Are Radiographic Guides Necessary?

A Paradigm Shift in Implant Site Assessment, Digital Planning, and Surgical Guide Fabrication

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INTRODUCTION

We were taught in dental school the axiom "failing to plan is planning to fail," and that we must thoroughly plan our treatment and visualize the end-point goals prior to starting treatment. To get there, we were taught (and continue to teach) that additive wax-ups for partially dentate patients and tooth arrangements on stabilized record bases for edentulous patients is absolutely the gold standard in diagnosis and treatment planning. While for many, this treatment philosophy is still a relevant and critical aspect of treatment planning, the age of digital dentistry is rapidly changing this paradigm. For some, this may be uncomfortable, but many recognize that it is possible to change while still respecting traditional philosophies for treatment planning success.

CBCT SCANNING AND IMPLANTOLOGY

One of the best examples of the integration of digital technology in dentistry is implant dentistry. The use of cone beam CT (CBCT) has gained popularity as it allows for 3-D evaluation as opposed to traditional 2-D radiographic techniques. CBCT allows proper visualization of critical anatomical structures and provides a superior amount of information.[1-3] The radiographic visualization of the alveolar ridge, tooth position, and the restorative plan are necessary steps in the treatment sequence and planning of implant restorations. Figure 1 illustrates a pretreatment panoramic assessment of an edentulous patient interested in dental implants to retain his mandibular denture. Many clinicians would look at this radiograph and the proposed implant site and think that this patient would be an excellent candidate for dental implants. The first response typically given to this type of radiographic appearance is, "He has a mile of bone!" Figures 2 and 3, however, illustrate the clinical reality that exists: a bottle-shaped mandibular ridge with incomplete healing. Placement of standard-diameter dental implants would be challenging, and the clinician would potentially be surgically unprepared if solely basing the treatment assessment solely upon the panoramic radiographic.

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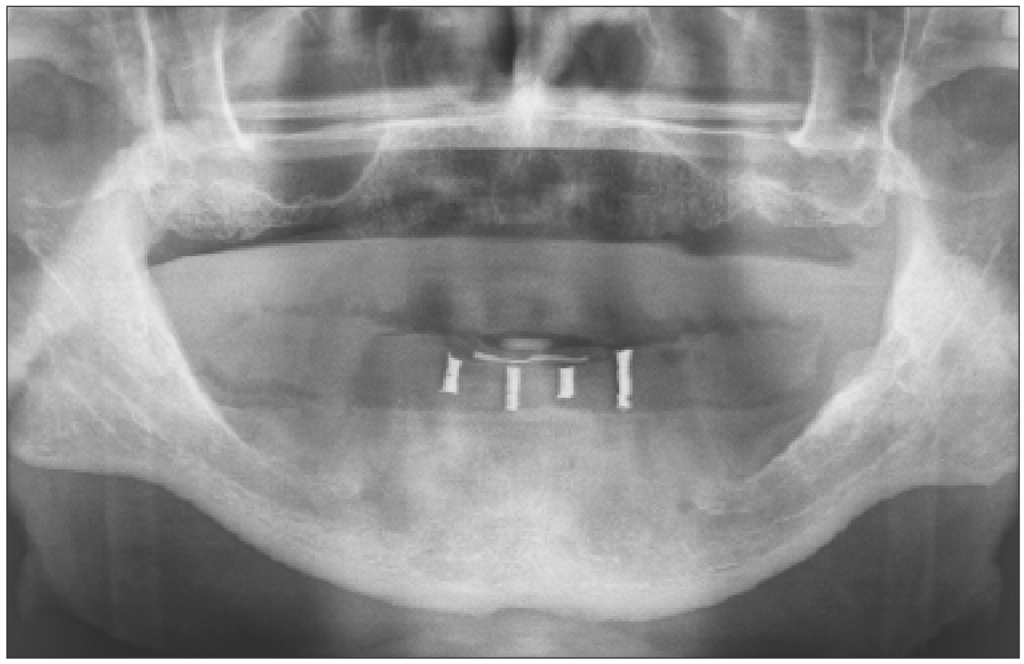

Figure 1. Panoramic radiograph of a patient showing adequate bone height for dental implants.

