication with presurgical fabrication of a provisional or final prosthesis that can be delivered at the time of surgery. This chapter introduces this approach and presents a case in which it was utilized.

The concept of guided implant surgery enables the surgeon, restorative dentist, and laboratory to share in the diagnosis and treatment planning of each patient receiving implants. All members of the team can assess the three-dimensional computer model of the patient's oral structures, in which the bone available for implant placement and the proximity of the placement site(s) to adjacent dentition, existing implants, the maxillary sinus, and inferior alveolar nerve can be evaluated easily. Using the 3-D computer model enables the implants to be placed within the greatest available volume of bone, improving stability. The emergence profile and aesthetics can be optimized, with adequate lip support and tongue space ensured.

Guided Surgery Approach

The guided surgery approach begins with an evaluation of the patient's dental aesthetics by both the restorative doctor and the surgeon. The length and shape of the prosthetic teeth, tooth exposure when smiling and talking, the relationship of the teeth to the gingival contours, the occlusion, and the phonetics are among the factors deserving attention.

Once an ideal restorative outcome has been agreed upon, an ideal prototype of the final restoration is fabricated. For fully edentulous cases, it may be possible to revise the patient's existing prosthesis rather than creating a new one. A bite registration is then made and a #8 round bur is used to drill at least 10 to 12 points on the prototype prosthesis. The holes are prepared to a depth of 1 mm and placed at different levels in relation to the occlusal plane. Gutta percha is flowed into the holes, transforming the prosthesis into a radiographic guide. The planning software will later utilize the radiopacity of these markers to ensure that the prosthesis is properly aligned with the patient's bone in the computer model.

In preparation for the CT scan, the patient, wearing the prototype prosthesis, is asked to bite evenly and firmly on the bite registration. Either a multislice or cone beam scanner may be used to take the scan. A second CT scan of the prototype prosthesis alone is then taken to compensate for the fact that the acrylic of the prototype in the first scan will become invisible after the planning software has adjusted the first scan's density to reveal the presence of the bone. However, the gutta percha markers will remain visible. When both scans are imported into the NobelGuide software (Nobel Biocare, Yorba Linda, CA) the shape of the prosthesis, captured in the second scan, will be precisely aligned with the image of the surgical site, using the gutta percha markers as reference points.

Having a 3-D computer model of the bone in relation to the ideal prosthesis gives the surgeon an invaluable tool for deciding where the implant(s) should be placed for optimal anchorage, provision of support for the prosthesis, and a superior restorative outcome. Alternatively, the computer model may reveal that grafting is necessary. Either the surgical or the restorative doctor may do the initial planning, and then the computer model can be shared with the other team member(s).

After a final decision has been made about the implant(s) positioning, the planning software creates a rendition of a surgical guide that will enable precise placement of the actual implants in the predetermined positions and orientations. A computer file containing the 3D model of this surgical guide is then transmitted electronically for rapid prototyping by a suitable facility. Once fabricated, the surgical guide is sent to a dental laboratory trained in working with the guided surgery concept, to be used in making the surgical index (a special bite registration created on the articulator) and the master cast from which the restoration will be created.

After the master cast has been made, the surgical guide is returned to the surgeon. During implant placement surgery, the surgical guide is positioned using a surgical index and secured with guided anchor pins. The minimally invasive guided surgery is accomplished by using appropriate instrumentation and drilling sequentially with increasing diameters. The implants are then inserted, and the temporary or final premade restoration is delivered.

Guided surgery is not currently suitable for all cases of implant placement immediately following extraction. It can be used routinely when treating partially and fully edentulous ridges, as well as single-implant placement sites anywhere in the mouth.

Case Report: Using the Guided Surgery Approach

A 56-year-old female patient presented who had been fully edentulous for a number of years. Her mandible had been restored with four implants and a bar-supported over-denture. Tired of the instability of her removable maxillary denture (Figure 18-1, *A*), she sought an implant-supported solution.

Clinical examination of the edentulous arch (Figure 18-1, *B*) revealed a thick, healthy ridge. The tissue firmness and tone were ideal, with no preprosthetic surgery indicated. The patient was advised that she appeared to be an ideal candidate for Teeth In An Hour (Nobel Biocare). This is the treatment option the patient chose.

