THE POWER OF 3-D COMPUTER-GENERATED IMPLANT PLANNING AND SURGERY

Gary Orentlicher, DMD, Douglas Goldsmith, DDS, Andrew Horowitz, DMD, MD

INTRODUCTION

Implant dentistry is in the midst of a revolutionary change. Medical-grade CT scanners (CT) and in-office conebeam scanners (CBCT) allow dentists and surgeons to visualize a patient's anatomy in three dimensions. The bone available for implant placement, soft tissue thicknesses, location of the maxillary sinuses, and pertinent vital structures such as the mandibular canal can all be visualized.[1-3] A patient's images can be imported into proprietary software programs that allow the doctor to virtually place implants on his or her computer. The type and size of the planned implant; its position within the bone; its relationship to the planned restoration and adjacent teeth or other implants; and its proximity to the mandibular canal, incisive canal, and maxillary sinuses can all be determined prior to surgery.[1-5] Computer-generated drilling guides can be fabricated from the virtual treatment plan, allowing surgical placement of the planned implants in precisely the same positions in the patient's mouth as in the virtual treatment plan. This process results in more accurate and predictable implant placement[6-12] and reduces patient morbidity.[13-16]

All current systems have similar protocols. First, the doctor creates a prosthesis for the patient to wear during their CT or CBCT scan. This partial or full denture, termed a scan prosthesis, duplicates the planned final restorations. (Fig. 1) A CT or CBCT scan is then taken with the patient wearing the scan prosthesis. The scanned images, in DICOM format, are then imported into one of the available proprietary software programs (e.g., Simplant®, NobelProcera®, EasyGuide®, Facilitate™) The software is then used to virtually place implants into their ideal position relative to the planned restoration and the underlying bone. (Fig. 2) The virtual treatment plan is then uploaded to the software company, which fabricates a surgical guide. (Fig. 3) The surgeon uses the surgical guide, with implant-specific drilling instrumentation, to precisely place the implants according to the virtual treatment plan.

Virtual treatment planning and computer-generated drilling guides benefit the patient by allowing flapless surgery, reducing surgical time, reducing discomfort and swelling, and allowing a quicker return to their lives and work.[6,13-23] It benefits the doctor by reducing chair time, reducing stress at the time of surgery, facilitating an accurate means of placing dental implants, and reducing potential surgical complications.[7-12,24] Potential implant positioning mistakes are alleviated by first making them on the computer.

Computerized implantology can be used for any implant case, although the increased treatment planning time and expense may outweigh its benefits in certain cases. In our practice, we have found that these techniques are appropriate for treatment of many cases. (Table 1) The first section of this article discusses how the adoption of these technologies into the practice of

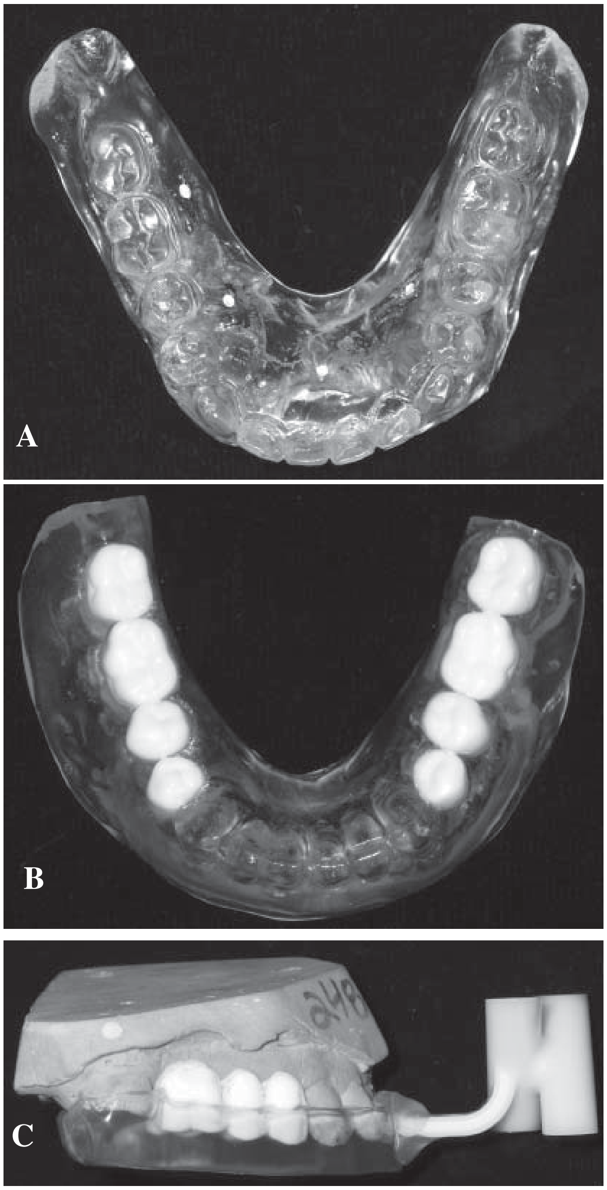


Figure 1. Examples of scan prostheses. **A.** NobelGuide™ Radiographic Guide, **B.** Simplant® scan prosthesis, **C.** EasyGuide™ scan prosthesis.

oral and maxillofacial surgery benefits both doctors and patients. The second section illustrates cases where these techniques are most beneficial. These examples should help others determine those cases where these techniques are appropriate for evaluation and treatment.

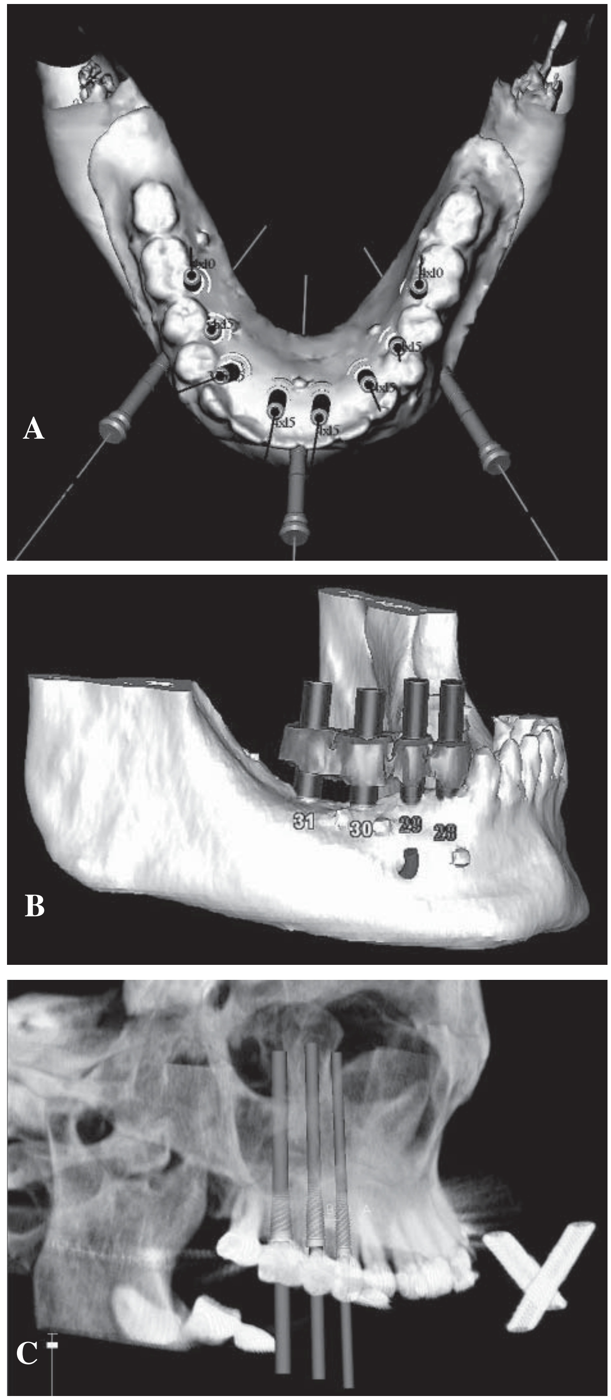


Figure 2. Virtual treatment plans designed for the scan prostheses in Figure 1. **A.** NobelGuide™ Treatment plan, **B.** Simplant® Treatment plan, **C.** EasyGuide™ Treatment plan.

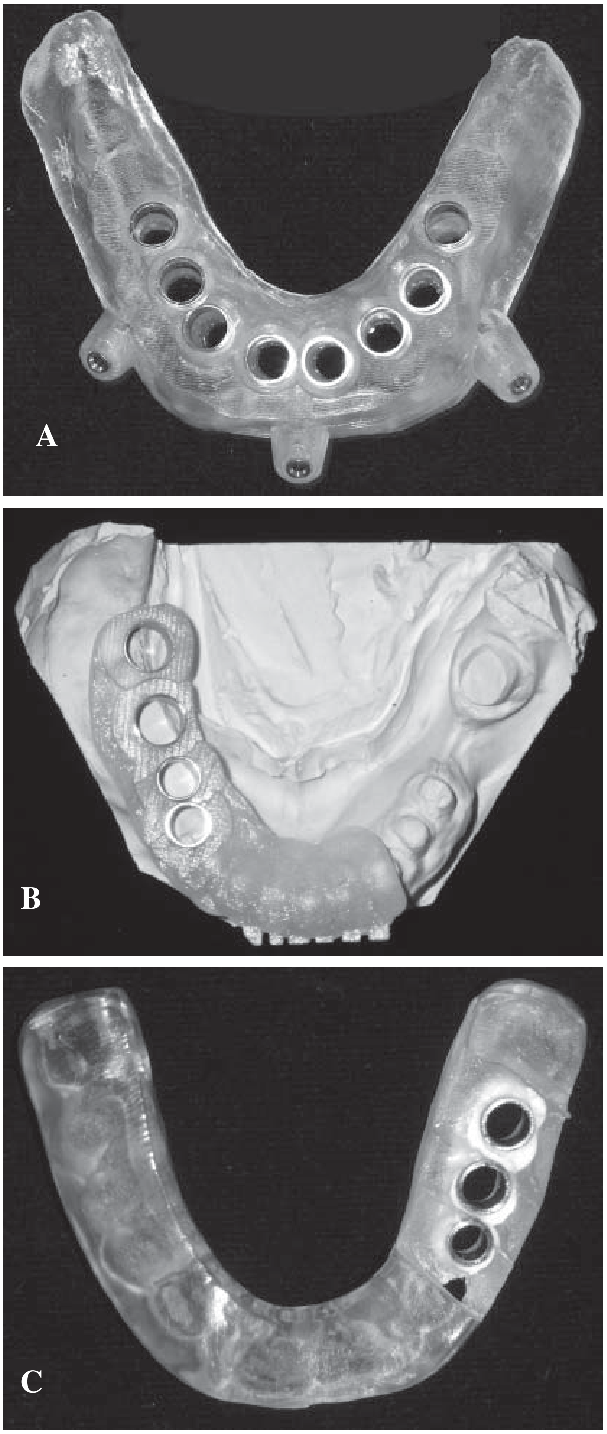


Figure 3. Surgical Guides fabricated from the virtual treatment plans in Figures 1 & 2. **A.** NobelGuide™ , **B.** SurgiGuide®, **C.** EasyGuide™ .

Table 1: Indications for Computer-generated Implant Surgery.

Questionable bone volume
Problems related to proximity of adjacent teeth
Proximity to vital anatomic structures
Three or more implants in a row
Placement of a multiple unit or full arch immediate restoration.
Significant alteration of the soft tissue or bony anatomy by prior surgery or trauma
Patients with medical comorbidities

INTEGRATION OF CT-GUIDED TECHNOLOGY INTO THE PRACTICE OF ORAL AND MAXILLOFACIAL SURGERY

The major excitement and buzz in the field of implant dentistry in recent years involves the introduction of three-dimensional virtual evaluations of patients using CT or in-office cone beam (CBCT) scanners. These technologies can be utilized for three-dimensional diagnoses, virtual treatment planning, and designing surgical guides that allow the surgeon to duplicate a virtual treatment plan at the time of surgery.[6-9,17-23] Predictability of implant placement is no longer limited to a surgeon's "best guess" followed by "exploratory" surgery on the patient. Virtual treatment planning and computer-generated drilling guides allow minimally invasive surgery,[6,13-16,22,23] reduced surgical time, and reduced patient discomfort and swelling.[6,13-23] It reduces surgical complications such as mandibular nerve injury, sinus perforation, fenestrations and dehiscences.[7-12,24] Computer-generated drilling guides provide accurate placement of an immediate, temporary, or final prosthesis according to a prosthetically-driven treatment plan.[6-12,17-24]

What are the goals of the doctor and the patient in treatment planning for dental implants? The **doctor** wants to place the patient's implants in a predictable fashion, considering the position of the planned dental restoration and the patient's medical history, bone biology, and individual anatomy. He or she wants the implants to be: 1) placed with minimal trauma, with minimal involvement of surrounding vital structures and teeth, and 2) fully surrounded with the highest quality bone to assure successful osseointegration and overall success. The **patient** wants teeth that look and function like natural teeth and last a lifetime. They want the treatment to be performed quickly, predictably and successfully; with minimal pain, swelling, stress, or other complications; and with little interruption in their everyday lives

Computerized implantology requires a three-stage process. First, the patient wears a **scan prosthesis** during a CT scan that follows the protocol of the particular proprietary software used by the doctor. The scan prosthesis duplicates the planned implant restorations. Second, using the software, the clinician reviews the relationships of the planned prosthesis to the patient's three-dimensional bony architecture and associated anatomical structures. Implants and abutments can be virtually placed by the doctor on the computer screen. A prosthetically-driven treatment plan is created by placing the implants in an ideal relationship to the planned dental restorations and the associated supporting bone. The virtual treatment plan is then electronically transferred to the manufacturer for the production of a stereolithographic surgical drilling guide. Third, the surgeon uses the drilling guide and surgical drills with "drill stops" to place the implants accurately into their planned positions.

The benefits to the doctor of these technologies are enormous. Three-dimensional patient evaluation allows:

- Detailed 1:1 measurements of the width and height of the available bone in the areas planned for dental implants
- Precise location of the inferior alveolar nerve, mental foramen, lingual and buccal concavities, incisive canal, nasal floor, and the maxillary sinuses
- Accurate measurement of distances between the planned implants, angulations of adjacent implants, angulation differences from one side of the arch to the other, and soft tissue thicknesses
- Evaluation of the path of prosthesis insertion, exact placement of screw chambers, and choice of abutments prior to surgery
- Preoperative evaluation of the risk of fenestrations and need for possible preoperative or intraoperative sinus lift bone grafting, ridge splitting, or ridge augmentation, including the necessary volume of bone graft material are all possible.
- Preoperative determination of the exact lengths and widths of the implants that will be placed

The result is minimal intra-operative surprises.

Once the doctor is comfortable and familiar with the drilling instrumentation, placing implants through a surgical guide not only reduces the time necessary to place implants by 50%, but it reduces the stress that the doctor experiences while placing the implants by an equal amount.

The positioning of the implants is predetermined by the virtual treatment plan and built into the surgical guide.

Most importantly, this technology allows the surgeon and restorative dentist to treatment plan and place implants according to a **prosthetically-driven treatment plan**. The treatment planning process starts with visualizing the final prosthetic result and precisely working backwards from there. The positions of the planned restorations, as they relate to the underlying bone, are determined prior to surgery.

Why Doesn't Everyone Use It?

If this technology has been shown to increase the accuracy of implant placement, decrease surgical complications, and increase the predictability of implant case outcome, why isn't it more widely used in dental implant placement? The reasons are time and money.