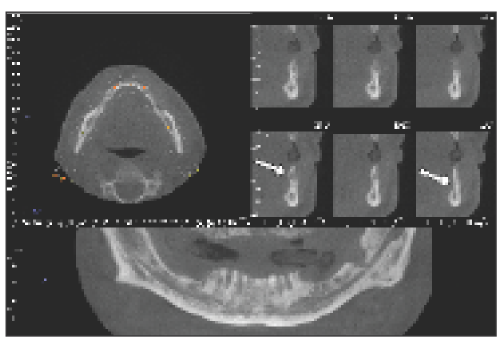

Figure 2. Bottle-shaped mandibular anterior ridge not visible on the panoramic radiograph.

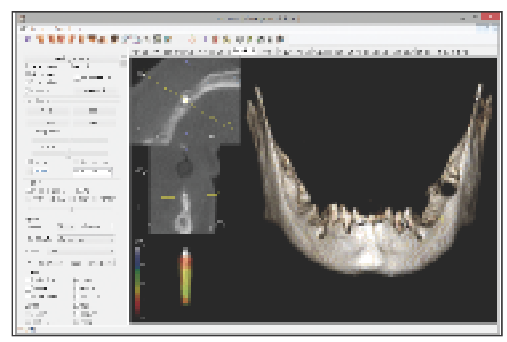

Figure 3. Volumetric rendering of bone volume illustrating clinical reality of 2-D versus 3-D diagnostic imaging.

Proper evaluation of 3-D tooth position, angulation, and restorative space is essential during treatment evaluation for implant restorations. This restorative space is bound by the proposed occlusal plane, mesial-distal distance between teeth, denture bearing tissues of the edentulous ridge, and orofacial tissues.[4] Inadequate attention to analyzing the restorative space may lead to problems such as an overcontoured restoration, fractured teeth and/or denture bases, artificially opened occlusal vertical dimension, and the need to perform additional surgical and restorative procedures.[5-8] Figure 4 shows an example of implants placed without regard to a restorative goal or guide. While the implants appeared healthy and properly within bony contours, the restoration

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required custom abutments and splinted overcontoured restorations, which ultimately led the patient to feel as if a less than optimal result was achieved (Figure 5). Preventing errors in treatment planning, as shown in the previous Figures, can be accomplished by establishing a restorative plan prior to placing implants.

Various radiographic visualization methods have been previously described with many reports and techniques involving duplicating the existing or proposed restoration and fabricating a radiographic guide.[9-12] Many of these radiographic guides contain markers such as gutta-percha,[13-15] ball bearings,[16-17] metal tubes,[10] metal strips,[18-19] and barium sulfate.[9,11,20-22] These markers can reliably act as tooth or restoration outline markers indicating incisal edge position, bucco-lingual position aides, and denture base contour. By using these surfaces and markers, critical anatomical features are identified, and dental implants may be digitally planned. While visualization can be achieved with this approach, some practitioners choose not to fabricate radiographic guides because of the extra steps and costs involved. Laboratories typically charge between $50 and $200 for fabrication of a radiographic guide, in addition to approximately $50 worth of impression material used, dental gypsum, and packing material potentially needed to ship to the laboratory. Additionally, a second clinical appointment is necessary to try in the prosthesis to confirm adequate fit prior to the CBCT scan. This extra effort necessary to fabricate radiographic guides is challenging to manage in busy clinical practices that may or may not have CBCT scanners in the office. When referring out to an imaging center, many clinicians are concerned that their radiographic scanning center may not be able to reposition the guide adequately. With full-arch restorations, this can become more of a factor due to the fact that tissue resiliency may cause guides to seat more in some areas than others.