The patient's dental aesthetics were evaluated, and it was decided to modify her existing denture, adjusting the contours and relining the intaglio surface with a soft-line material to achieve an intimate fit with her soft tissue. Because of the soft lining, it was necessary to duplicate the optimized denture in hard clear acrylic. (The exact thickness of the gingival and palatal tissue cannot be identified precisely with a soft-lined prosthesis.) Ten gutta percha radiographic markers were added to the clear acrylic denture (see Figure 18-1, *C*).

In the offices of the surgeon, an i-CAT CT scan (Imaging Sciences International, Inc., Hatfield, PA) was taken of the patient wearing the radiographic guide with the bite registration. The radiographic guide alone was then scanned. The data from the scans were loaded into the planning software. Three-dimensional images of the patient's bone and the optimized denture were generated within the planning software. The plan consisted of three anchor pins and six definitive implants that were then placed virtually (Figure 18-2, *A* and *B*).

The i-CAT software gives the user the power to turn various layers of the 3-D computer model off and on, an important capability when evaluating whether implant placement has been optimized. For example, Figure 18-2, *A* and *B* are different views of the same computer model. The difference between them is that in part *B* the prosthesis has been removed, revealing the positioning of the implants in the bone. This view makes it clear that the first, second, and fifth implants (going

Figure 18-1. **A,** Preoperative clinical photo. The patient was seeking a more stable replacement for her removable maxillary denture. **B,** A thick edentulous ridge with healthy tissue and ideal tone. **C,** The clear acrylic radiographic guide. Some of the gutta percha markers can be seen.

from left to right) are well positioned. The fourth and sixth implants have been positioned too far labially and the inclination of the third implant is tilted too far to the labial.

Altering the position of the implant on the computer model is easy to do. For example, Figure 18-2, *C*, is a two-dimensional facial-to-palatal slice that was taken from the 3-D image seen in part *E*. Although the 2-D image cannot be rotated (as the 3-D one can), the implant inclination can be changed by clicking on one of the red dots near the bottom of the screen and pulling it facially or palatally. The red dot at the top of the screen is the fulcrum point. As the implant inclination is changed, the position of the implant within the bone changes before the viewer's eyes so an appropriate inclination can be readily determined. The prosthesis can then be added to the image (Figure 18-2, *D*) to confirm the emergence profile and the alignment of the implant to the ultimate final prosthesis. Alternating between views of the prosthesis while adjusting the implant placement allows for clinical skills and experience to be married to the virtual planning capabilities of the software.

Changing the depth of an implant is equally intuitive. The software user clicks on the thin green line that runs through the implant and moves it apically or coronally.

Numerous other views of the implants being placed are accessible with the software. In Figure 18-2, *E*, the fixture mounts have been removed from the 3-D image. The rings that appear to be floating in space are the sleeves that will be incorporated in the surgical guide to help place the actual implant precisely, controlling the angulation, mesial-distal positioning, and depth. By rotating the 3-D image, the palatal aspect of the computer model can be assessed (Figure 18-2, *F*). Yet another view is accessible by using the software's "reslice" tool, as shown in Figure 18-2, *G-I*. This tool makes the images more closely resemble a traditional radiograph, with which most clinicians are more accustomed to working. The reslice tool can be moved around the arch, allowing for various cross-sectional slices. This allows for placement of the implants around the arch.

After the ideal positioning was agreed upon, the computer file of the patient's case was sent via the Internet to a certified manufacturing facility, where a surgical guide was fabricated from acrylic resin using stereolithography technology. Metal sleeves were added to the surgical guide, which was then sent to the surgeon. The surgeon tried the surgical guide on the patient (Figure 18-3, *A*) and during the same visit, a polyvinyl siloxane surgical index was created to be used during surgery to stabilize the surgical guide against the lower prosthesis in the patient's mouth until the anchor pins were inserted (Figure 18-3, *B*).

The verified guide was forwarded to the laboratory. A laboratory technician inserted implant analogs and anchor pins into the surgical guide (Figure 18-4, *A*), and soft-tissue cast material was added (Figure 18-4, *B*) to create the gingival aspect of the master cast. The master cast was created