Time: It does take additional time for the doctor to 1) take impressions, 2) workup the planned positions of the restorations with a diagnostic wax-up of the planned implant prosthetics, 3) fabricate a scan prosthesis for the patient to wear while having a CT scan, 4) order or take the CT scan, 5) import the CT data into the desired software package, 6) plan the case virtually before treating the patient, 7) order the surgical guide, and 8) learn the techniques and equipment necessary to place implants through a surgical guide.

Money: The patient will incur additional costs for fabrication of the scan prosthesis, the CT scan, and the fabrication of the surgical guide. The surgeon will also incur additional costs in learning the new technologies, possibly upgrading computer hardware, purchasing new software programs, and purchasing new drilling and instrumentation kits.

Doctors may have the attitude, "I have been successfully treatment planning and placing implants non-virtually for many years, so why do it another way?" The doctor might also fear losing the case if any additional costs are added to the already expensive treatment plan presented to the patient. Implant and software manufacturers are marketing three-dimensional implant-planning software products with terms like "Teeth-in-an-Hour™" or "Immediate Smile", leading doctors to believe that these technologies are only useful in fully edentulous cases. Doctors might feel that the additional radiation exposure of a CT scan is not warranted.

It is true that treatment planning and virtually placing implants requires more preparatory steps prior to surgery for both the doctor and the patient. The doctor must commit both time and money to learning these technologies, planning the cases on a computer (or have someone help him plan the cases), and purchasing computer hardware, software, and surgical instrumentation. But remember that your implant patients are coming to you for teeth, not implants!

Presenting the Plan to the Patient

At an implant consult, a patient's biggest fears and first questions are usually, "How much is this going to hurt?", "What will recuperation after surgery be like?", and "How long am I going to be out of work?" When a patient is shown the virtual technology and hears that his or her implants can be placed with minimal cutting and swelling, that he or she will likely be able to return to work comfortably the following day, and that in some cases he or she can receive her restorations immediately, no "selling" to the patient is necessary. We frequently hear patients respond, "Why would anyone do it in any other way?" Patients understand the benefits of the technology better than some doctors.

For some patients costs may be a concern. Here in the New York City area, the added cost to the patient for fabricating the scan prosthesis, undergoing the CT scan, and fabrication of the surgical guide adds $1000 to $1200 to the cost of the case. But remember that many of these patients have been presented with surgical and restorative implant treatment plans that will cost tens of thousands of dollars. When told that the additional cost will result in implants being placed in ideal positions, with proper spacing for gingival and bone health, and proper implant angulations to distribute the bite forces well, the technology sells itself. Because the technology allows a treatment plan that first plans where the teeth are going to be and works backwards from there, there will be few "surprises" encountered at the time of surgery. In the 10-12 years we have been treatment planning cases virtually, not one patient has told us that they did not want a CT scan because of the additional radiation or asked for a different approach for financial reasons.

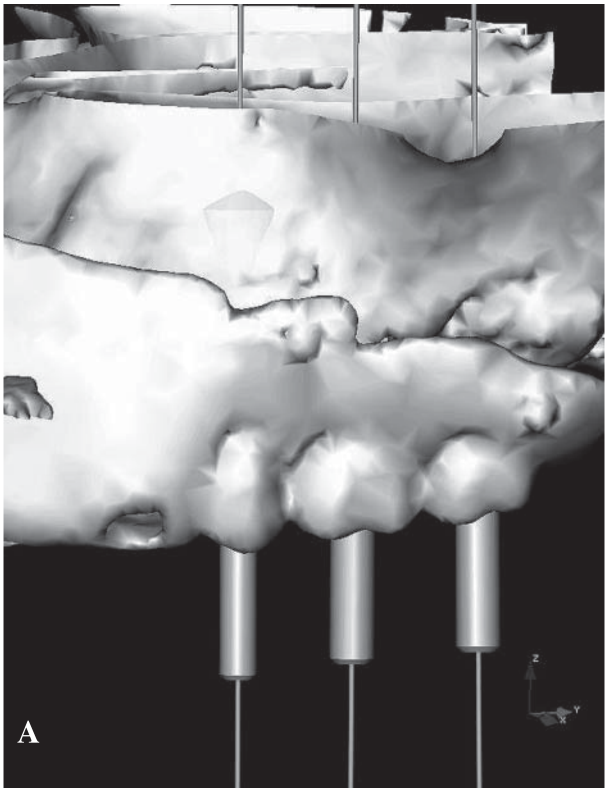
CASE SELECTION

Planning for Three or More Implants in a Row or Fully Edentulous Arches.

When placing a dental implant, it is common for the surgeon to use a surgical guide that is fabricated on articulated patient models. Guides of these types can be simple (e.g., vacuforms with the buccal or palatal/lingual facings of the planned restorations) or more complex (e.g., 2 mm drill holes or metal tubes in the middle of hard acrylic appliances that reproduce a planned restoration.) The one thing that all these appliances have in common is a lack of correlation between the planned restoration and the underlying bony anatomy. Only with computer-guided implant surgical guides can this anatomic relationship be predictably established and considered prior to surgery.

A surgical guide that is used in implant surgery is determined by the patient's anatomy and the local references, such as the numbers and locations of teeth in the arch to be treated or in the opposing arch. As the length of the edentulous area increases, the surgeon is left with fewer anatomic references to use to predictably place implants accurately. When the case is fully edentulous all local references, other than the soft tissue ridge, are lost. Additionally, as the bone and soft tissue are lost from periodontal disease, bony atrophy, sinus pneumatization, and long-term denture wear it becomes more difficult to predictably use a traditional surgical guide.

Therefore, virtual implant evaluation and treatment planning along with implant placement using computer-generated guides is ideal for most cases where three or more implants in a row



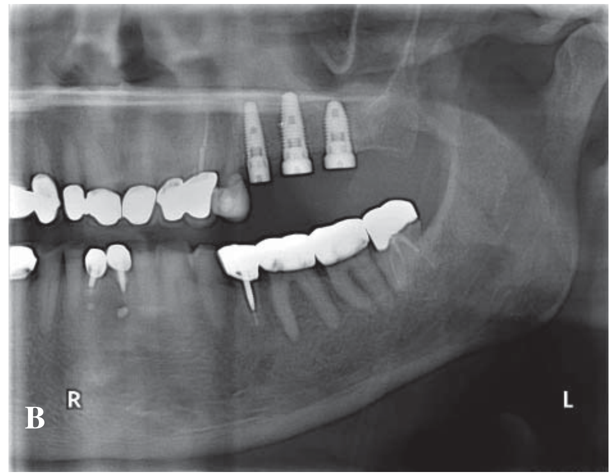
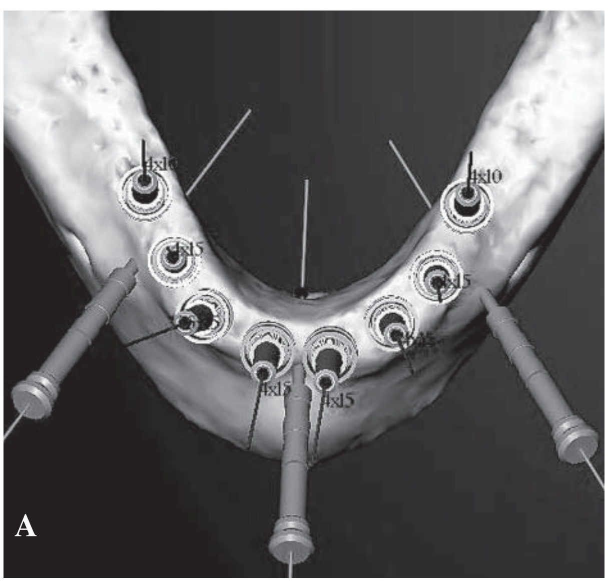


Figure 4. **A.** NobelGuide™ plan for 3 implants in the posterior left maxilla. Note the parallelism of the planned implants, **B.** Postoperative panoramic radiograph, **C.** Final restoration.



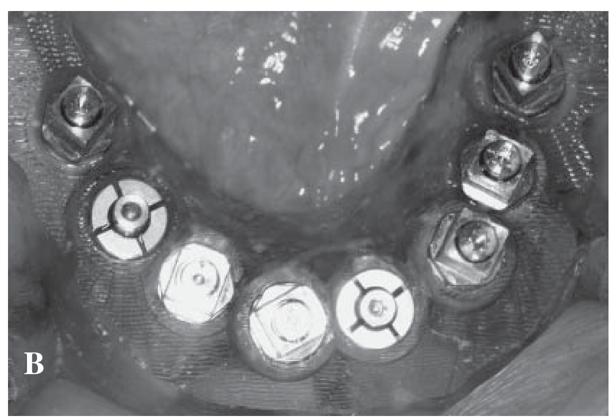


Figure 5. Virtual plan and implant placement in a fully edentulous mandible. **A.** Occlusal view of the implant placement plan, **B.** Implants in place using a NobelGuide™ .

are planned. (Fig. 4) The spacing and angulation relationships among multiple planned implants, as well as implant-to-bone relationships can all be established prior to surgery. (Fig. 5) In addition, the implants can be placed flaplessly and immediately loaded.[6,13-23]

Nerve Close to the Planned Implant Position.

Panoramic and periapical radiographs are two-dimensional representations of a patient's three-dimensional anatomy. Differences in x-ray machines and radiographic techniques commonly lead to distortion (i.e., elongation and shortening) of the anatomic structures in the radiographic images. Accurate evaluation and measurement of the relationship between the position of the mental, inferior alveolar, and nasopalatine/incisive nerves and the planned position of the implant can best be determined by a three-dimensional evaluation of the patient's anatomy using CT generated images.[3] (Fig. 6) Placement of implants in cases where there is a question of nerve or sinus proximity to the patient's available bone is most accurately performed using virtual treatment planning and implant placement using computer-generated surgical guides. Potential patient morbidity is held to a minimum by using these techniques. (Fig. 7)

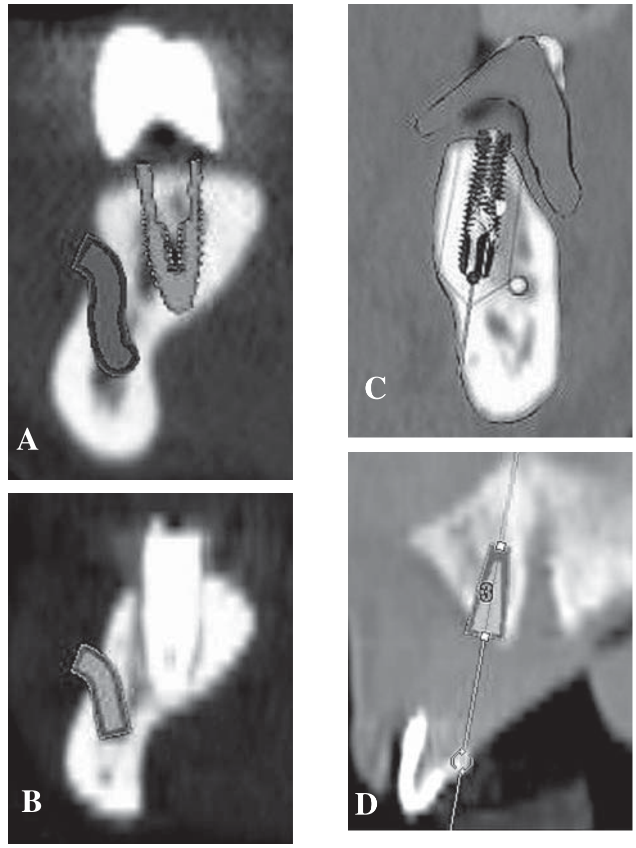


Figure 6. Comparison of **A.** Virtual treatment plan image for placement of implant #21, and **B.** CT scan image of actual implant placement. Note the close proximity of the planned implant and the actual implant placement to associated nerves and foramina. **C.** Implant planned close to the inferior alveolar nerve, **D.** Implant planned close to incisive nerve canal.

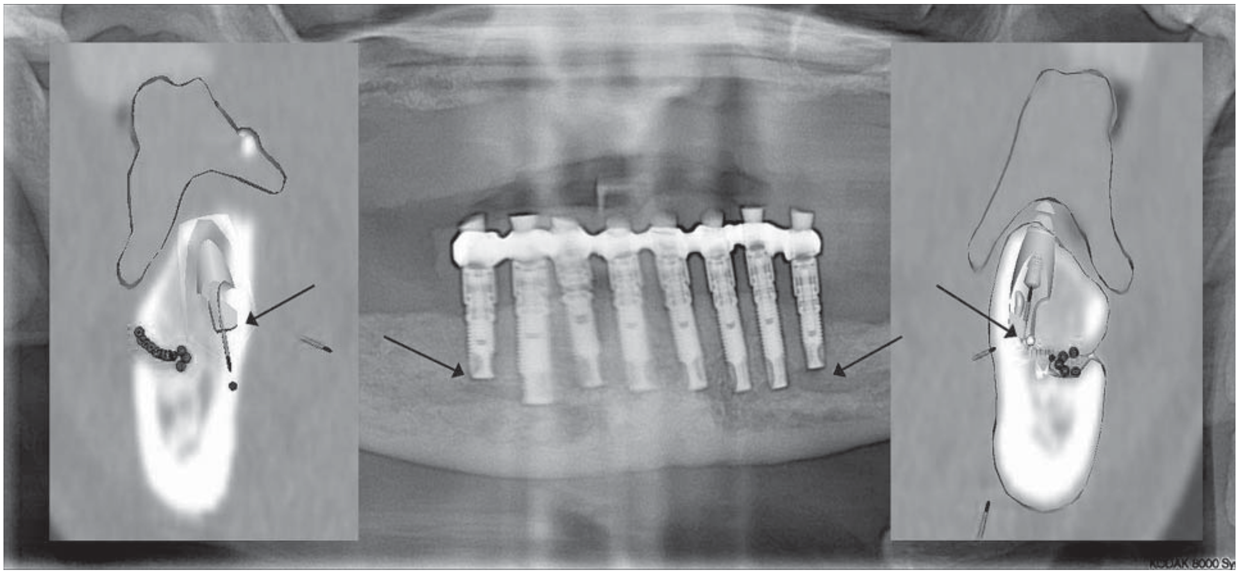


Figure 7. Postoperative panoramic radiograph of an 8 implant mandibular case (center image.) Note that in this image the most posterior implants appear to be encroaching on the mental foramina bilaterally. Compare this with the images on the right and left showing the planned positioning of the implants in the virtual treatment plan. Surgically, the implants were placed lingual to the mental foramina.

Questionable Bone Volume (Deficient Width, Height, or Unusual Bony Contours or Concavities)

Case 1: *A 17-year-old female with congenitally missing tooth #7. (Fig. 8) Orthodontics were performed to first open the space between teeth #'s 6 and 8 to accommodate an implant. The ideal implant position was limited both buccal-palatally and mesial-distally.*

Frequently dental-implant surgeons are required to place dental implants in a single, specific location or at a specific implant depth. They are frequently asked to place dental implants into tight spaces with minimal bony leeway mesial-distally, buccal-lingually, or both. Proximity of adjacent tooth roots can require the surgeon to "thread the needle" with implant placement. This is frequently a problem with congenitally missing teeth.