Clinical procedures that facilitate treatment, reduce cost and complexity, and still allow for an appropriate clinical outcome are always of interest to private practitioners. It is the opinion of the author that with the current digital technology and CB software packages, distinct radiographic templates are rapidly becoming unnecessary. Virtual wax-up and restorations allow the clinician to initially plan dental implants based upon bone volume and then correct based upon virtual restorative goals. This digital restorative, or crown-down treatment planning, represents a contemporary diagnostic methodology for treatment planning dental implants. This article aims to describe 2 case reports analyzing potential implant sites in partially dentulous and fully edentulous patients without the use of traditional radiographic guides.


Figure 4. Implants placed at challenging angulation due to lack of restorative-based planning.


Figure 5. Final restorations showing inadequate tissue form.

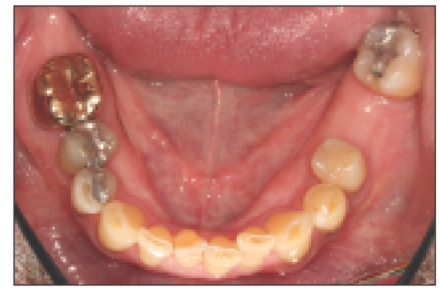
Figure 6. Patient missing tooth No. 19, seeking dental implant treatment.

CASE 1

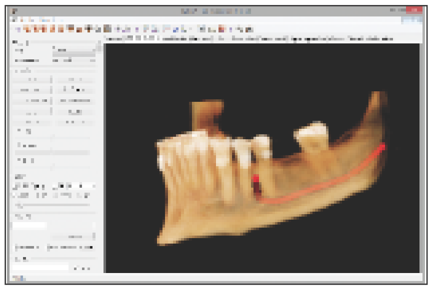
Figure 7. Patient CBCT opened in Invivo Dental (Anatomage) with nerve tracing and sectioning performed.

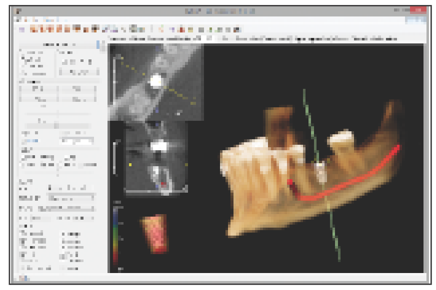
Figure 8. Initial implant placement according to available bone volume.

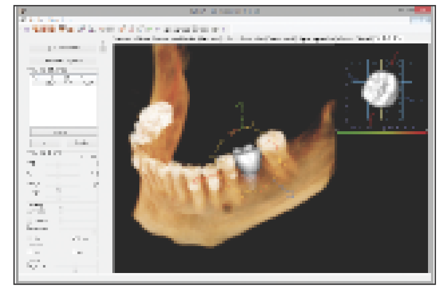
Figure 9. Add a virtual restoration to the implant, then resize and move until satisfied with the planned result.

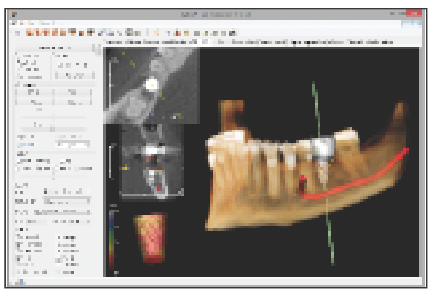
Figure 10. Implant position is inadequate according to restorative plan and an error in emergence form and biomechanics potentially could result.

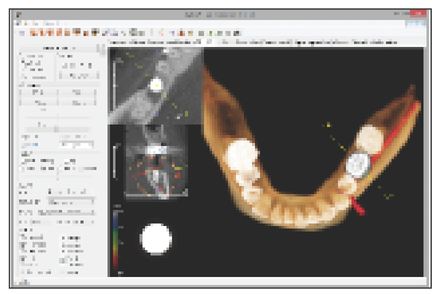
Figure 11. Modifications made to implant position relative to virtual restoration.