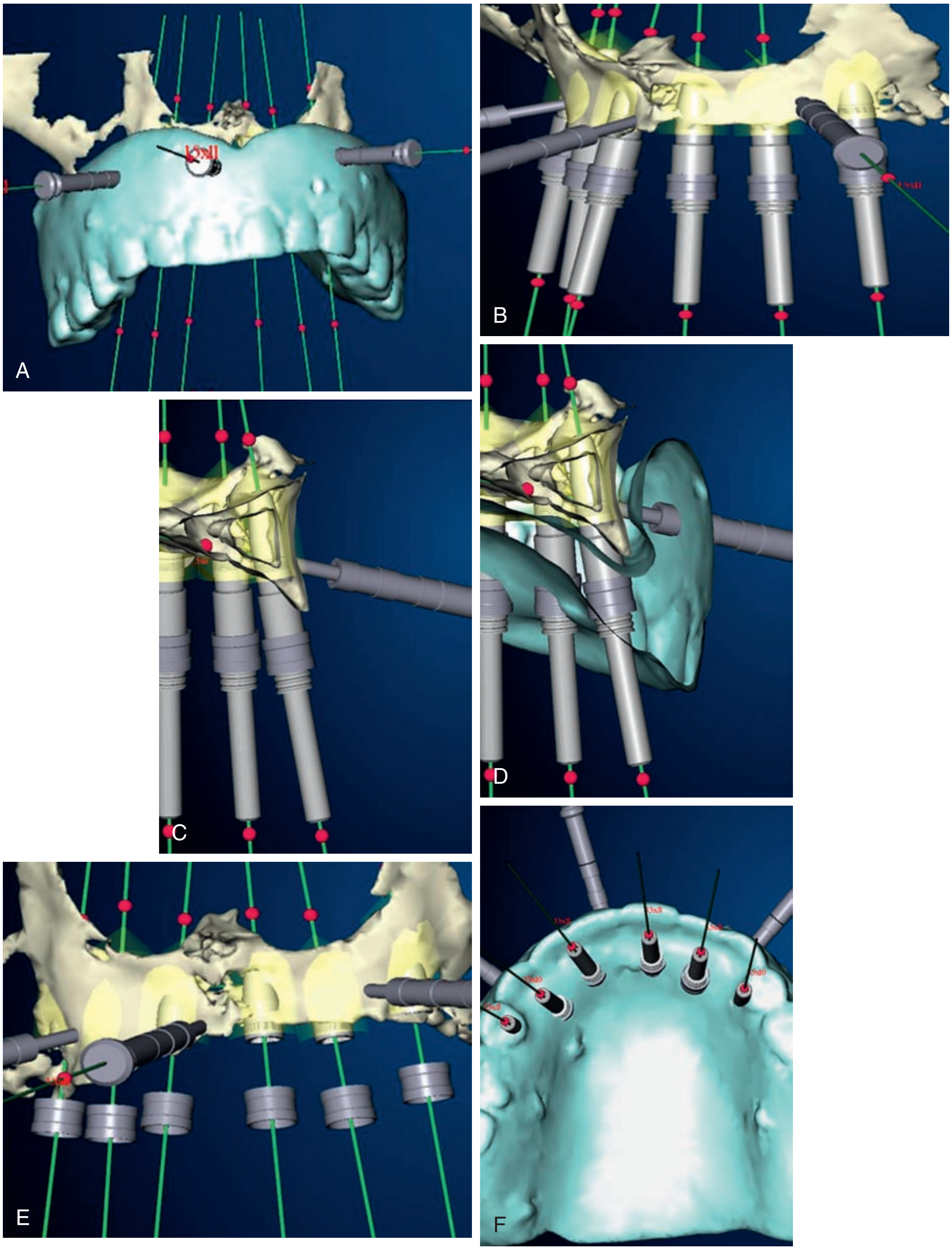

Figure 18-2. A, Three-dimensional image of the planned ideal prosthesis, anchored by six implants that have been placed virtually in the computer model of the patient's bone. **B,** A view of the same image shown in **A,** with the image of the virtual prosthesis turned off. Note that at this point the positioning of the third, fourth, and sixth implants has not yet been optimized. **C,** Two-dimensional facial-to-palatal slice taken from the image seen in **B.** The inclination of any of the implants can be changed by clicking on one of the red dots and rotating it facially or palatally. **D,** The same image as in **C** with image of the prosthesis turned on. **E,** The fixture mounts have been turned off. The rings are the sleeves that will be incorporated into the surgical guide to control the positioning, angulation, and depth of the implant placement. **F,** The computer model rotated to reveal the palatal view of the proposed implants' emergence.