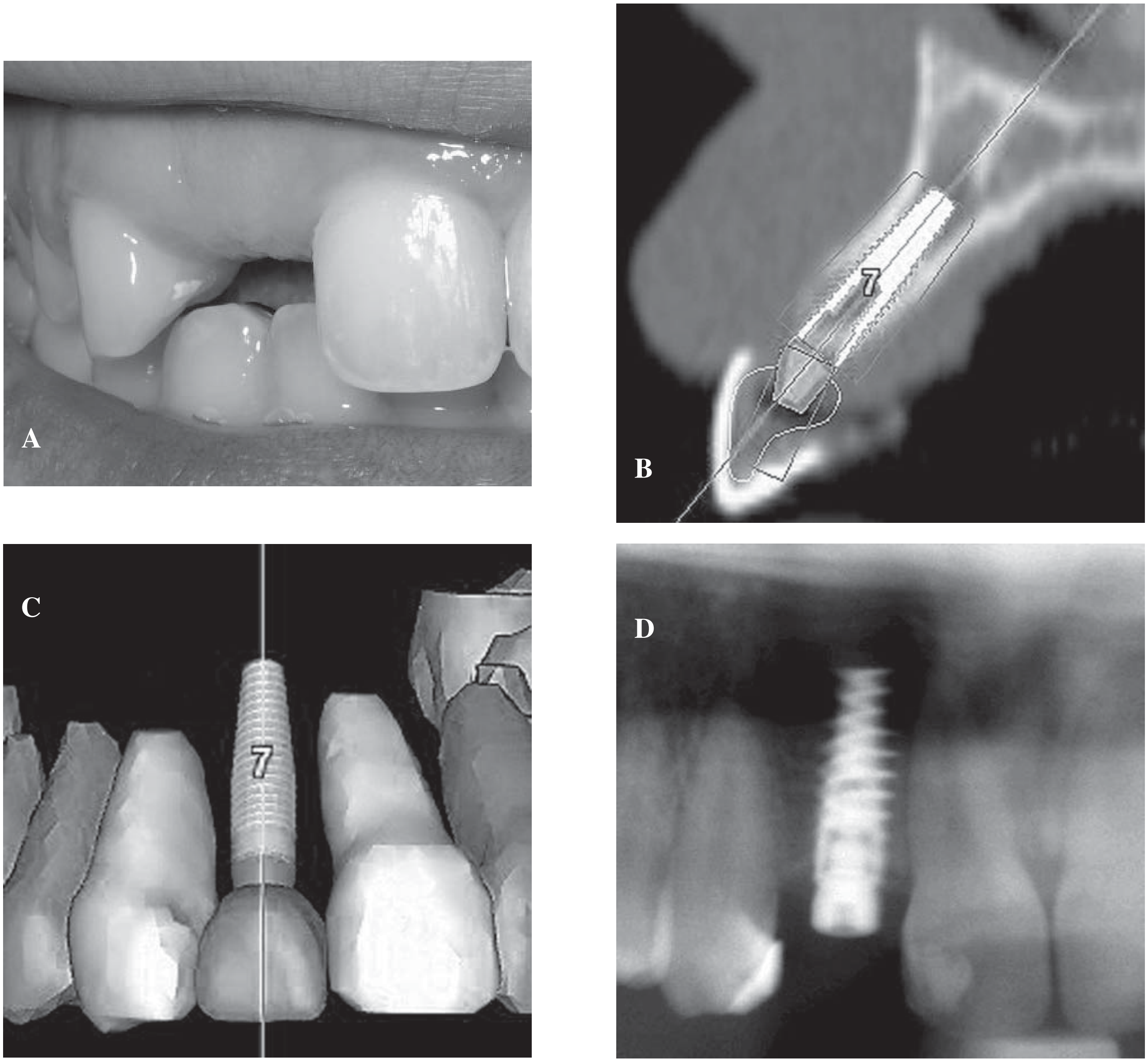


Figure 8. A 17-year-old female with a congenitally missing tooth #7. **A.** Preoperative photograph, **B.** Cross-sectional view (Simplant®.) Note placement of "virtual" angled abutment, **C.** Segmentation has been performed, removing the bone surrounding the adjacent teeth. An implant can then be accurately placed virtually, between the roots of the adjacent teeth, **D.** Postoperative radiograph with implant in place.

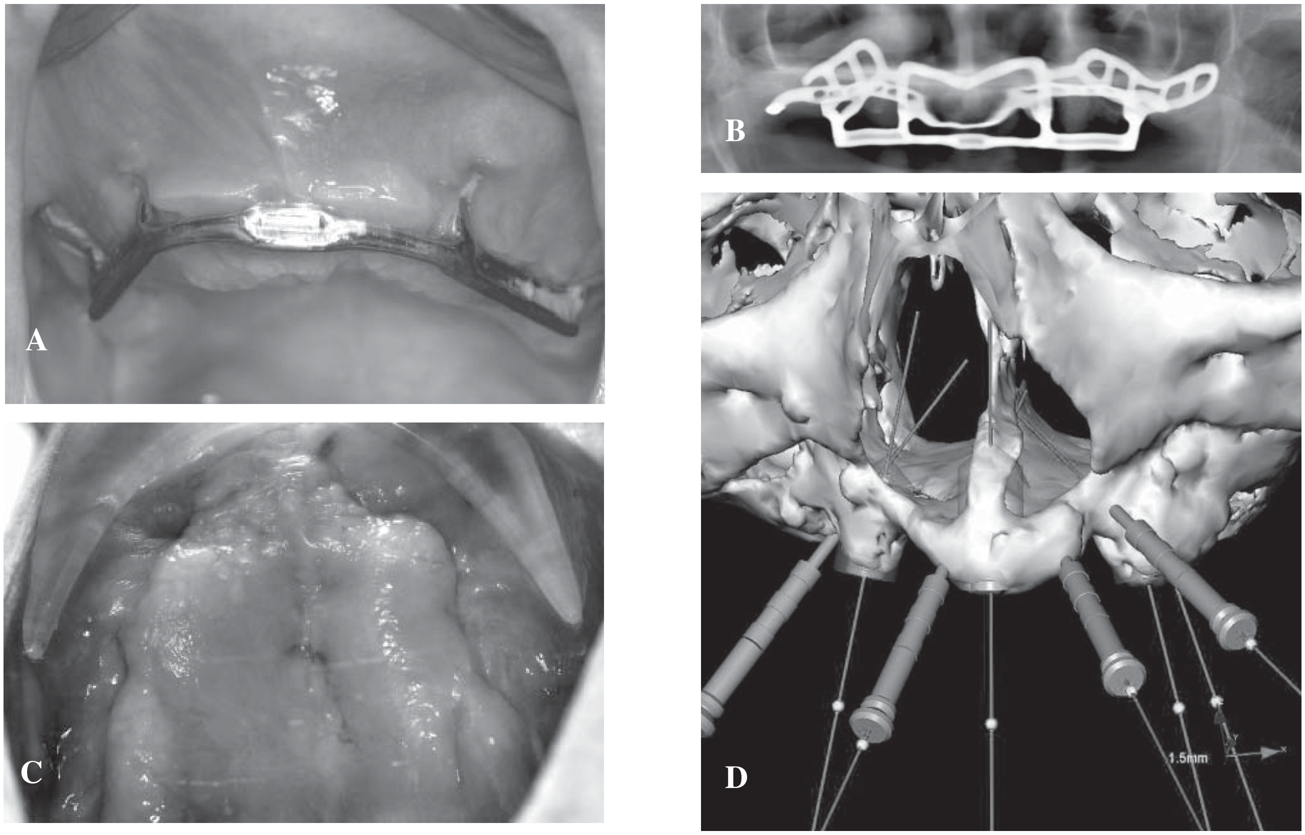


Figure 9. 79-year-old female with severe degeneration of the maxilla secondary to a long standing maxillary subperiosteal implant that resulted in chronic and acute infections, sinusitis, and sinus perforations. The subperiosteal implant was removed prior to the CT scan. **A.** Subperiosteal implant in place in maxilla, **B.** Preoperative radiograph, **C.** Maxillary ridge, after removal of the subperiosteal implant, prior to implant placement, **D.** CT scan image (NobelProcera®) after implants were virtually placed.

Case 2: *A 79-year-old female, with severe degeneration of the maxilla secondary to a long standing maxillary subperiosteal implant. This resulted in chronic and acute infections, sinusitis, and sinus perforations. The subperiosteal implant was removed prior to the CT scan. 3D planning software indicated that, without performing bone grafting procedures prior to implant placement, implants could be placed into only four select sites. (Fig. 9) A maxillary overdenture restoration was planned.*

Limited bone volume often dictates where the implant can be placed. Essentially, there is only one choice for placing the implant. 3-D planning software allows segmentation that virtually removes surrounding bone tissues from the image, leaving only the crowns and roots of the teeth. (Fig. 8) This visualization of the roots of the adjacent teeth allows precise positioning of an implant in limited mesial-distal spaces. Selection of the best implant for that specific clinical application can then be determined. Some software allows selection and determination of vir-

[Continued on page 13]

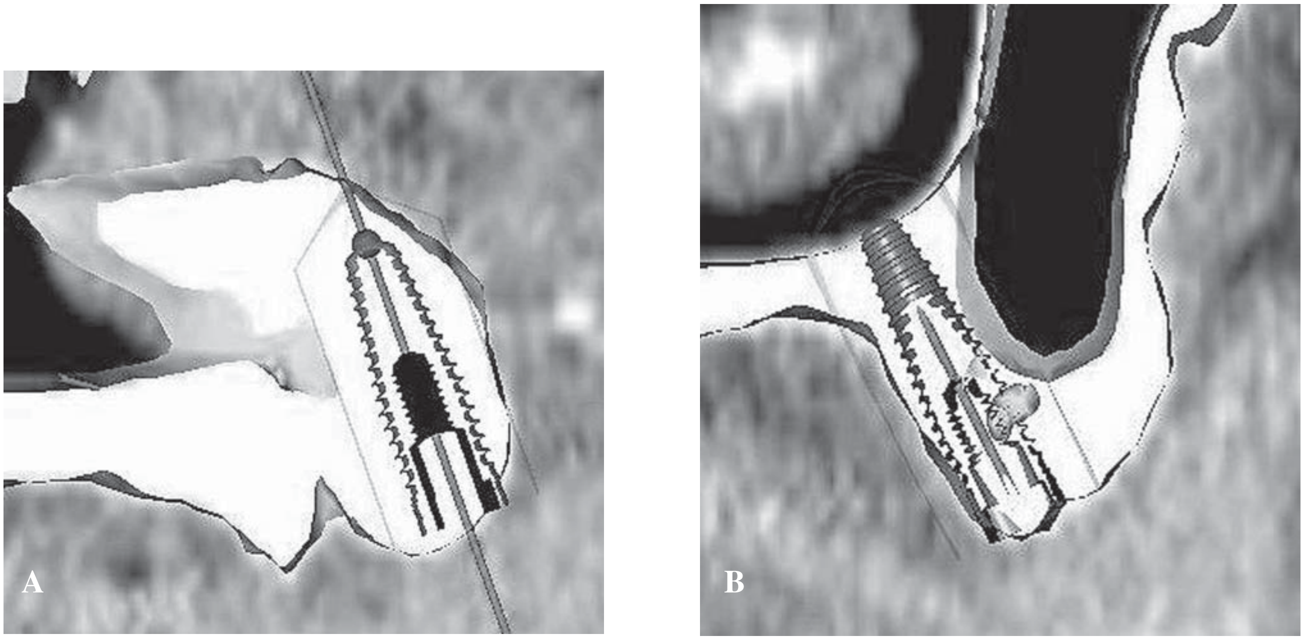


Figure 10. Cross sectional images, virtual treatment plan for implant placement in the anterior nasal spine region (**A**) and left premolar region (**B**).

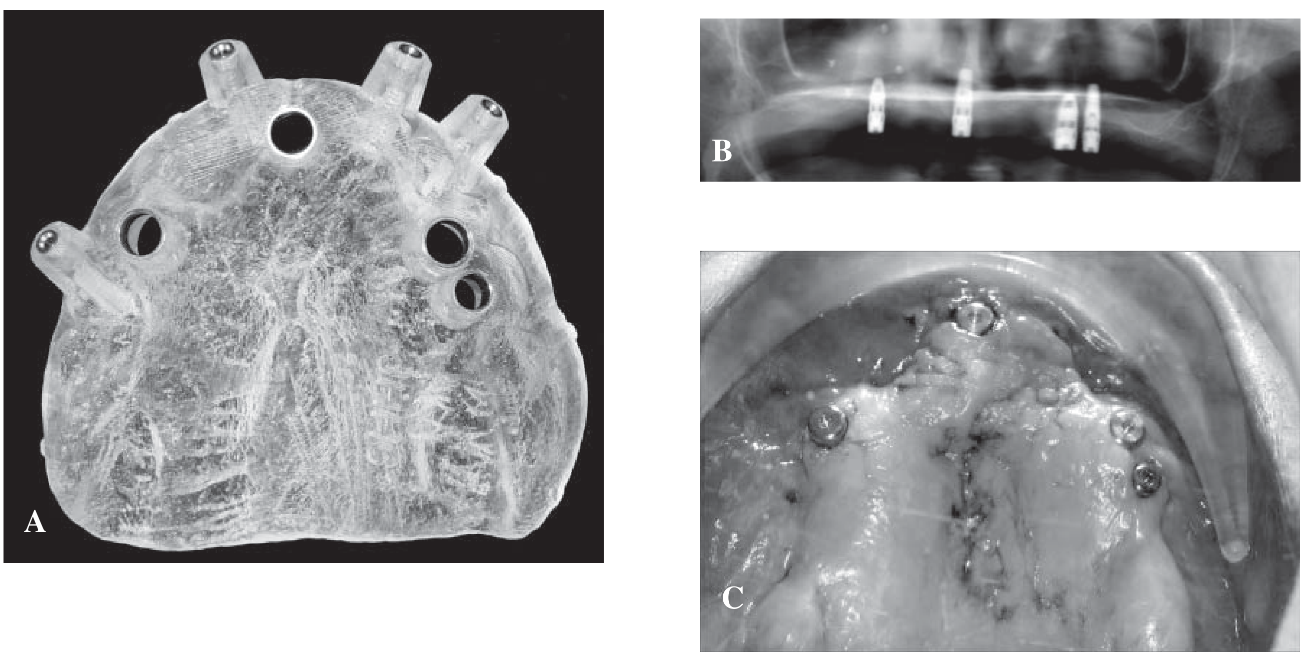


Figure 11. **A**. NobelGuide™ fabricated from the virtual treatment plan, **B**. Implant placement in the maxilla, **C.** Postoperative radiograph with implants in place.

tual stock and custom abutments as well. (Fig. 10) Implant placement can then be performed predictably and accurately according to the patient's individual anatomy. (Fig. 11) Because of the precision and accuracy of placing implants with these technologies, difficult cases are ideally suited for the utilization of 3-D computer-generated technologies.[25,26]

Flapless Surgery and Multiple Unit Immediate Placement/Immediate Load Cases

Today's implant technologies and surface characteristics have dramatically shortened the required time between implant placement and implant loading. Immediate placement and immediate loading of dental implants is now commonly performed in many dental surgical offices. In some cases, teeth can be extracted, an implant can be immediately placed, and a temporary crown can be placed at the time of implant insertion. Concepts of cross-arch stabilization of implants and loading of multiple implant cases have changed the way many dentists treatment-plan cases. New technologies are available to place single, multiple, or a full arch of implants without making an incision or elevating a tissue flap. Patients experience less surgical trauma, pain, and swelling. Recovery time is reduced and the ability to return to their normal lives is expedited.[6,17-23]

Case 3: *A 48-year-old male, following multiple extractions in the mandible by another practitioner. (Fig. 12) No socket-preservation grafting was performed. The patient desired full lower arch reconstruction with implants and an immediate full arch restoration.*

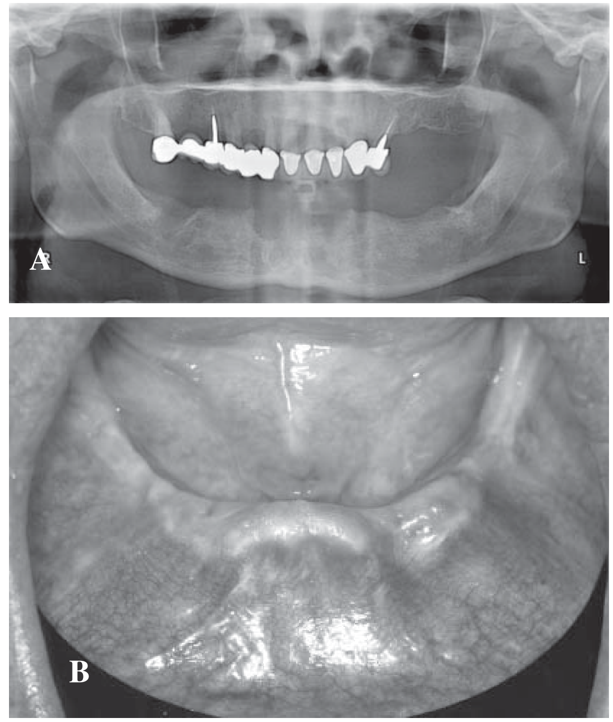


Figure 12. Preoperative condition of a 48-year-old male with multiple extractions in the mandible by another practitioner. **A.** Preoperative panoramic radiograph. Note the irregularities in the contours of the lower ridge, **B.** Preoperative ridge.