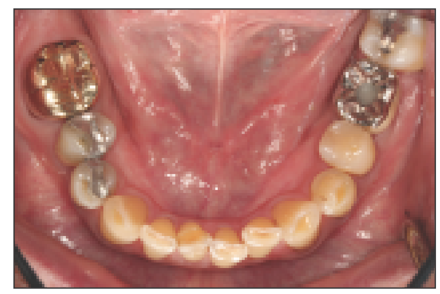
Figure 12. Final result shows ideal implant position relative to restoration.

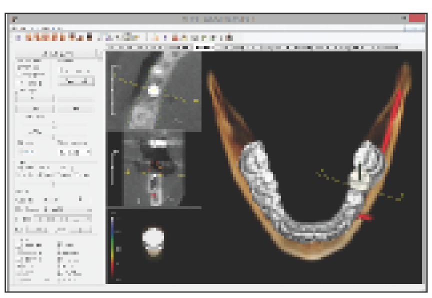
Figure 13. Superimposed optical scan of patient's cast or intraoral optical scan on CBCT volume allowing for precise planning.


Figure 14. Cotton rolls added to separate tongue, cheeks, and lips allowing for a creation of air space around dentition and periodontal tissues.

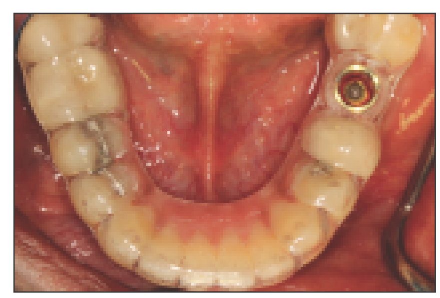
Figure 15. Computerized surgical guide based upon a patient cast superimposition with virtual restoration.

CASE REPORTS

Case 1: Planning Single Implants

Many clinicians encounter patients with a single missing tooth who are interested in a dental implant. Figure 6 shows an example of a patient who lost tooth No. 19 after being diagnosed with a vertical root fracture. While some would advocate fabricating a radiographic template and performing a CBCT scan with the template in place, the author determined that enough information was available to digitally plan the restorative goal without this template. Some of these factors include: tooth-bound edentulous site, appropriate occlusal plane, no malformed dental restorations that would require modification or replacement, and adequate tissue health. A traditional CBCT scan was made at 0.3-mm voxel resolution with cotton rolls placed on the occlusal surfaces of the teeth and with the patient biting down on the cotton rolls to slightly separate the occlusal plane.

The Digital Imaging and Communications in Medicine (DICOM) files were imported into Invivo Dental (Anatomage) for software analysis. The inferior alveolar nerve was traced and the mandible was sectioned from the cranial base and vertebral column to remove excess clutter (Figure 7). An

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implant was selected from the library with diameter and length chosen based upon the availability of bone present in the 3-D view. The implant was tentatively placed according to available bone volume with some regard to positioning relative to the dental arch configuration (Figure 8). A virtual restoration or wax-up is added to the implant by clicking the "restoration" button on the left side of the screen, which automatically takes the user to the restoration feature of the software. The latest version of Invivo Dental (version 5.3, at press time) will pop up with various preprogrammed tooth morphology options ranging from large, youthful, low-wear to small, mature, high-wear restorations.