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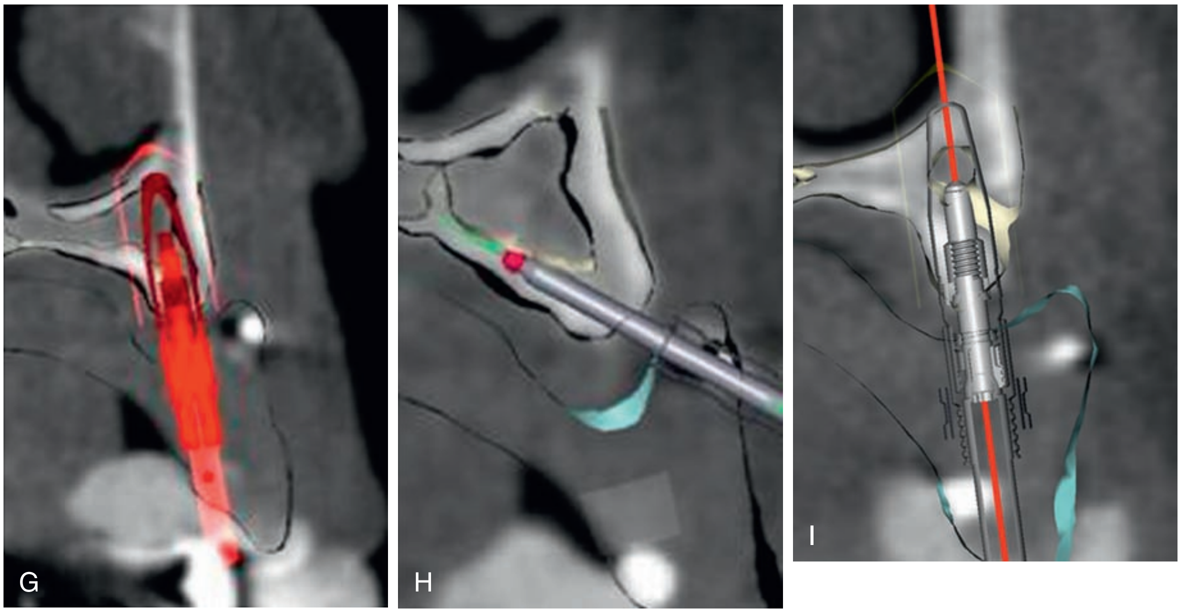

Figure 18-2, cont'd. Examples of the software's reslice tool, which makes the images more closely resemble a traditional radiograph. **G,** Emergence of the implant as it passes through the outline of the prothesis. **H,** Two-dimensional view of a guided anchor pin in position. **I,** Two-dimensional cross-sectional view showing the position and depth of the guide sleeve within the body of the prosthesis. Note that the implant is within the triangle of best available bone and that the placement meets the anatomical, surgical, and prosthetic requirements.

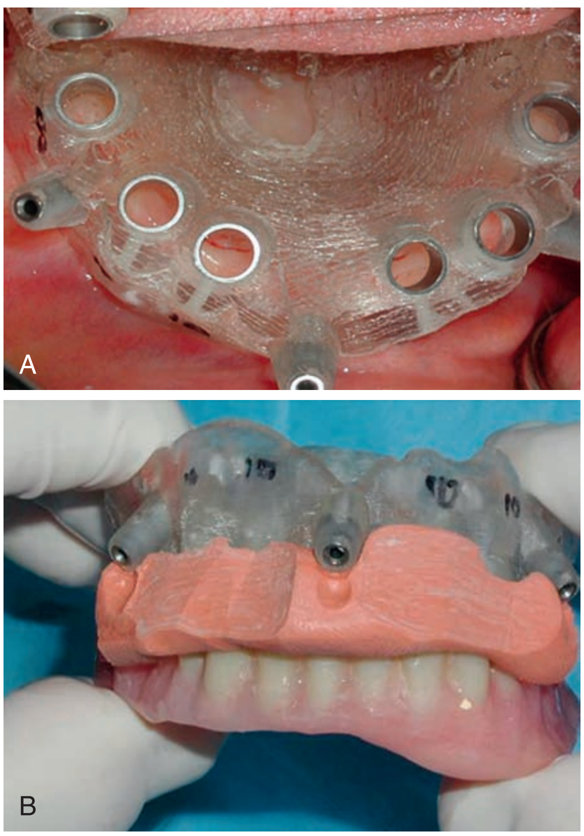

Figure 18-3. **A,** Try-in of the surgical guide demonstrating an intimate fit. **B,** The surgical guide and surgical index created against the lower complete denture.

(Figure 18-4, *C*). The master cast and the acrylic framework were scanned with a Forte Scanner (Nobel Biocare), capturing the contours of the gingiva and the exact position and orientation of the implants. The digital information was then sent to a milling facility, where the framework for the final restoration was milled from a solid piece of titanium.