The utilization of virtual implant treatment planning allows the dentist to evaluate the patient's bony anatomy as it relates to the planned restoration, and then plan the ideal placement and position of a dental implant in that clinical situation. (Fig. 13) Computer generated stereolithographic surgical guides are then fabricated from these virtual treatment plans. (Fig. 14) A dental laboratory then uses the surgical guide, along with mounted patient models, to fabricate temporary, and in some cases, final restorations, prior to implant placement surgery. (Figs. 14, 15) At the time of implant placement surgery, the surgeon can use the surgical guide to place the planned implants flaplessly, removing

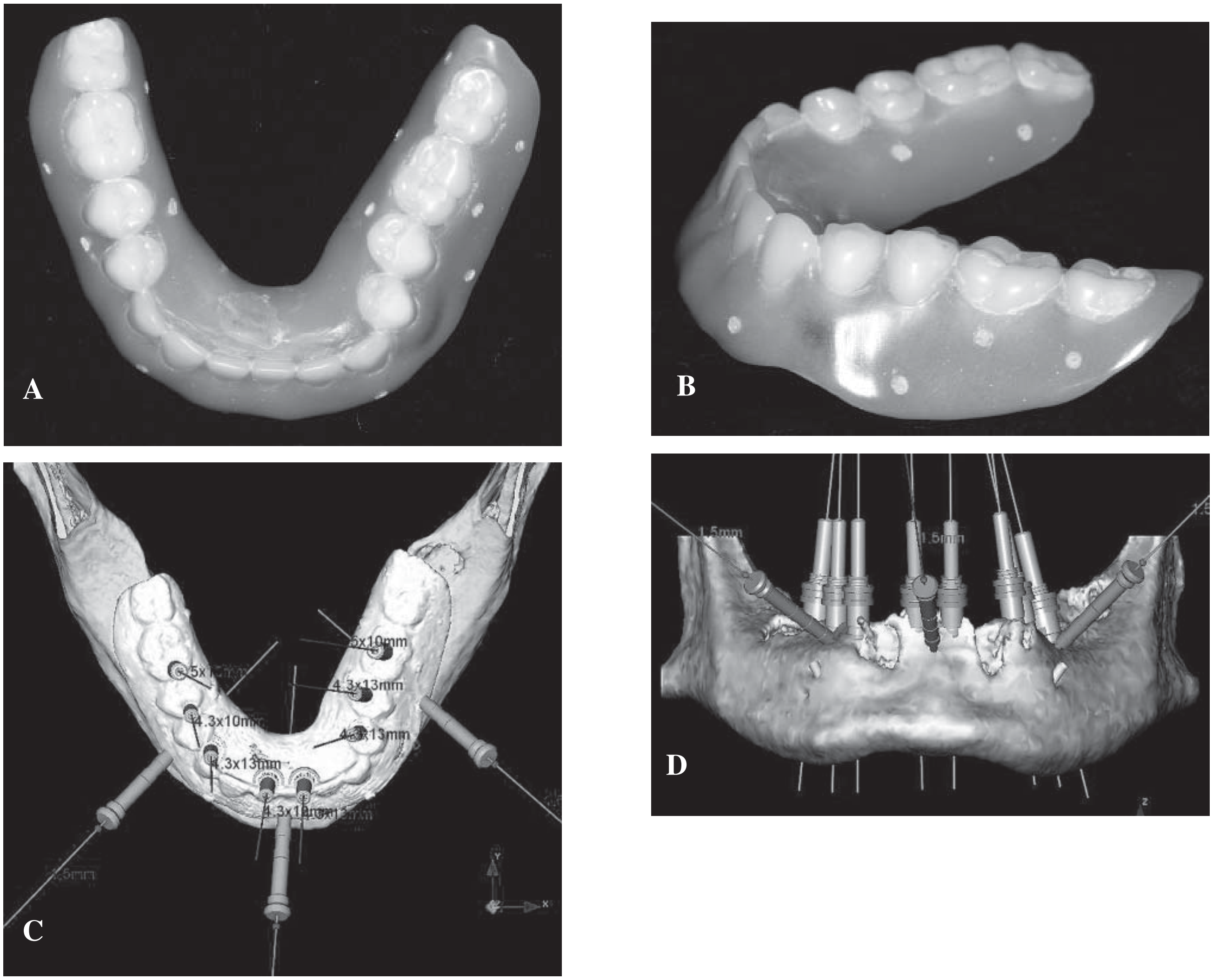
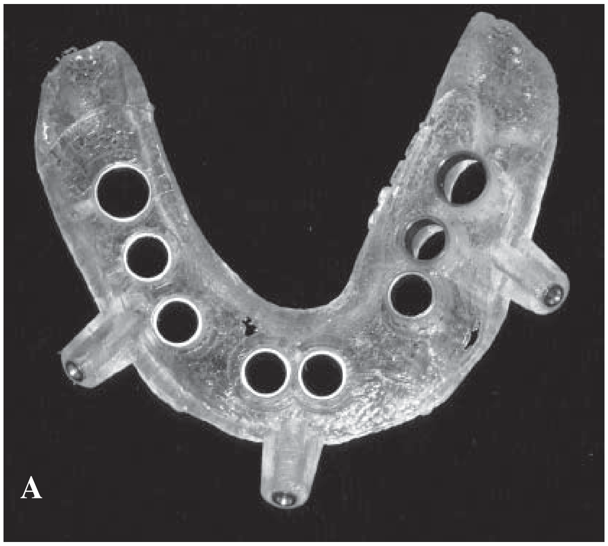


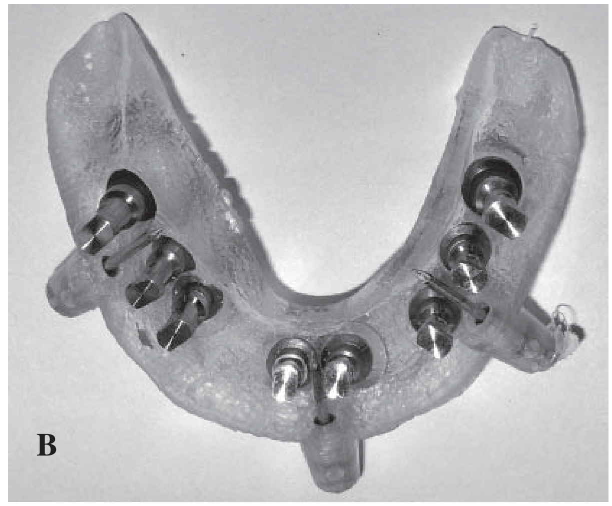
Figure 13. The virtual treatment plan for patient in Figure 12. **A.** Occlusal and **B.** left lateral views of the scan prosthesis for NobelProcera®/NobelGuide™ utilizing the patient's existing well fitting denture. Note the gutta percha reference points added to the denture as per the NobelGuide™ protocol, **C.** Occlusal and **D.** frontal views of the virtual treatment plan (NobelProcera®) for eight implants in the mandible.

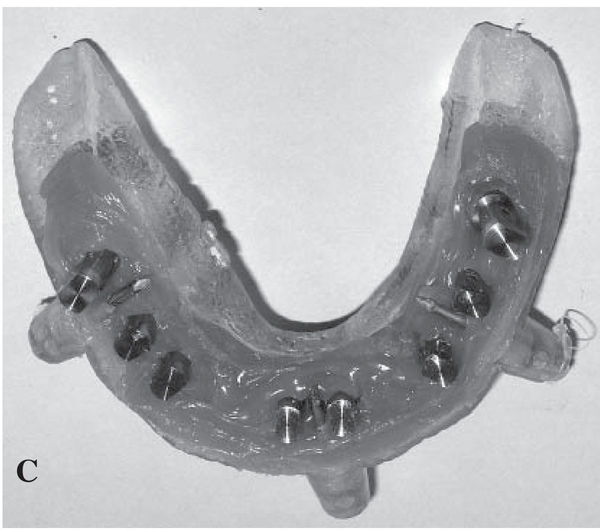
---

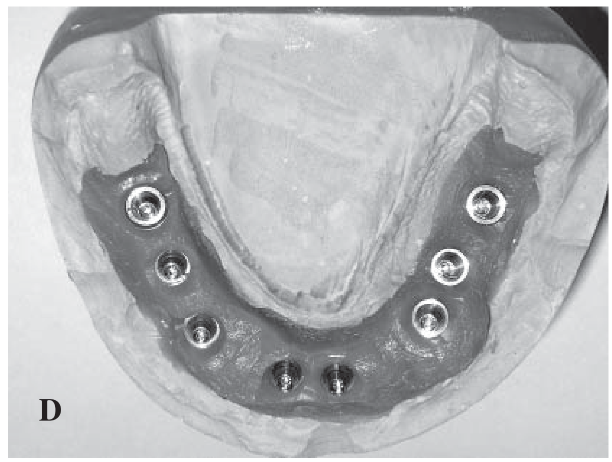
only a core of tissue at the planned implant sites. (Fig. 16) Abutments are then immediately placed on the implants, and temporary, or in some cases, final restorations are then inserted. (Figs. 17-18) [Continued on Page 20]

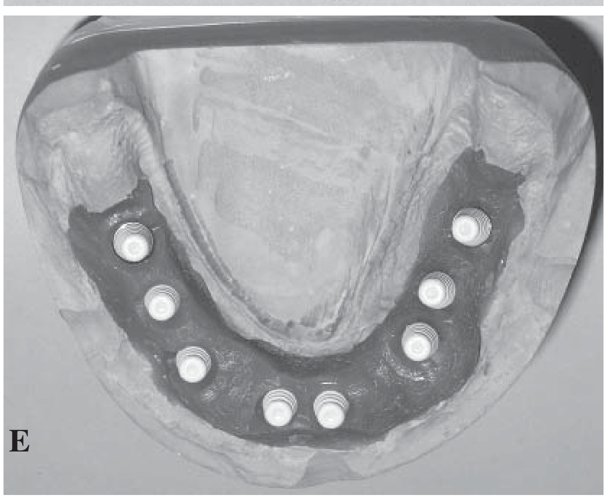
Figure 14. (Facing page) Surgical guides created for the patient in Figures 12 and 13. **A.** NobelGuide™ generated from the virtual treatment plan, **B.** Laboratory placement of implant analogs in the NobelGuide™, **C.** Laboratory addition of gingival mask material around the implant analogs in the NobelGuide™, **D.** Laboratory master cast created by pouring stone

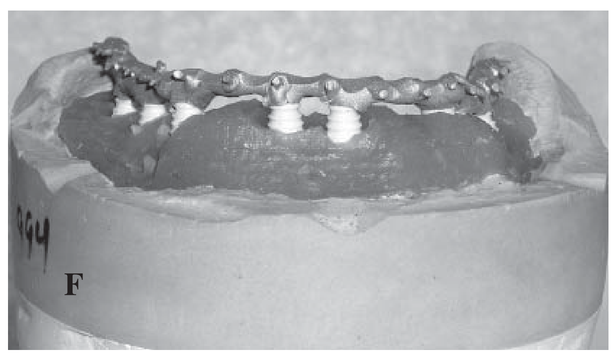












into the NodelGuide™ . Placement of QuickTemp™ multiple unit temporary abutments on the implant analogs, **E.** Laboratory placement of white “pick up” plastic sleeves on QuickTemp™ abutments, **F.** Laboratory fabrication of provisional bridge metal framework.

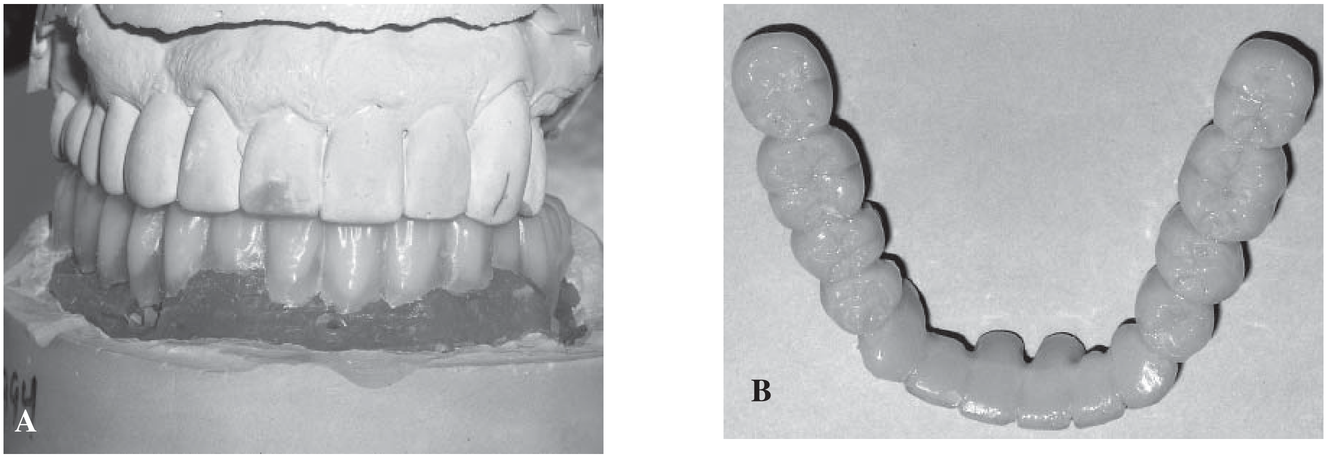


Figure 15. Provisional prosthesis for patient in Figures 12-14. **A.** Laboratory, mounted models with lower provisional wax-up, **B.** Laboratory provisional restoration fabricated prior to implant placement.