In this new screen, one can move and rotate the restoration buccolingually, mesiodistally, and incisal-gingivally to orient the restoration between adjacent teeth. By moving this virtual wax-up around, it gives a sense of the available space for the proposed restoration within the confines of the dental arch (Figure 9). The restoration feature of the software will also allow for dynamic resizing in all dimensions of the wax-up, allowing the user to precisely plan the restorative goal. Once the restoration is finalized, the implant position can be viewed according to the restorative goals (Figure 10). Using the digital crown-down philosophy, one can see that the implant position is too lingual and tilted too facially, leading to a potential facial cantilever and improper emergence form. The implant position can be easily modified to represent a more appropriate implant position relative to the restorative goal (Figure 11). Based upon the virtual wax-up and plan, measurements can be made and traditional surgery can be performed based upon the restorative planning. In this patient case report, it was determined that ideal implant positioning required buccal grafting of the implant at time of placement. Figure 12 illustrates the outcome of digital crown-down treatment planning: a screw-retained implant crown with the retaining screw located in the central pit, proper emergence form.

One of the biggest drawbacks of CBCT scans is the amount of backscatter from metal-based restorations. Backscatter was evident in this patient presentation and is seen in Figures 8 to 11; this may potentially interfere with proper radiographic visualization. To reduce the effect of backscatter on restoration planning, the clinician can superimpose an optical scan of a patient's cast or intraoral optical scan (Figure 13). To facilitate patient scan superimposition, the clinician should separate the soft tissues from the teeth with cotton rolls to facilitate the visualization of intraoral soft-tissue profiles (Figure 14). Based upon this superimposition, a clinician can order a computerized surgical guide to perform guided surgery (Figure 15).

CASE 2

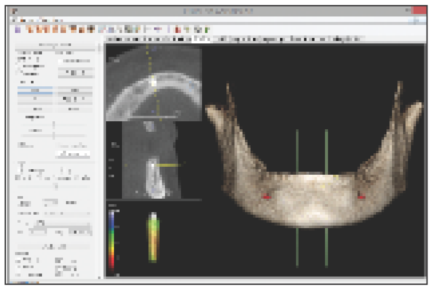

Figure 16. CBCT scan without a radiographic template showing incomplete restorative information. Patient was wearing complete dentures in occlusion during this scan.

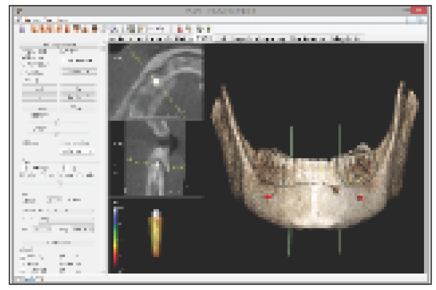

Figure 17. Traditional barium sulfate radiographic template based upon the patient's complete denture.

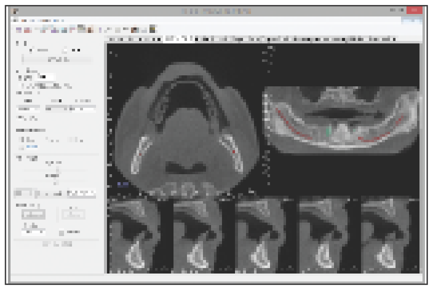

Figure 18. CBCT scan while wearing complete dentures with soft-tissue separation from the mandibular complete denture. Note the dark areas between the denture and ridge in the areas of extraction sockets representing ridge resorption.

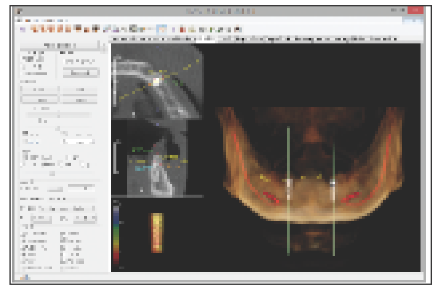

Figure 19. Dental implant planning with only soft-tissue separation from a mandibular complete denture.

