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Digital Technology for Implant Dentistry

Considerations for Implementation

INTRODUCTION

The use of digital technology in clinical practice allows clinicians to implement a modern approach to dental treatment. While there are many avenues for adopting digital technology in clinical practice, facilitating dental implant surgical and restorative procedures is an interest of general dentists and dental specialists.

Historically, 2-D or 3-D radiography and free-hand approaches have been utilized to surgically place dental implants. This traditional method combines conventional radiographic methods and knowledge of anatomical features to perform surgical procedures to best determine positions of implants. Many have advocated the use of radiographic and/or surgical instruments and templates to assist in proper implant angulation and bodily position of implants.[1,2] While this method has been successfully employed for many years, limitations of free-hand surgical procedures exist and may preclude ideal implant positions for restorative dentistry. Ideal placement of a dental implant helps contribute to the overall health of the bone, periodontium, and implant.[3] The desire to improve surgical and restorative outcomes has driven clinicians to implement modern, digital methods in their procedures.

CBCT, intraoral scanning, and 3-D printing technology have become readily employed in dental laboratories and offices around the world and, to this author, are an invaluable combination for dental implantology. Combining these various technologies and making them work seamlessly, with the correct guidelines and techniques, is paramount for successful integration of the technology to enhance treatment outcomes.

This article describes the various technologies and best practices and utilizes them together to create surgical guides for guided surgical implant procedures.

CBCT

CBCT allows for 3-D evaluation and proper visualization of anatomical structures where dental implant surgical procedures are to be performed. The radiographic visualization of bone volume, the alveolar ridge, the soft-tissue relationship, the proposed tooth position, and the restorative plan are necessary for the proper planning of implant restorations.[4] When an implant is to be placed in proximity to vital structures, 2-D radiography provides only limited information with which to properly assess whether the distance is possible. Errors from traditional imaging lead to potential complications, including prosthetic complications, soft-tissue insufficiency, implant

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Figure 1. CBCT machine options: **(left)** sit-down (i3D Premium [Vatech America]), **(middle)** standing (Green CT [Vatech America]), and **(right)** lie-flat (NewTom 5G [NewTom]).

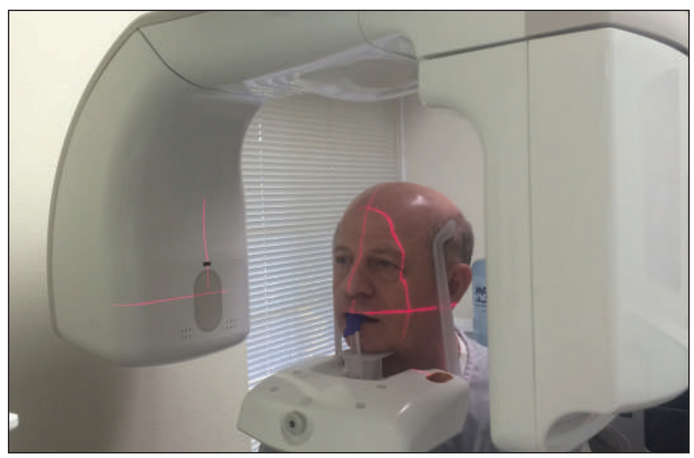

Figure 2. A patient was positioned within a CBCT machine (PaX-Duo3D [Vatech America]) for a scan to evaluate his missing maxillary teeth.

Table 1. Considerations for Implementing CBCT

- **Implants**: Enhanced visualization of bone volume
- **Endodontics**: Greater understanding of root anatomical factors
- **Orthodontics**: Facial and alveolar position analysis, airway analysis
- **Engagement with patients**: Increased patient case acceptance in addition to the "wow factor"
- **Enhanced revenue**: Billing for CBCT and potential for medical billing

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failure, and paresthesia, and may also lead to an unsatisfactory patient outcome, a referral to other specialists, and/or medicolegal claims.[5] As a result of the aforementioned, many in the profession are calling for CBCT scanning to be labeled as the "standard of care" for dental implant surgical procedures while also calling for increased implementation of the technology.[5-7]

When evaluating where to begin implementing advanced technology in clinical practice, the evidence reasonably points to integrating CBCT technology as an essential tool (Table 1). In this author's opinion, CBCT is an excellent place to get started with digital technology in clinical practice as it permits enhanced visualization for dental implants and diagnostic treatment planning.

Proper image acquisition is important and begins with the selection of the machine to use within an office. There are 3 major types of CBCT machines that are available for dental offices: sit-down, stand-up, and lie-flat. (Figure 1). Many dental offices will opt for the stand-up configuration as image quality is excellent and costs are lower compared to the other versions. Additionally, stand-up units are simple to integrate in a constrained footprint within a dental office where patient positioning is facilitated (Figure 2).