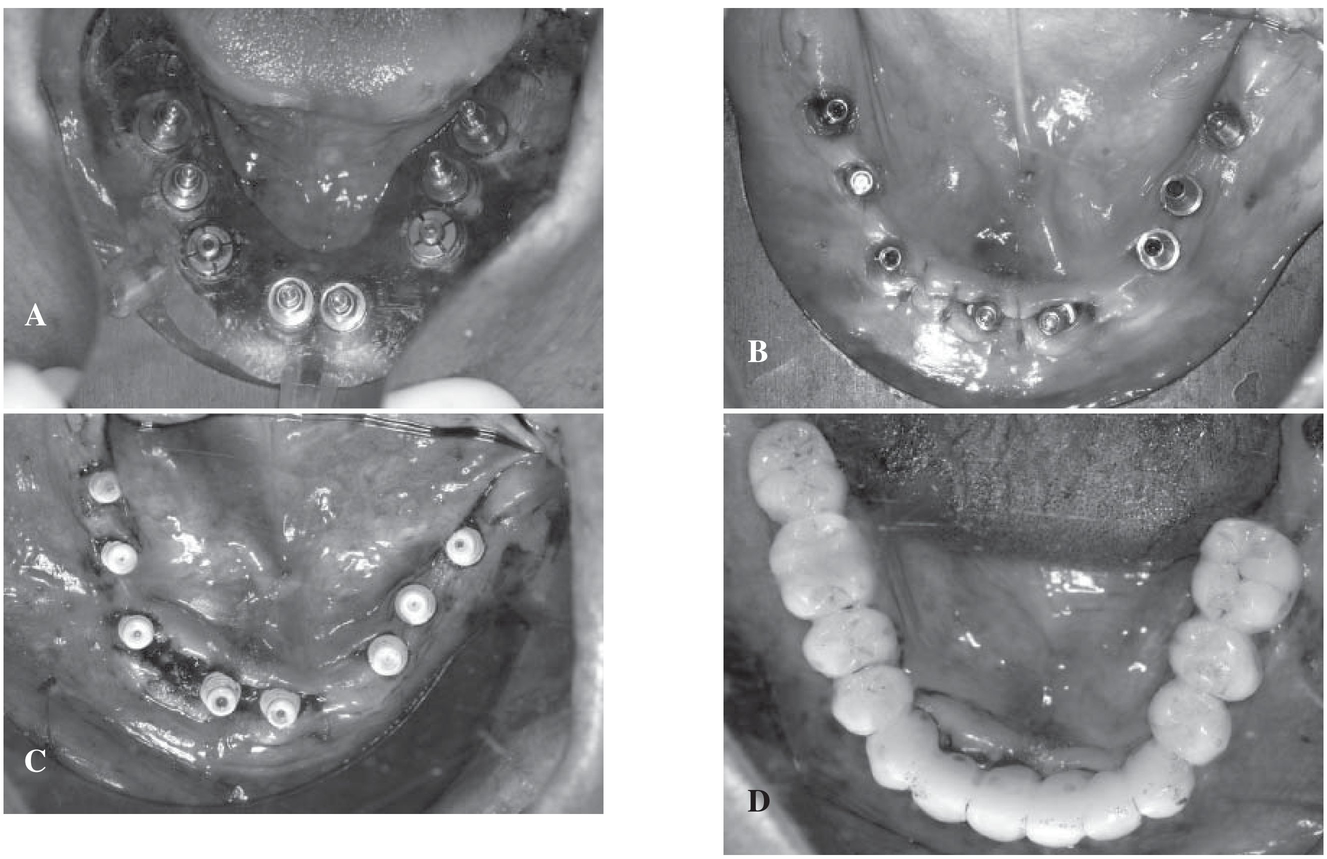


Figure 16. Surgical placement of the implants in patient in Figures 12-15. **A.** Clinically, implants in place through a NobelGuide™ , **B.** Implants in place and QuickTemp™ abutments placed immediately, **C.** White "pick up" sleeves in place on the QuickTemp™ abutments, **D.** Provisional restoration immediately placed at the time of implant placement.

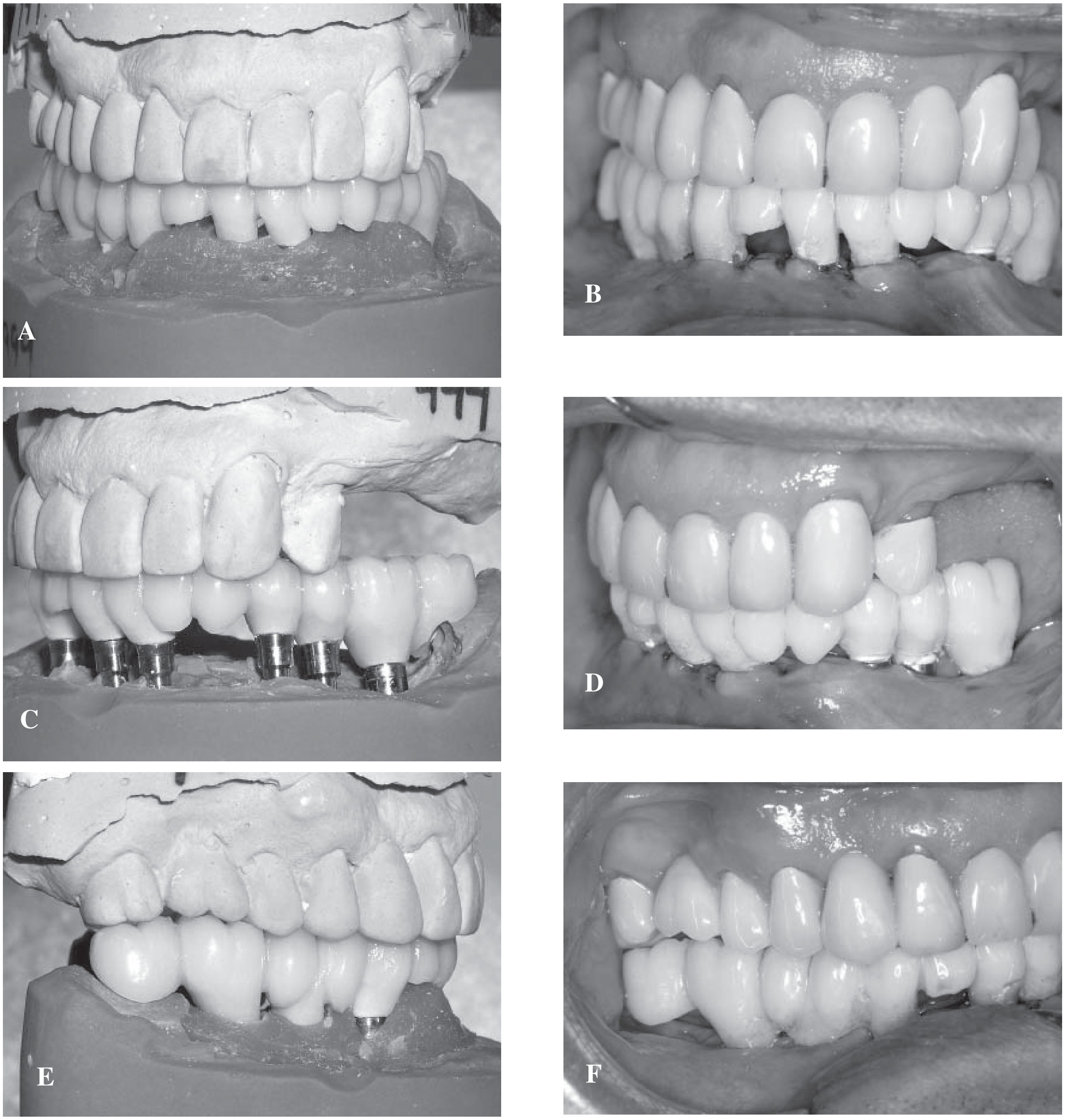


Figure 17. Placement of provisional prosthesis in patient in Figures 12-16. **A.** Frontal view of laboratory provisional prosthesis on models, **B.** Frontal view of provisional prosthesis try-in at time of surgery, no occlusal adjustment. Note, bone reduction performed at the time of surgery, **C.** Left side occlusion with laboratory provisional prosthesis in place, **D.** Left side view of provisional prosthesis try-in at the time of surgery. No occlusal adjustment, **E.** Right side occlusion with laboratory provisional prosthesis in place, **F.** Right side view of provisional prosthesis try-in at the time of surgery. No occlusal adjustment.

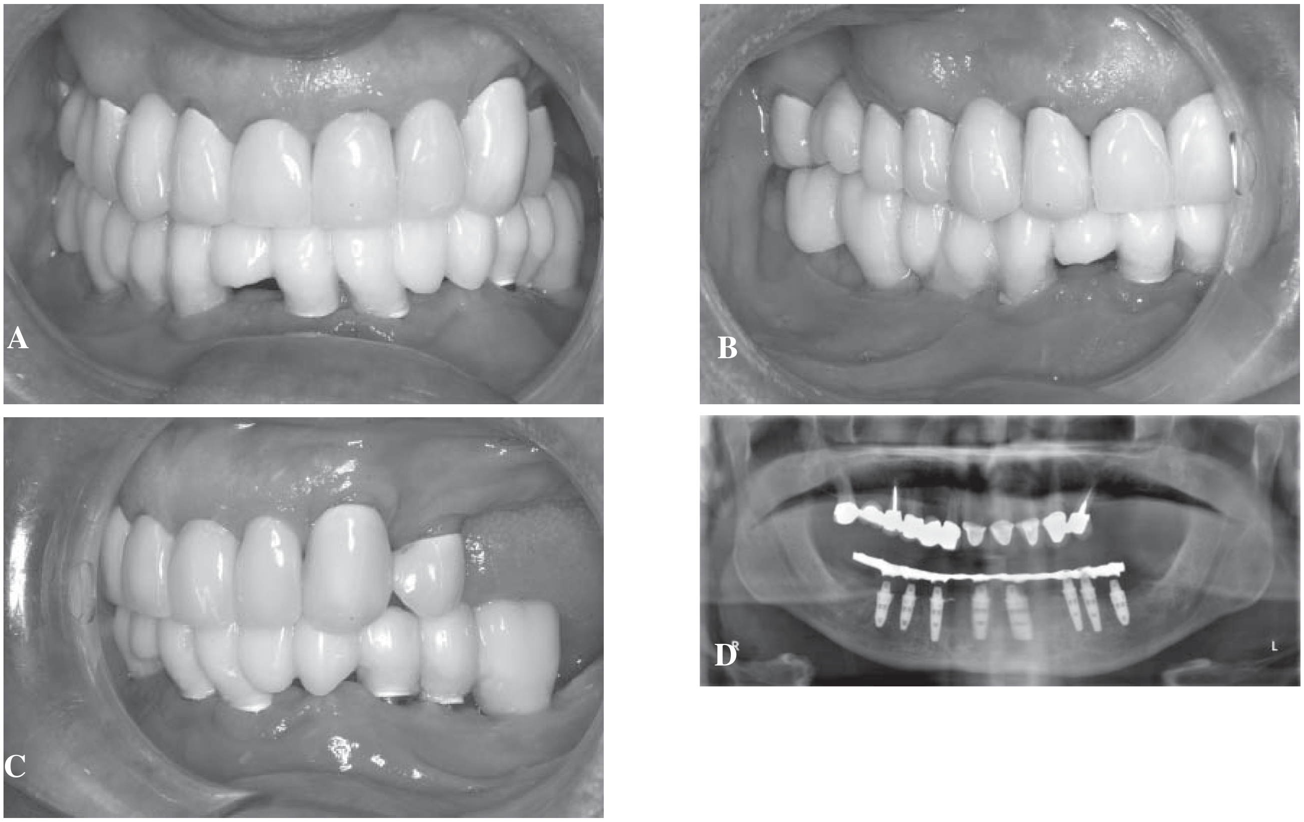


Figure 18. Post-treatment results for patient in Figures 12-17. **A**. Provisional restorations in place six weeks after implant placement, **B.** Provisional restorations in place on right and **C.** left sides six weeks after implant placement, **D.** Immediate postoperative panorex showing implants and provisional restoration in place.

Case 4: *A 65-year-old female, with a bilateral partially edentulous mandible. Treatment planned for implant placement with immediate loading. (Fig. 19)*

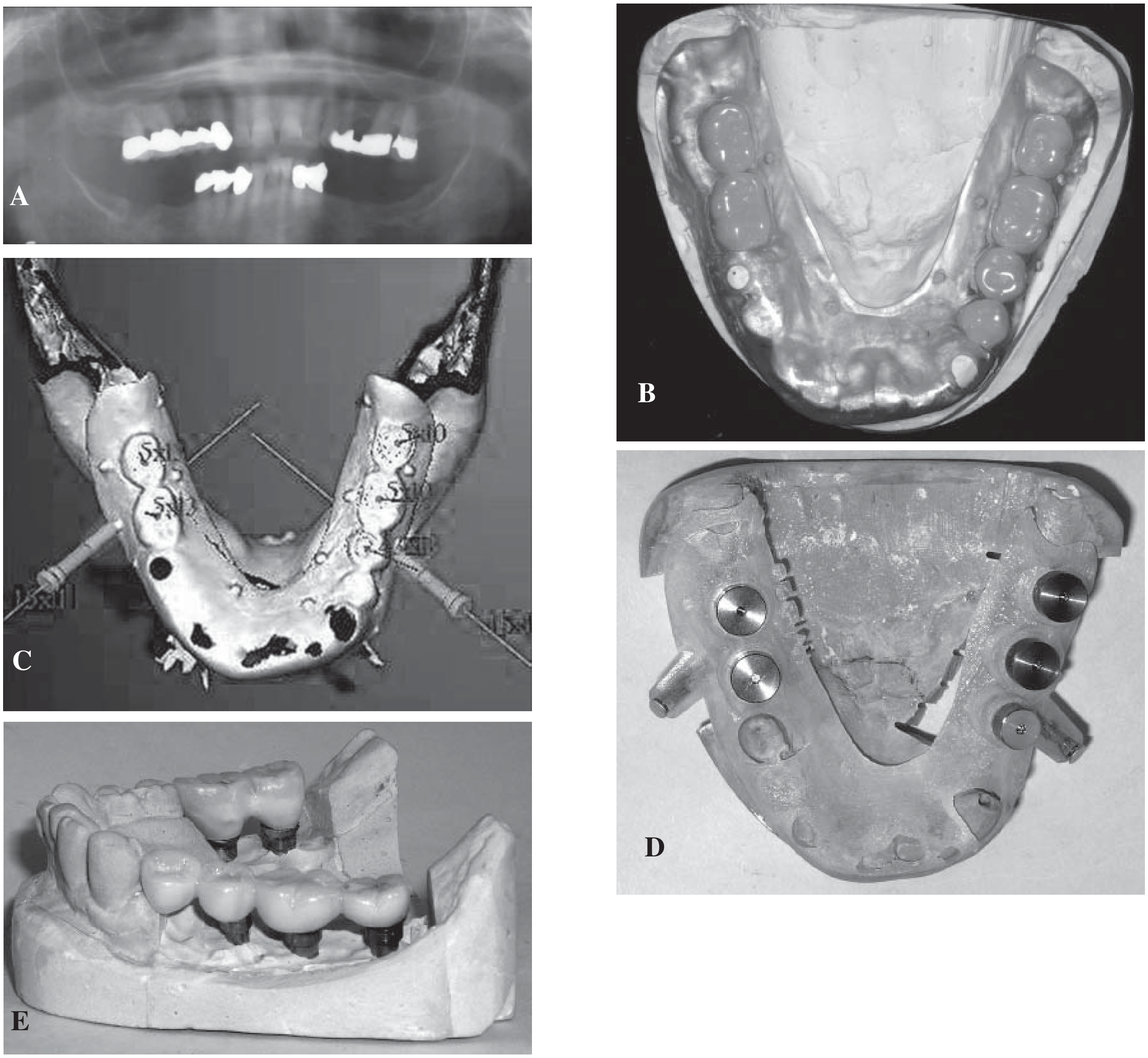


Figure 19. Treatment planning for a 65-year-old female with a bilateral partially edentulous mandible. **A.** Pre-operative panoramic radiograph, **B.** Mandibular scan prosthesis, **C.** Occlusal view of the virtual treatment plan, NobelGuide™ , **D.** Model cut out posteriorly to show the implant analogs secured bilaterally in the NobelGuide™ , **E.** Provisional restoration with an internal titanium framework, fabricated prior to implant placement surgery.