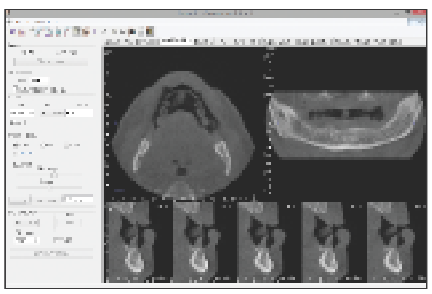

Figure 20. Mandibular complete denture with radiopaque VPS liner (Green-Mousse [Parkell]) applied to intaglio surface combined with soft-tissue and occlusal separation.

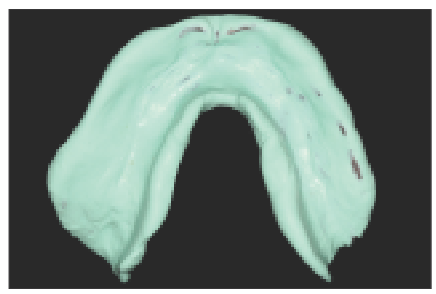

Figure 21. Radiopaque VPS applied to intaglio surface of complete denture.

Figure 22. Cotton roll separation of the tongue, cheeks, and lips from the mandibular complete denture. Patient was scanned at 0.3 mm voxel resolution.

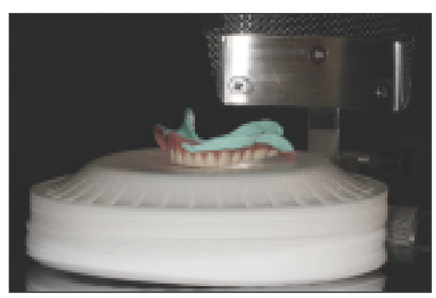

Figure 23. Denture scanned at 0.2 to 0.3 mm voxel resolution.

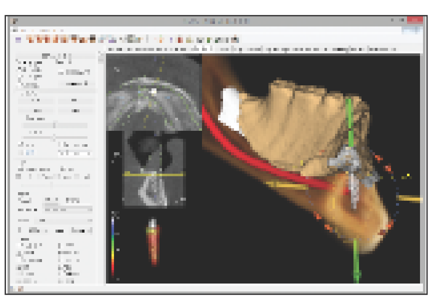

Figure 24. CBCT plan with digital registration of denture and soft tissues on patient scan, allowing for layers to visualize denture in 3-D volumetric rendering.

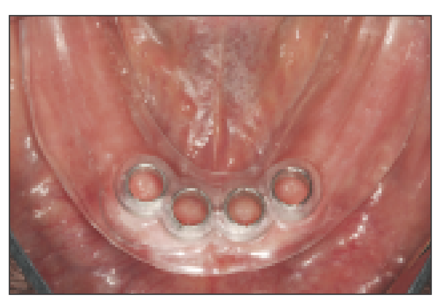

Figure 25. Computerized soft-tissue supported surgical guide fabricated based upon crown-down digital planning.

Case 2: Planning Multiple Implants

While digital implant treatment planning for multiple missing teeth traditionally requires a slightly more complicated approach as compared to planning for single missing teeth, this case report will illustrate a unique and simple approach to implant treatment planning edentulous patients. Often, a CBCT scan is performed without regard to restorative goals and the resultant radiographic image depicts sufficient information related to bone quality and volume but provides limited information regarding tooth position (Figure 16). The traditional method for radiographic visualization of restorative goals for edentulous patients is to duplicate the patient's denture or diagnostic tooth arrangement with laboratory vinyl polysiloxane (VPS) putty or alginate. Using this impression, a barium duplicate denture can be fabricated which will show up as radiopaque replica on the CBCT scan (Figure 17). This method does provide predicable assessment for dental implant treatment planning; however, as mentioned previously, this method typically requires 2 clinical appointments and potentially increases cost.