The framework was returned to the dental laboratory, where it was tried in on the master cast, and a passive and precise fit was confirmed. Teeth were added, in accordance with the preprosthetic plan agreed on by the doctor and the patient.

On the day of surgery, local anesthetic was administered about 10 minutes prior to starting the procedure to allow for dissipation of the anesthetic. The surgical guide and surgical index were seated into the patient's mouth and the patient was instructed to bite down on the surgical index. The three guided anchor pins were then placed after preparation with a depth-controlled 1.5-mm twist drill (Figure 18-5, *A* and *B*). The lower denture and surgical index were removed, and osteotomies were created at the second and fifth implant positions by using the kit drills through the sleeves in the surgical guide. The sleeves control not only the position and angulation of the drilling, but also the depth.

A tapered implant was placed in both the second and fifth positions (Figure 18-5, *C*). The fixture mounts were removed and special template abutments were connected. The template abutments, when tightened, lock to the surgical guide to provide additional vertical stability and anchorage. At this point the surgical guide was extremely stable. Four additional

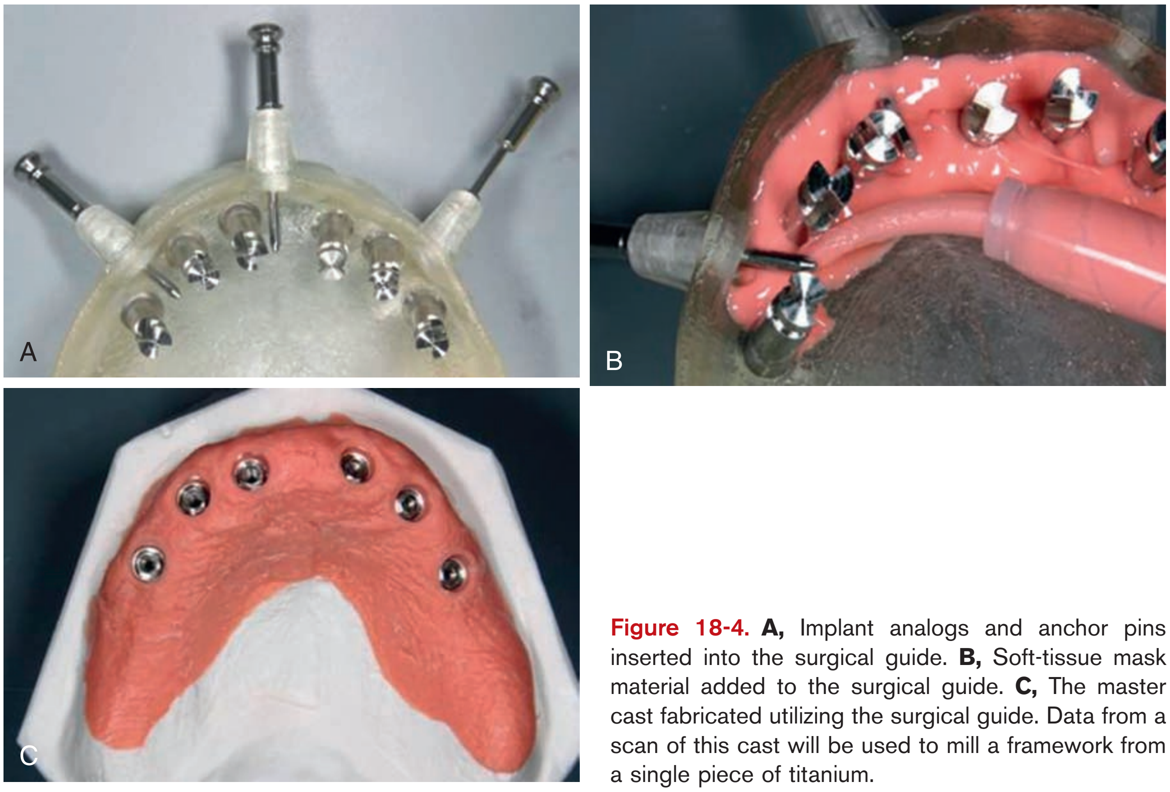

Figure 18-4. A, Implant analogs and anchor pins inserted into the surgical guide. **B,** Soft-tissue mask material added to the surgical guide. **C,** The master cast fabricated utilizing the surgical guide. Data from a scan of this cast will be used to mill a framework from a single piece of titanium.