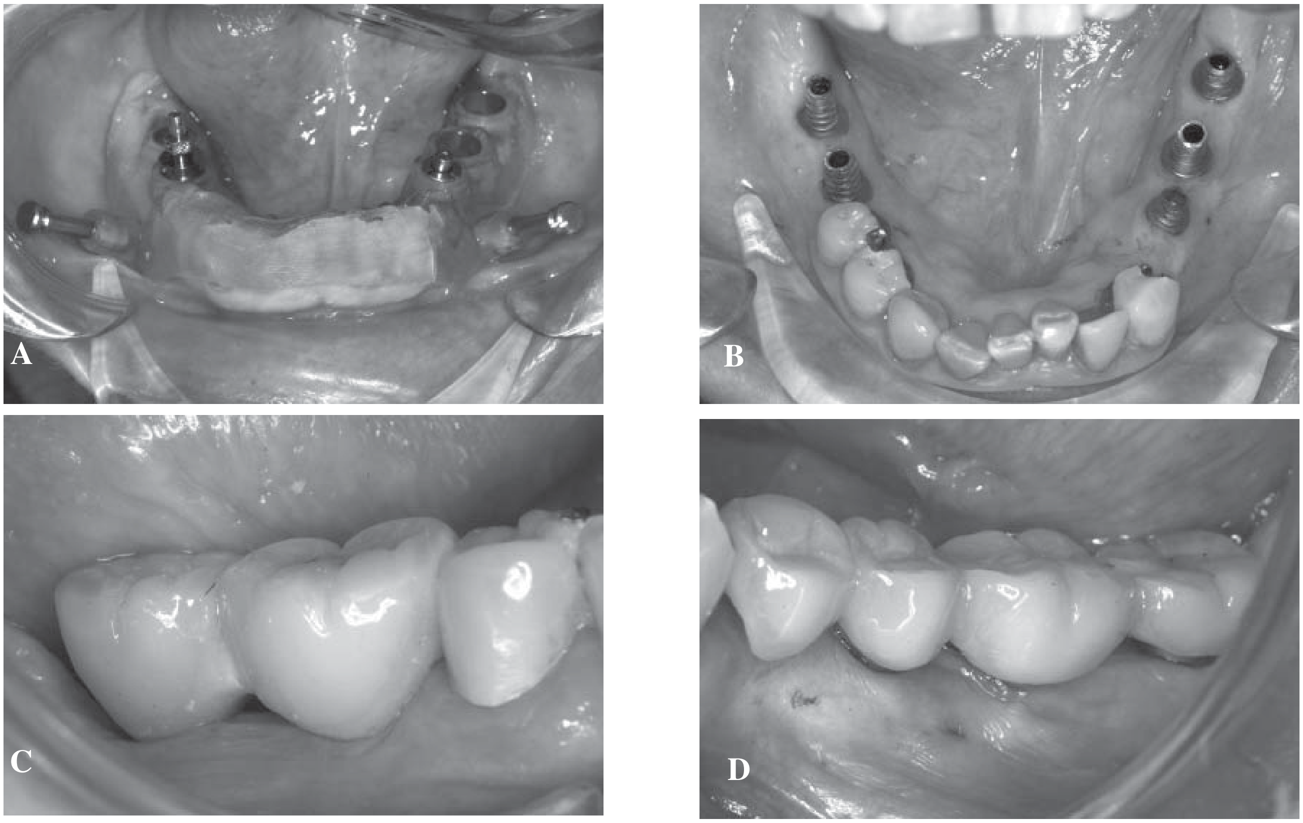


Figure 20. Surgical placement of implants for patient in Figure 19. **A.** Surgical guide in place and implants placed (NobelGuide™), **B.** Implant abutments immediately placed, **C.** Right side view of immediate temporary restorations, **D.** Left side view of immediate temporary restorations.

[Continued from page 14]

Depending on the clinical circumstances and the dentist's experience and comfort level, these technologies can be used to place implants as a two stage, a single stage with healing abutments, or as an immediate placement/immediate load case. (Figs. 20, 21) Implants can be placed accurately with a tissue incision or flaplessly.[6,13-16,22-23]

Complex Problems Following a Significant Alteration of the Bony Anatomy

Previous surgical procedures, including the placement of many different types of dental implants (i.e. blade and subperiosteal implants) can leave patients with challenging reconstructive bony defects. Other patients may have lost bone, teeth and soft tissue as a result of traumatic injuries. Bony defects of varying sizes can occur as a result of benign or malignant pathology of the jaws. Reconstructive surgical procedures to treat benign and malignant diseases can leave areas of abnormal bony anatomy and scarred soft tissue.

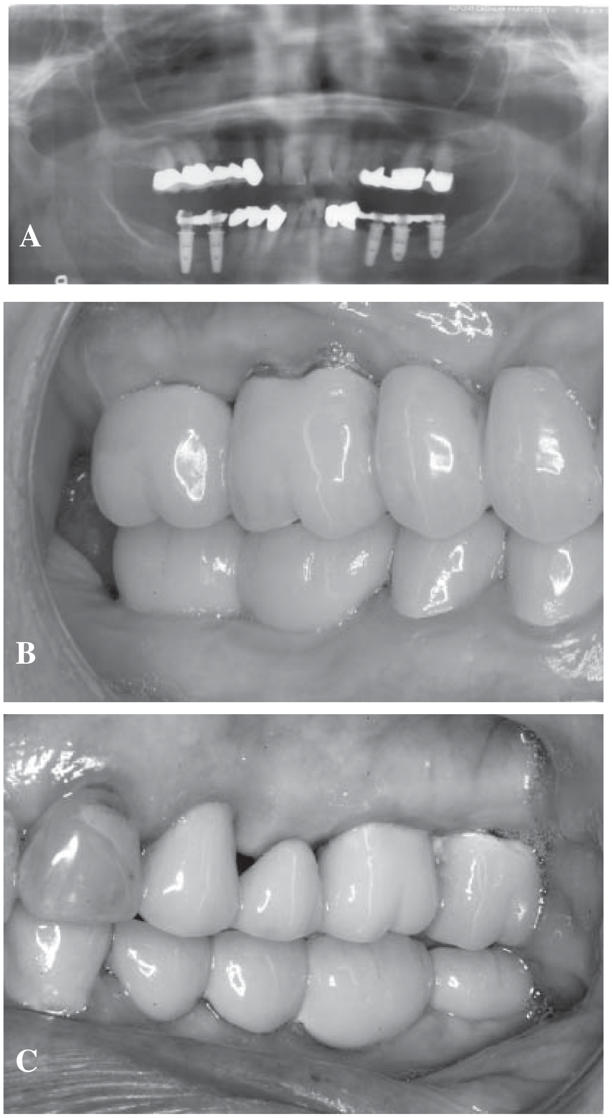
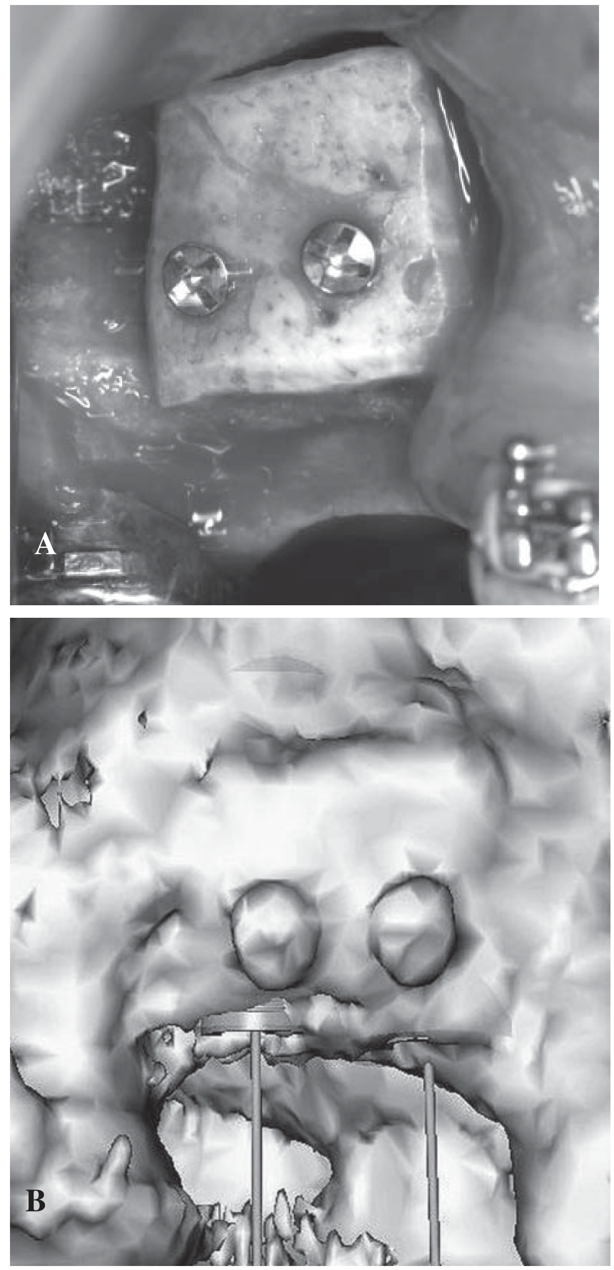


Figure 21. Postoperative results from patient in Figures 19 and 20. **A.** Immediate postoperative panoramic radiograph, **B.** Final restorations in mandibular right and **C.** left quadrant, four months after implants placement.

Implant dentistry is moving away from the days of “placing the implants where the bone is.” Current technologies allow various soft tissue and bone alteration procedures to prepare the planned implant site prior to placing dental implants.

Figure 22. Maxillary buccal block bone graft. **A.** Clinical view and **B.** CT scan image with virtual placement of implants (NobelProcera®).



Sinus lift grafts, block bone grafts, ridge splitting, and alveolar distraction procedures, as well as large and small soft tissue and connective tissue grafts are a few of the procedures that are routinely performed to prepare the recipient jaw site prior to placing dental implants. (Fig. 22)

Case 5: *A mandibular anterior trauma patient. (Fig. 23) The patient underwent removal of the superior 6 mm to 8 mm of the traumatized irregular mandibular alveolar bone, followed by a mandibular anterior alveolar distraction.*

After healing, graft maturation, and settling of graft materials, resultant bone and soft tissue volumes can be unpredictable. Lateral block-onlay grafts can resorb a portion of their bone volume before implant placement.[27-29] In sinus-lift grafting, CT technology allows the surgeon to predict the necessary volume of graft material to augment the area to a desired bone height.[30] In alveolar distraction procedures, the shape and width of the newly distracted bone can be variable. Evaluating these areas with conventional panoramic or periapical radiographs is inadequate, but three-dimensional analysis can allow a more adequate assessment. (Fig. 24)
[Continued on page 24]

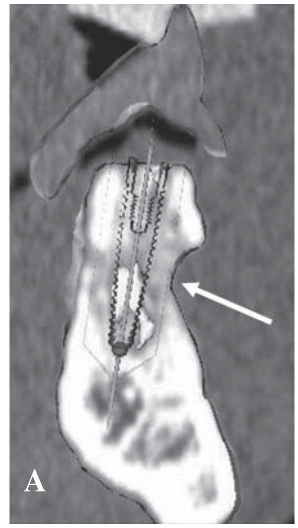


Figure 24. Treatment of patient in Figure 23. **A.** (above) Cross-sectional image (NobelProcera®) of planning of implant placement. Note the differences in buccal-lingual contour and density of the distracted bone, **B.** (facing page) 3-D reformation of alveolar distraction area with implants virtually placed, **C.** Nobel-Guide™ in place with implants inserted, **D**. Periapical radiograph after alveolar distraction, implant placement, and restoration. Note the normal pattern of bone surrounding implants, **E.** Final restoration in place.

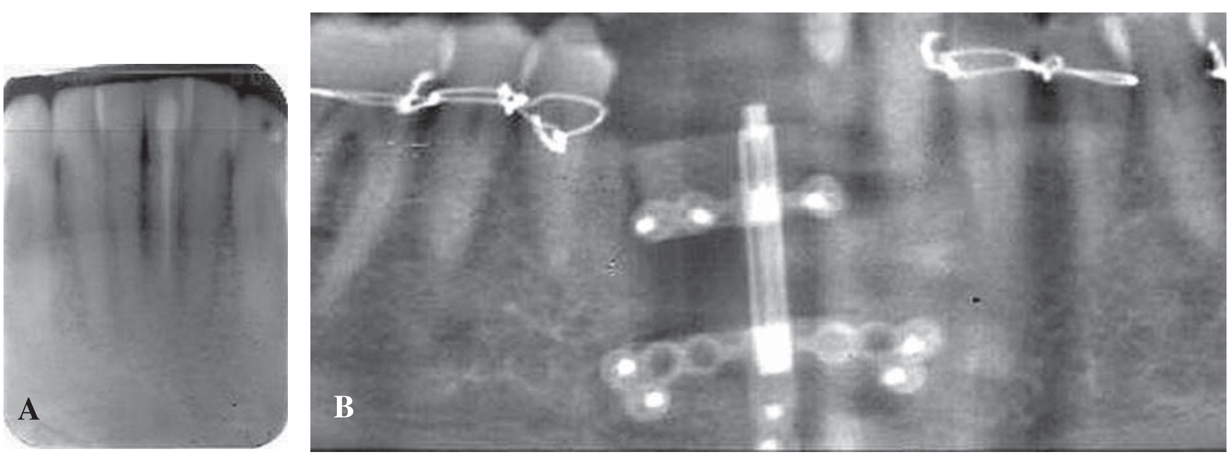
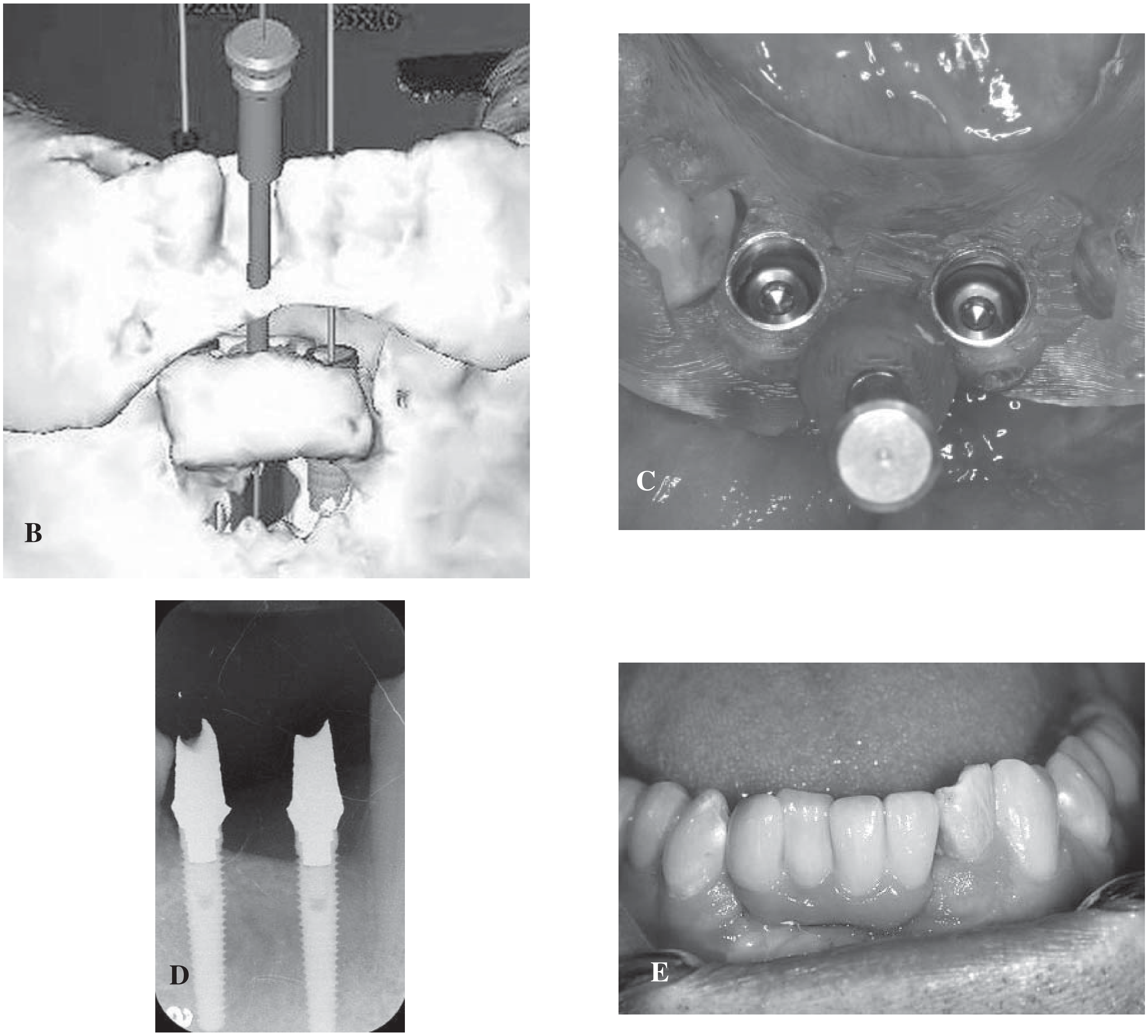


Figure 23. Mandibular anterior trauma patient. **A.** Periapical radiograph prior to injury, **B.** Part of a postoperative panorex. Note fully activated mandibular anterior distractor.