Radiodensity of cortical bone (1,700 HU) allows it be easily visible on CBCT radiographs as compared to air (-1,000 HU) and tissues (50 HU).[22] The comparison of tissue radiodensity and that of denture acrylic resin (70 HU) makes it more difficult to discern the differences between the 2.[22] Figure 18 illustrates a CBCT radiograph of a mandibular complete denture with soft-tissue and occlusal separation. Looking at this radiographic representation of the denture contour, it is easy to see all of the major factors related to essential treatment planning: tooth position, denture base contour, and occlusal morphology. Interestingly, there is

Digital planning for soft tissue-supported implant surgical guides requires a few additional simple steps.

also visible air space around recent extraction sites illustrating the healing process associated with an immediate denture. Traditional implant planning with measurement-based CBCT analysis is facilitated with this simple yet intuitive approach for fully edentulous patients (Figure 19).

While this traditional surgical approach is facilitated with this simple solution, digital planning for soft tissue-supported implant surgical guides requires a few additional simple steps. Figure 20 shows a mandibular complete denture with a radiopaque VPS reline (Green-Mousse [Parkell]) and soft-tissue separation. The VPS liner shown in Figure 21 is applied to the intaglio surface of the denture or diagnostic tooth arrangement prior to the CBCT scan using a simple reline technique. The patient is then scanned at 0.3 mm voxel resolution using a similar soft-tissue and occlusal separating protocol described earlier (Figure 22). At this point, remove the denture and scan the denture and radiopaque liner separately at 0.2 to 0.3 mm voxel resolution with the denture suspended on a foam block or plate (Figure 23). This is commonly referred to as a *dual-scan protocol*. After the completion of the second scan, the radiopaque VPS liner can easily be removed and the denture returned to the patient without having to drill any holes or have to add any acrylic resin. Depending upon one's specific dental state board laws and regulations, this VPS protocol can also be potentially delegated to a dental assistant or radiology scan center technician to free the clinician to concentrate on other procedures.

The dual-scan protocol produces 2 separate DICOM data sets: one is of the patient wearing the denture and radiopaque VPS liner, and the second of just the denture with the radiopaque VPS liner. The CBCT radiographs can be virtually joined together, dental implants planned, and they allow for complete visualization of the soft tissue and denture as separate layers (Figure 24).

Soft tissue-guided surgery requires a radiographic template that is fully adapted to the soft tissues in order to properly relate dental implant positions with the digital soft-tissue analogs. The markers within the radiopaque VPS contain unique features that allow the object to be reliably detected and analyzed with a computer algorithm. Once the marker has been recognized, the algorithm will allow for digital re-orientation based upon a pair of CBCT scans that contain an identical orientation of markers. Based upon the patient and prosthesis scan registrations, a dental laboratory technician can reliably separate a soft-tissue profile from the denture surface. In addition, the markers imparted by the soft-tissue surface-based fiducial registration allow superimposition of a soft-tissue cast or optical scan. The combination of these 3 parts (patient CBCT scan, denture CBCT scan, soft-tissue cast optical scan) allows the dental laboratory to fabricate a soft-tissue supported dental implant surgical guide to assist in dental implant placement (Figure 25).

CLOSING COMMENTS

Digital CBCT software is becoming widely accepted throughout clinical dentistry for its ability to rapidly and easily make visible alveolar bone volume and quality. These systems allow clinicians to manipulate 3-D images of patients' dentition and restorative templates, facilitating dental implant planning. Presented was a unique, radiographic, template-free approach to treatment planning dental implants aided in part by soft tissue and occlusal separation with virtual restoration planning. These clinical procedures that facilitate treatment, reduced cost, and complexity and yet still allow for the clinical outcome of proper dental implant planning is of particular interest to clinicians. Virtual planning of dental implants with these protocols allows one to ask, "Do we really need a radiographic guide?" While these 2 clinical case reports of patients were planned and treated using these simple protocols, every patient situation is unique, and there may be times when a completely virtual plan may be challenging. Ultimately, crown-down digital implant treatment planning challenges the conventional paradigm of radiographic visualization for dental implant treatment planning.✦

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Disclosure: Dr. Scherer is a clinical consultant to ZEST Anchors.