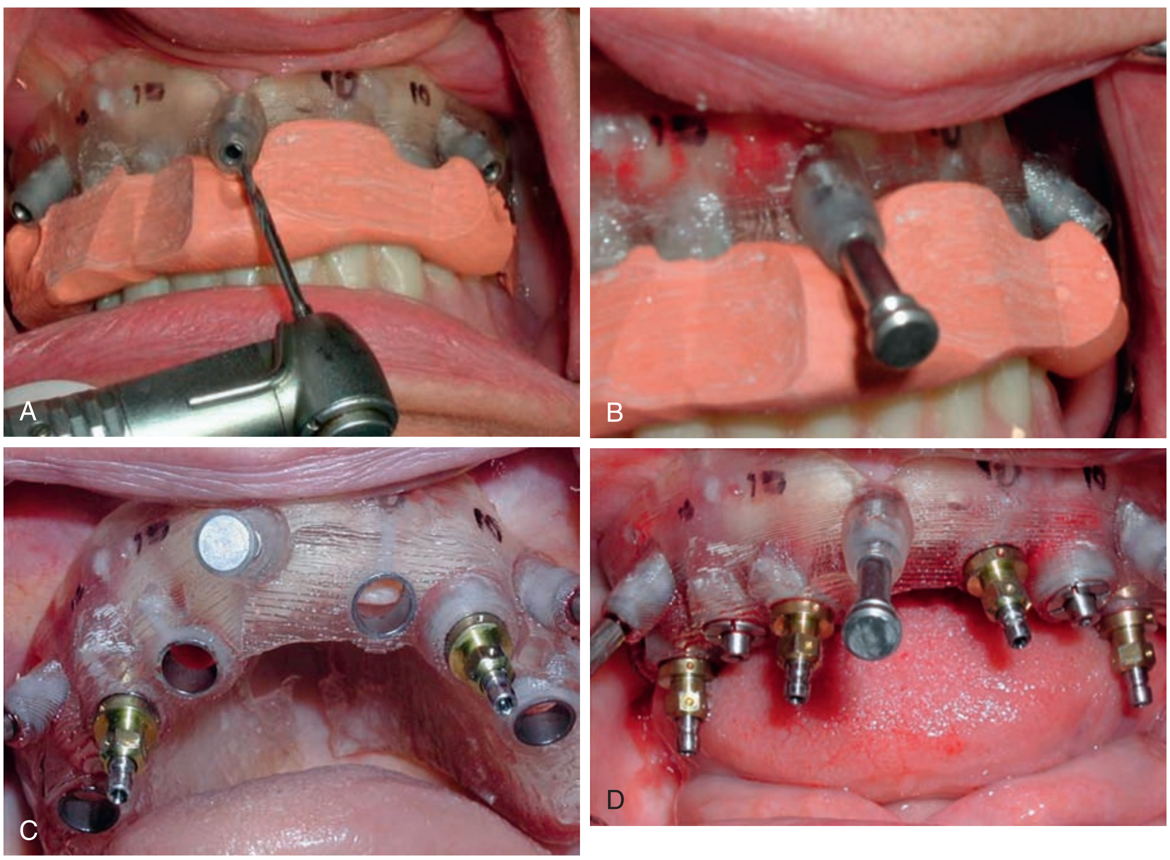

Figure 18-5. A, Guided anchor pins placed with a depth-controlled 1.5-mm twist drill. **B,** One of the anchor pins in place. **C,** The implants in the second and fifth positions placed first. **D,** The implants in the second and fifth positions secured with template abutments, and four additional implants placed. The combination of the template abutments and the anchor pins (also visible) makes the surgical guide extremely stable.