B
C
D
E

Case 6: *A 19-year-old female who underwent an iliac crest bone graft reconstruction immediately after the excision of an ameloblastoma in the left posterior mandible. (Fig. 25) Implant planning was with NobelProcera® software and implant placement was with a NobelGuide®.* [Continued on page 25]

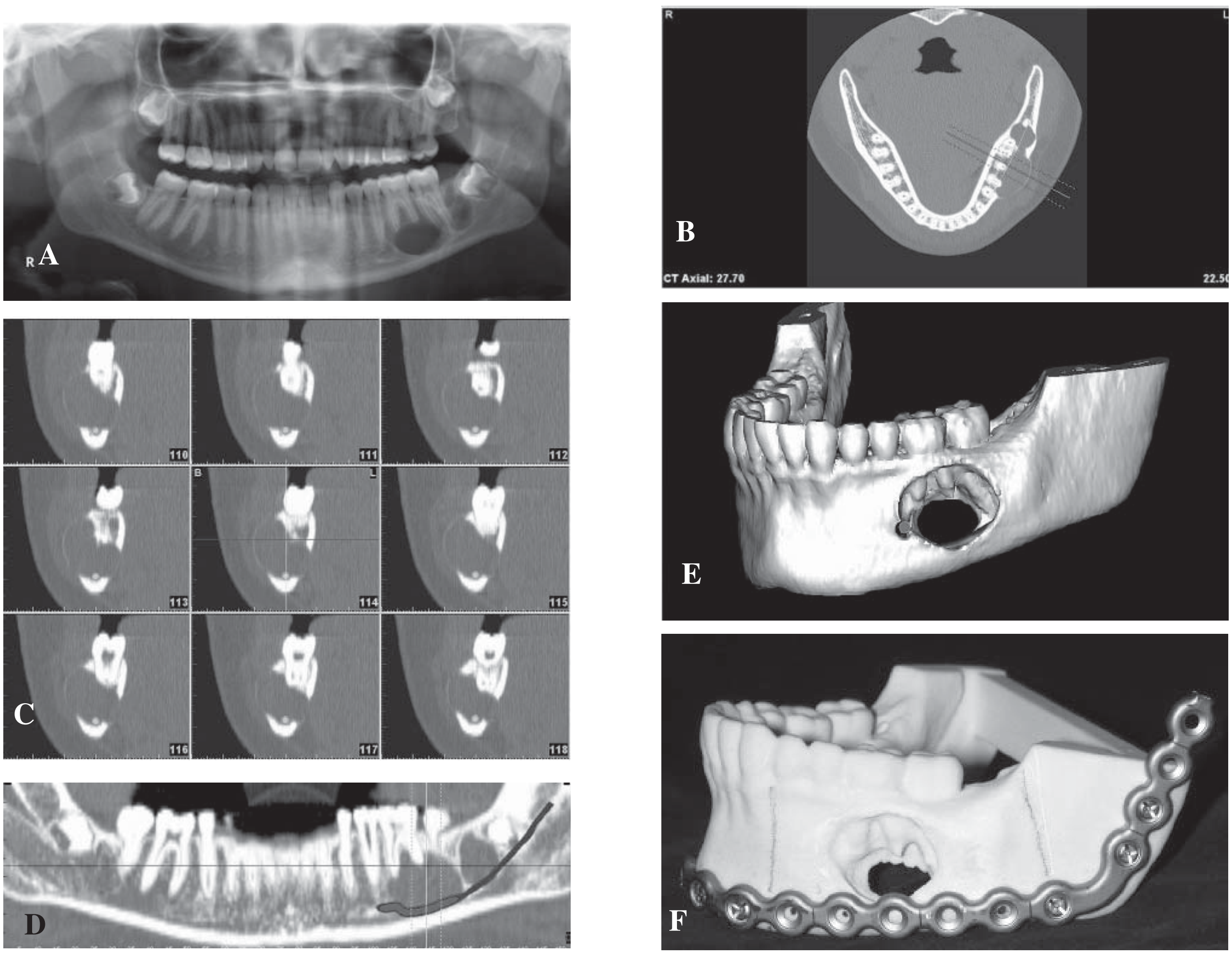


Figure 25. A 19-year-old female who underwent an iliac crest bone graft reconstruction immediately after the excision of an ameloblastoma. **A.** Preoperative panorex showing the ameloblastoma in her left posterior mandible, **B.** & **C.** Preoperative CT scan viewed in Simplant® software revealing the dimensions of the tumor, **D**. Digitally reconstructed panorex showing extent of tumor, **E.** Three-dimensional reconstruction showing the extent of the tumor, **F.** Stereolithographic model (Medical Modeling®) fabricated from CT scan data with a mandibular reconstruction plate (Stryker-Liebinger®).

These are both examples of ideal situations in which computer-guided implant surgery should be used to evaluate and plan the placement of dental implants. These technologies allow the implant surgeon to visualize and evaluate a patient's distorted anatomy (Fig. 26) without making an incision or removing any soft tissue or bone.[25] The doctor can then accurately

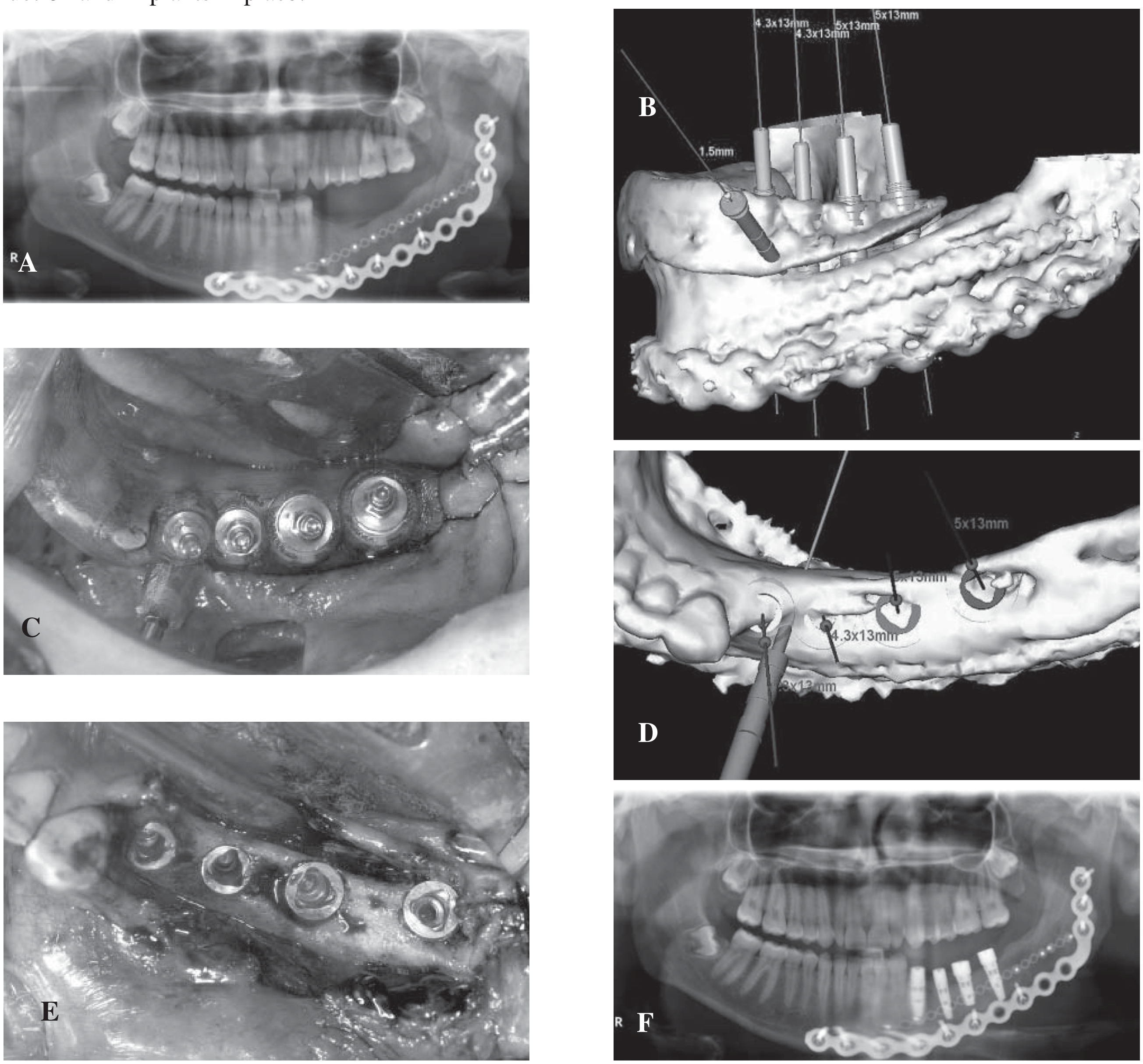


Figure 26. Treatment of patient in Figure 25 after removal of ameloblastoma. **A.** Postoperative panorex, prior to implant placement, iliac crest bone graft reconstruction of left mandible, **B.** Preoperative virtual implant treatment plan (NobelGuide™), **C.** Placement of four implants, as per the virtual treatment plan with the NobelGuide™ secured in place, **D.** NobelGuide™ treatment plan of the left mandible, **E.** Four implants in place according to virtual treatment plan, **F.** Postoperative panorex, showing reconstruction and implants in place.

and predictably place a patient's dental implants with a clear knowledge of the patient's underlying distorted bony anatomy. Additionally, dental implants can be placed flaplessly, without making an incision and removing the periosteal vascularization from grafted areas.

Patients with Other Medical Comorbidities (e.g., Radiation Therapy, Blood Dyscrasias).

Head and neck cancer patients are often treated with pre- and postoperative radiation therapy that can alter healing capacity. Research and treatment protocols call for patients who have received radiation therapy to undergo pre- and postoperative courses of hyperbaric oxygen therapy (HBO) to increase the vascularity of the bone prior to implant placement.[31-34] Placing implants with minimal flap elevation and soft- and hard-tissue trauma reduces the likelihood of osteoradionecrosis of the jaws in head and neck cancer patients who received radiation therapy.[31,35] Bleeding, swelling, and alteration of bone and soft tissue vascularization are minimized by using these technologies.[36]

Minimizing bleeding, is also indicated in patients with difficult medical management issues, such as blood dyscrasias, anticoagulation issues, or significant cardiovascular disease. These conditions require specific medication protocols that cannot be altered or adjusted prior to surgery. Three-dimensional implant evaluation and planning (Fig. 27), with CT-guided implant placement allows the surgeon to precisely place dental implants flaplessly, while minimizing soft and hard tissue trauma. (Fig. 28)

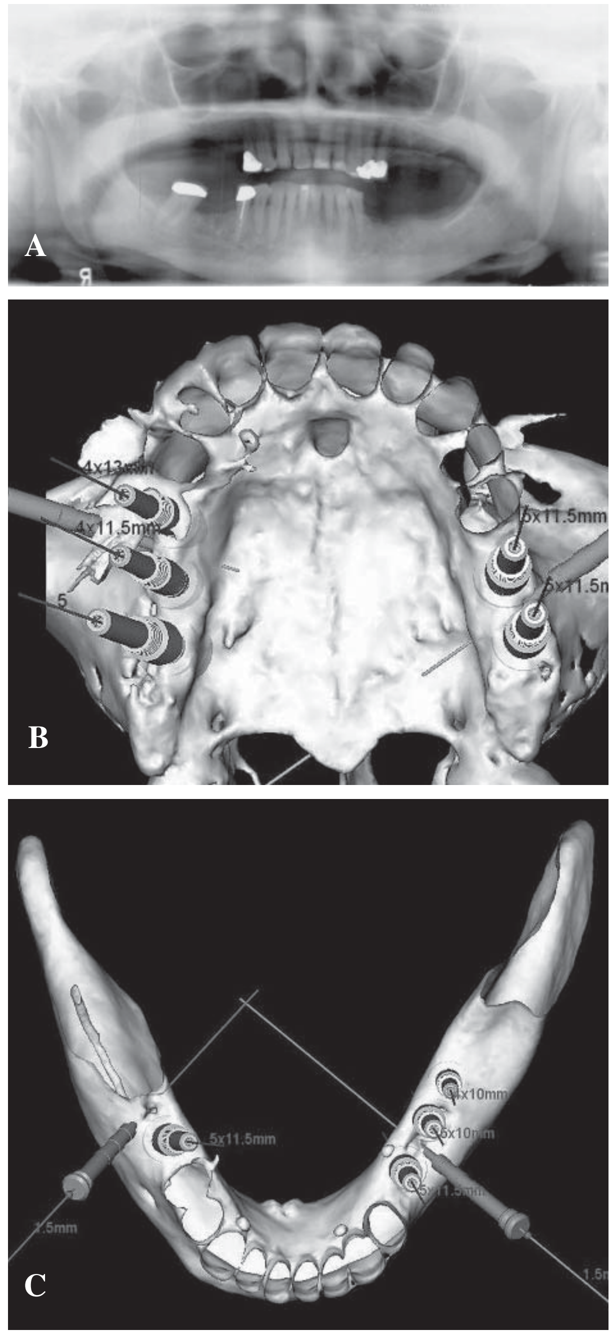


Figure 27. **A.** Preoperative panorex, **B.** Virtual treatment plan for the maxilla, **C.** Virtual treatment plan for the mandible (NobelProcera®).