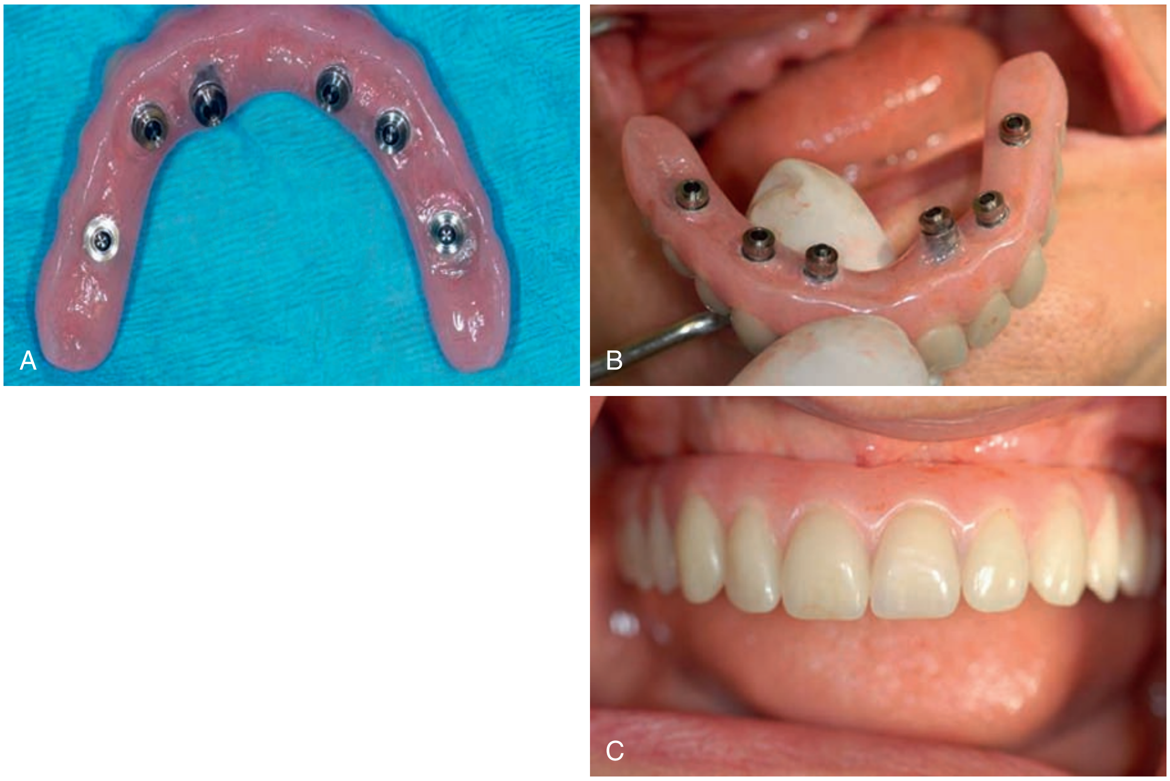

Figure 18-6. **A,** The final prosthesis prepared for delivery. **B,** Special guided abutments secure the prosthesis to the implants with 0.4-mm vertical correction possible. **C,** The final restoration in place, less than an hour after initiation of the surgery.

implants were inserted (Figure 18-5, *D*), completing the surgical operation.

The fixture mounts and template abutments were removed, along with the anchor pins and the surgical guide. Soft tissue tags were removed with a tissue punch. (A blade also can be used to accomplish this.) The final prosthesis was delivered (Figure 18-6, *A*). Note that the final prosthesis was retained using special guided abutments (Figure 18-6, *B*) that can move vertically 0.4 mm to compensate for any compressive distortion that may have occurred from soft tissue. The guided abutment screws were torqued to 35 Ncm. The patient was dismissed with instructions to eat a normal diet but avoid chewing on excessively hard foods for approximately 2 months, to avoid interfering with the osseointegration process. Figure 18-6, *C*, shows the final restoration in place.

Discussion

The flapless surgery enabled by the guided implant surgery system offers a number of advantages to both the implant team and the patient. Because the surgery is minimally invasive and requires no suturing, patients typically experience no significant pain or swelling. In addition, receiving an immediate restoration enables most patients to avoid any disruption of their normal work and social lives, a significant cost savings for many. Fewer appointments and reduced chair time are attractive features of this system.

The guided surgery approach allows the implant team members to offer these benefits (and thus expand their practices) while enjoying a high degree of confidence that adequate implant support can be achieved and an aesthetic restoration delivered. Furthermore, the ability to coordinate case planning between the surgical and restorative doctors and the laboratory reduces opportunities for miscommunication and allows the teammates to coordinate product inventories and other aspects of patient care.

Although the greatest amount of information, and hence predictability, is achievable by using the CT scans to generate a computer-based planning model, it is possible to use the guided implant surgical protocol and instrumentation to improve placement predictability and accuracy for surgeries that have been traditionally planned on a model. Flapless surgery and delivery of an immediate restoration can be offered in such cases, assuming that careful preoperative evaluation and diagnostic radiographic imaging have confirmed the presence of adequate bone volume and revealed no other contraindications. Prosthetic alternatives are feasible as well.