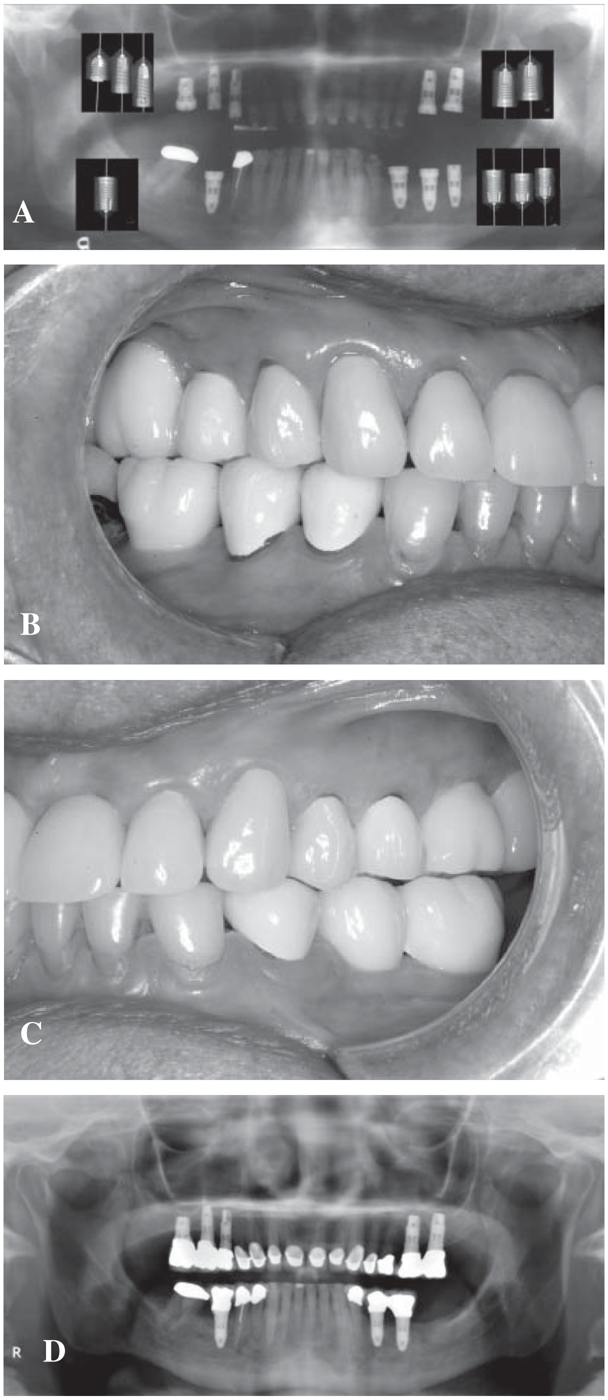


Figure 28. **A.** Postoperative panorex with superimposition of treatment planned implants, maxilla and mandible, **B.** Final right side restoration, **C.** Final left side restoration, **D.** Final panorex. Note failure of the implant in the site of tooth #18.

Medical Problems, Both Physical and Emotional, That Might Limit the Amount of Time a Patient Can Sit in a Dental Chair

Some patients have had bad experiences in dental offices. Stress, anxiety, and phobias can prevent these patients from tolerating procedures that require long periods in a dental chair. Orthopedic and spinal problems can also limit the amount of time a patient can sit in a dental chair, and wheelchair-bound patients pose another set of logistical treatment problems. These patients require extensive planning and preparation prior to treatment in a dental or surgical office. Treatment must be performed quickly and efficiently, without compromising quality.

3-D computer-generated implant planning is ideally suited for utilization in this group of patients with unusual management issues. Most planning and anatomic issues that might be encountered during surgery are visualized prior to the patient sitting in the dental chair. By using surgical guides, implants can be placed quickly and predictably, thus minimizing the patient's stress, pain and surgical time in the dental chair.

CONCLUSIONS

Any case can be treatment planned virtually. We have used this technology to place single, multiple or full arches of implants. Implants can be buried (two stage), placed as a single stage (healing abutments), or immediately loaded. Implants can be placed after immediate extractions or with concurrent bone grafting procedures. In essence, implants can be placed exactly as we have always been placing them, but with more precision and with less pain and swelling for our patients.

Both doctor and patient goals can be accomplished accurately, predictably, safely, comfortably, quickly, and with minimal stress by treating our implant patients using CT-based virtual three-dimensional implant planning and placing implants through surgical guides. It is our opinion that this technology is the future of implant dentistry.

Gary Orentlicher, DMD graduated from the University of Medicine and Dentistry of New Jersey in 1982 and completed his residency in oral and maxillofacial surgery at Long Island Jewish Medical Center in 1986. He graduated from dental school with six major awards in various dental specialties. In 1984, while a resident, he was the recipient of the prestigious Merck, Sharpe & Dohme Resident Research Award. He has authored many publications and has lectured extensively, both nationally and internationally, on subjects such as the evaluation and treatment of patients with temporomandibular joint disorders and dentofacial deformities, bone grafting for dental implants, computer-guided implantology, CT scan use in dental implantology, and new dental implant innovations. He has given numerous training courses for dental specialists on CT-based dental implant software applications in implant dentistry, and new techniques and technologies for the planning and placement of dental implants. He has been involved with 3-D virtual treatment planning for dental implant placement for over 13 years. Dr. Orentlicher is a consultant to several implant and CT-based software manufacturers for the development of new technologies for computer implantology. Dr. Orentlicher and Dr. Douglas Goldsmith were the founders of Facial Imaging, LLC, a northeast U.S. company developed to provide 3-D imaging to dentists for implant dentistry. Dr. Orentlicher is currently Chief of Oral and Maxillofacial Surgery at White Plains Hospital and Medical Center. He is a Diplomate of the American Board of Oral and Maxillofacial Surgery, a Fellow of the American Association of Oral and Maxillofacial Surgeons, and a member of many regional and national dental and oral and maxillofacial surgery organizations. He is currently in the private practice of oral and maxillofacial surgery in Scarsdale N.Y.

Douglas Goldsmith, DDS, graduated from the UCLA School of Dentistry in 1974 and completed his residency in oral and maxillofacial surgery at Montefiore Medical Center in New York. After his residency, he completed a fellowship in the correction of dentofacial deformities at John Peter Smith Hospital in Fort Worth, Texas. He returned to Montefiore Medical Center in a full time academic position in the Department of Oral and Maxillofacial Surgery and was a member of the Center for Cleft Palate and Craniofacial Anomalies for 20 years. He has lectured nationally and internationally on topics such as the correction of dentofacial deformities, facial reconstruction, and implant dentistry. He has been a featured speaker for numerous national dental organizations. Dr. Goldsmith has published over 30 articles in the medical and dental literature and co-authored chapters in 7 textbooks. He has been involved with 3-D virtual treatment planning and computer implantology for over 13 years. He is a consultant to several implant and CT-based software manufacturers for the development of new technologies for computer implantology. He is board certified in oral and maxillofacial surgery and dental anesthesiology, and a Fellow of the American Association of Oral and Maxillofacial Surgeons. He is Chief Emeritus of the Department of Oral and Maxillofacial Surgery at White

Plains Hospital and Medical Center and is currently in the private practice of oral and maxillofacial surgery in Scarsdale, N.Y.

Andrew Horowitz, DMD, MD, received his dental degree from the University of Pennsylvania School of Dental Medicine. He received his medical degree from The Mount Sinai School of Medicine, where he also completed his oral and maxillofacial surgery residency. He has lectured both locally and nationally on CT-guided implant surgery and minimally invasive implant surgery. He has authored or co-authored a number of recent articles on the subject in both the dental and oral and maxillofacial surgery literature. He is a Diplomate of the American Board of Oral and Maxillofacial Surgery and a Fellow of the American Association of Oral and Maxillofacial Surgeons. He is an assistant clinical professor at Columbia University College of Dental Medicine and an associate clinical professor at White Plains Hospital and Medical Center. He is currently in the private practice of oral and maxillofacial surgery in Scarsdale, N. Y.

ACKNOWLEDGMENTS:

Selected Readings in Oral and Maxillofacial Surgery thanks the following journals for permission to reprint excerts from their publications: *Implant Dentistry* (Vol. 4, 2008), *Compendium of Continuing Education in Dentistry* (Vol. 30, 2009) and *Journal of Oral and Maxillofacial Surgery* (Vol. 67, 2009).

REFERENCES

1. Ramez J, Donazzan M, Chanavaz M, et al: The contribution of scanner imagery in implant surgery and sinus overflow using frontal oblique orthogonal reconstruction. Rev Stomatol Chir Maxillofac 93: 212, 1992.

2. Pattijn V, van Cleynenbreugel T, vander Sloten J, et al: Structural and radiological parameters for the nondestructive characterization of trabecular bone. Ann Biomed Eng 29: 1064, 2001.

3. Sonick M, Abrahams J and Faiella R: A comparison of the accuracy of periapical, panoramic, and computerized tomographic radiographs in locating the mandibular canal. Int J Oral Maxillofacial Impl 9: 455, 1994.

4. Todd A, Gher M, Quintero G, et al: Interpretation of linear and computed tomograms in the assessment of implant recipient sites. J Periodontol 64: 1243, 1993.

5. Gehr ME and Richardson AC: The accuracy of dental radiographic techniques used for evaluation of implant fixture placement. Int J Periodont Rest Dent 15: 268, 1995.

6. van Steenberghe D, Glauser R, Blombäck 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 Impl Dent Rel Res 7 (Suppl 1): S111, 2005.

7. Tardieu P and Vrielinck L : Implantologie assistèe par ordinateur: le propramme SimPlant/SurgiCase™ et le SAFE System™ mis en charge immediate d'unbridge mandibulaire avec des impalt transmuqueux. Implant 9: 15, 2003.

8. Rosenfeld AL, Mandelaris GA and Tardieu PB: 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. Int J Periodontics Restorative Dent 26: 493, 2006.

9. Vrielinck L, Politis C, Schepers S, et al: 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 clinical follow-up study. Int. J. Oral Maxillofac Surg 32: 7, 2003.

10. Sarment DP, Sukovic P and Clinthorne N: Accuracy of implant placement with a stereolithiographic surgical guide. Int J. Oral Maxillofac. Implants 18: 571, 2003.

11. Tardieu PB, Vrielinck L, Escolano E, et al: Computer assisted implant placement: scan template, simplant, surgiguide, and SAFE system. Int J of Period and Restor Dent 27: 141, 2007.

12. Vercruyssen M, Jabovs, R, Van Assche N, et al: The use of CT scan based planning for oral rehabilitation by means of implants and its transfer to the surgical field: a critical review on accuracy. J Oral Rehabil 35: 454, 2008.

13. Hahn, J: Single stage, immediate loading, and flapless surgery. J Oral Implantology 26: 193, 2000.

14. Campelo LD and Dominguez Camara JR: Flapless implant surgery: a 10 year clinical retrospective analysis. J Oral Maxillofac Implants 17: 271, 2002.

15. Becker W, Goldstein M, Becker BE, et al: Minimally invasive flapless implant surgery: a prospective multicenter study. Clin Implant Dent Relat Res 7 (Suppl 1): S21, 2005.

16. Becker W, Wikesjo UME, Sennerby L, et al: Histologic evaluation of implants following flapless and flapped surgery: a study in canines. J Periodontol 77: 1717, 2006.

17. Tardieu P, Vrielinick L and Escolano E : Computer-assisted implant placement. A case report: Treatment of the mandible. Int J Oral Maxillofac Implants 18: 599, 2003.

18. van Steenberghe D, Naert I, Andersson M, et al: A custom template and definite prosthesis allowing immediate implant loading in the maxilla: A clinical report. Int J Oral Maxillofac Implants 17: 663, 2002.

19. Di Giacomo GA, Cury PR, de Araujo NS, et al: Clinical application of stereolithographic guides for implant placement: Preliminary Results. J Periodont 76: 503, 2005.

20. Van Assche N, van Steenberghe D, Guerrero ME, etal: Accuracy of implant placement based on pre-surgical planning of three-dimensional cone-beam images: A pilot study. J Clin Periodont 34: 816, 2007.

21. van Steenberghe D, Ericsson I, Van Cleynenbreugel J, et al: High precision planning for oral implants based on 3-D CT scanning. A new surgical technique for immediate and delayed loading. Appl Osseoint Res 4: 27, 2004.

22. Wendelhag I, van Steenberghe D, Blombäck U, et al: Immediate function in edentulous maxillae with flapless surgery including a 3-D CT-scan based treatment planning procedure. Clin Oral Implants Res Abstract. Poster 144. 2004.

23. Sanna AM, Molly L and van Steenberghe D: Immediately loaded CAD-CAM manufactured fixed complete dentures using flapless implant placement procedures: a cohort study of consecutive patients. J Prosthet Dent 97: 331, 2007.

24. Orentlicher GP, Goldsmith DH and Horowitz A: “Virtual” implant treatment planning: The future of implant dentistry? Inside Dentistry 4: 44, 2008.

25. Orentlicher GP, Goldsmith DH and Horowitz A: Thinking out of the box – The use of “virtual” implant treatment planning and surgery in challenging cases. Inside Dentistry 4: 58, 2008.

26. Hammerle CH, Stone P, Jung R, et al: Consensus statements and recommended clinical procedure regarding computer-assisted implant dentistry. Int J Oral Maxillofac Implants, Proceedings of the Fourth ITI Consensus Conference. 24(Suppl): 126, 2009.

27. Johansson B, Grepe A, Wannfors K, et al: A clinical study of changes in the volume of bone grafts in the atrophic maxilla. Dentomaxillofac Radiol 30: 157, 2001.

28. Verhoeven JW, Ruijter J, Cune MS, et al: Onlay grafts in combination with endosseous implants in severe mandibular atrophy; one years results of a prospective, quantitative radiological study. Clin Oral Implants Res. 11: 583, 2000.

29. Smolka W, Eggensperger N, Carollo V, et al: Changes in the volume and density of calvarial split bone grafts after alveolar ridge augmentation. Clin Oral Implants Res 17: 149, 2006.

30. Krennmair G, Krainhofner M, Maier H, et al: Computerized tomography-assisted calculation of sinus augmentation volume. Int J Oral Maxillofac Implants 21: 907, 2005.

31. Marx RE: Osteoradionecrosis: A new concept of its pathophysiology. J Oral Maxillofac Surg 41: 283, 1983.

32. Marx RE and Ames JR: The use of hyperbaric oxygen therapy in bony reconstruction of the irradiated and tissue-deficient patient. J Oral Maxillofac Surg 40: 412, 1982.

33. Granstrom, G: Placement of dental implants in irradiated bone: The case for using hyperbaric oxygen. J Oral Maxillofac Surg 64: 812, 2006.

34. Granstrom, G: Radiotherapy, osseointegration, and hyperbaric oxygen therapy. Periodontology 2000 33: 245, 2003.

35. Koga DH, Salvajoli JV and Alves FA: Dental extractions and radiotherapy in head and neck oncology: review of the literature. Oral Diseases 14: 40, 2008.

36. Horowitz A, Orentlicher GP and Goldsmith DH: Computerized implantology for the irradiated patient. J Oral Maxillofac Surg; 67: 619, 2009.

RELATED ARTICLES IN ***SELECTED READINGS IN ORAL AND MAXILLOFACIAL SURGERY***

Peri-implantitis: Management of Soft and Hard Tissue Complications. Garth R. Griffiths, DDS, MS. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 11, #1, 2003.

Reconstruction of Alveolar Defects Prior to Implant Placement. Alan S. Herford, DDS, MD. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 11, #6, 2003.

Office-Based Autogenous Bone Graft Harvesting Techniques for Dental Implants. Likith V. Reddy, DDS, MD, FACS and Karen K. Potaczek, DDS. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 16, #1, 2008.

Reconstruction of the Atrophic Maxilla. Jay M. Neugarten, DDS, MD and Salavatore L. Ruggiero, DMD. MD. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 17, #2, 2009.

Treatment of the Edentulous Maxilla with Non-grafting Option: Part 1, Standard Techniques. Edmond Bedrossian, DDS, FACS, FACOMS. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 17, #3, 2009.

Treatment of the Edentulous Maxilla with Non-grafting Option: Part 2, Advanced Techniques. Edmond Bedrossian, DDS, FACS, FACOMS. *Selected Readings in Oral and Maxillofacial Surgery* Vol. 17, #4, 2009.