Regardless of how the surgery is planned, use of the guided implant system does not require placement of a final restoration at the time of surgery. A temporary restoration can be utilized or nonaesthetic areas may be left untemporized. However, immediate function has been extensively documented to be both safe and predictable,[15-19] and it offers the patient the advantages cited previously.

If bone volume is not adequate and augmentation must be undertaken, use of the approach is not indicated, for routine use, until after the grafted site(s) have completely healed.

It is important to note that when using a computer-based model for planning, the accuracy of the model depends on proper CT scanning procedures. The radiographic guide also must be fabricated and positioned properly. As CT scanners become more common in dental offices, ensuring that the guided surgery scanning protocol is properly carried out should become easier.

Conclusion

The guided implant surgery system gives implant teams a detailed 3-D computer model of a patient's oral structures, which provides invaluable guidance when planning implant placement. The computer model makes it possible to see the prosthetic outcome of a variety of placement options. Once a plan has been agreed upon, a computer-fabricated surgical guide enables the procedure to be carried out in a highly precise manner. A final restoration can be delivered at the time of surgery, if desired. The system is highly accurate and predictable, easy to use, and results in benefits for both patients and dental practitioners.

REFERENCES

1. Federick DR, Del Rey M: A surgical guide for insertion of implant fixtures, Implant Dent 1(2):129-131, 1992.
2. McKinstry RE, Zini I: A homemade microwaveable denture reline jig, J Prosthet Dent 67(2):269-274, 1992.
3. McMillan AS, Walton JN: Fabrication of an implant surgical guide using a denture replace technique, Quintessence Int 25(9):611-615, 1994.
4. Becker CM, Kaiser DA: Surgical guide for dental implant placement, J Prosthet Dent 83(2):248-251, 2000.
5. Koyanagi K: Development and clinical application of a surgical guide for optimal implant placement, J Prosthet Dent 88(5):548-552, 2002.
6. Shotwell JL, Billy EJ, Wang HL, Oh TJ: Implant surgical guide fabrication for partially edentulous patients, J Prosthet Dent 93(3):294-297, 2005.
7. Atsu SS: A surgical guide for dental implant placement in edentulous posterior regions, J Prosthet Dent 96(2):129-133, 2006.
8. Ganz SD: The triangle of bone—a formula for successful implant placement and restoration, Implant Society Inc 5(2):2-6, 1995.
9. Ganz SD: CT scan technology—an evolving tool for predictable implant placement and restoration, Int Mag Oral Implantol 1:6-13, 2001.
10. Ganz SD: Use of stereolithographic models as diagnostic and restorative aids for predictable immediate loading of implants, Pract Proced Aesthet Dent 15(10):763-771, 2003.
11. Ganz SD: Presurgical planning with CT-derived fabrication of surgical guides, J Oral Maxillofac Surg 63(9 Suppl 2):59-71, 2005.
12. Ganz SD: Techniques for the use of CT imaging for the fabrication of surgical guides, Atlas Oral Maxillofac Surg Clin North Am 14:75-97, 2006.
13. Sarment DP, Sukovic P, Clinthorne N: Accuracy of implant placement with a stereolithographic surgical guide, Int J Oral Maxillofac Implants 18(4):571-577, 2003.
14. van Steenberghe D, Glauser R, Blomback U, et al: A computed tomographic scan-derived customized surgical template and fixed prosthesis for flapless surgery and immediate loading of implants in fully edentulous maxillae: a prospective multicenter study, Clin Implant Dent Relat Res 7(Suppl 1):111-120, 2005.
15. Lee CYS: Immediate load protocol for anterior maxilla with cortical bone from mandibular ramus, Implant Dentistry 2:153-159, 2006.
16. Lozada J, Ardah A, Rungcharassaeng K, et al: Immediate functional loading of mandibular implant overdentures: a surgical and prosthodontic rationale of 2 implant modalities, J Oral Implantol 5:297-306, 2004.
17. Locante W: Single-tooth replacements in the esthetic zone with an immediate function implant: a preliminary report, J Oral Implantol 6:369-375, 2004.
18. Ganeles J, Wismeijer D: Early and immediately restored and loaded dental implants for single-tooth and partial-arch applications, Int J Oral Maxillofac Implants (suppl):92-102, 2004.
19. Degidi M, Piatelli A: Comparative analysis study of 702 dental implants subjected to immediate functional loading and immediate nonfunctional loading to traditional healing periods with a follow-up of up to 24 months, Int J Oral Maxillofac Implants 1:99-107, 2005.