While all CBCT systems allow for image capture and the processing of Digital Imaging and Communications in Medicine (DICOM) files, many CBCT systems differ regarding the integration of systems, simplicity of software use, and long-term service and support (Table 2). In this author's opinion, one should choose the largest field of view (FOV) that one can reasonably afford to ensure flexibility with scanning requirements both today and in the future. For example, many of the lower cost CBCT systems scan at 50 mm × 50 mm (5 × 5 cm), which is adequate for simple diagnostics for single-implant procedures and endodontics. If a clinician purchased a small FOV unit and wished to expand his or her practice into full-arch implantology, oral surgical procedures, or orthodontic diagnostics, the scanner would be insufficient for those tasks without upgrading or changing systems.

Table 2. Features To Look for in a CBCT Machine

- **Reasonable costs**: Consider up-front vs delayed (service contract) costs
- **Size of unit**: Footprint will fit into existing or new space
- **Field of view (FOV)**: Buy the largest FOV possible
- **Support**: Service reputation and length of warranty service
- **Flexibility**: CBCT scanners that have modes for scanning casts and impressions

Figure 3. Optical scanner options: **(left)** intraoral (TRIOS [3Shape]) and **(right)** desktop (E2 [3Shape]).

Figure 4. Dental assistants are extremely effective team members for making intraoral scans (TRIOS).

OPTICAL SCANNING

Optical scanning is done with a computerized input device that uses light projected onto an object to convert that physical object into a virtual one. They are available in 2 categories: desktop scanning and intraoral optical scanning. Desktop, also known as laboratory scanning, has historically been the method that most laboratories and some clinicians utilize for digitizing their dental treatments and cases. Laboratories and clinicians wishing to digitize physical gypsum casts typically prefer investing in desktop scanners, and the resolution and flexibility of a desktop scanner is ideal for many purposes (Figure 3, right). The advantages of desktop scanners include simplicity, flexibility, and resolution. While there are many advantages to utilizing a desktop optical scanner, many clinicians would prefer to directly image the dentition to minimize the errors often found when taking physical impressions and cast preparations.[8]

Intraoral optical scanning has rapidly evolved into the preferred method of replication of the dentition and oral tissues. Intraoral scanning utilizes a similar light projection as a desktop scanner; however, it is designed to be placed directly into a patient's mouth, and images are prepared using a wand-style capture device (Figure 3, left). These types of scanners are typically configured with a portable laptop, tablet, or desktop physical cart that enables the user to move readily around the clinical office from room to room, facilitating the patient experience. The wand device is activated while the patient's dentition is isolated, and optical images are projected onto the surface and reflected back to the capture device, converting the light into a 3-D image on the computer screen. Advantages of intraoral scanning include direct image acquisition, no physical impressions required, and speed. Disadvantages include cost, learning curve, difficulty of maintaining scanner calibration, and computer updates. While some maintain desktop scanners are the de-facto gold standard of optical imaging, others advocate for intraoral scanning as increasingly more and more accurate when compared to the desktop variety.[8]

When evaluating whether to incorporate desktop or intraoral scanning into a clinical practice, many factors are involved (Table 3). While the research is indicating the trend toward intraoral scanning as the preferred method for clinicians, some still advocate for desktop scanners for simplicity and cost. Intraoral scanning is a tremendous improvement in clinical dentistry workflows and the patient experience, and, in this author's opinion, is the preferred method for optical image generation in a clinician's environment (Figure 4).

GUIDE DESIGN AND 3-D PRINTING

After acquiring the radiographic images via CBCT and the optical images via desktop/intraoral scanning, the clinician and/or laboratory technician can utilize the 2 separate digital files together for implant surgical procedures. While there are various software packages and techniques available for generating surgical guides for clinical use, 2 main methods are employed: in-laboratory industrial and in-office clinician production.

In-laboratory industrial production methods for surgical guides

Table 3. Considerations for Implementing Optical Scanning

DESKTOP SCANNER

ADVANTAGES:
- **Accuracy**: Gold standard of accuracy
- **Simplicity**: No changes to workflow needed
- **Reasonable costs**: Compared to other optical imaging methods

DISADVANTAGES:
- **Cumbersome**: Need dedicated laboratory space
- **Learning curve for clinicians**

INTRAORAL SCANNER

ADVANTAGES:
- **Accuracy**: Reliable for clinical workflows
- **Direct imaging**: Eliminates PVS and Stone Models
- **Patient Experience**: Enhances "cool" factor and minimizes laboratory errors

DISADVANTAGES:
- **Higher costs**: Expensive compared to other optical scanning methods
- **More challenging initially**: Potentially changes office workflows and creates a need to adapt techniques

have been utilized for years and, historically, have been controlled by the dental implant manufacturers or independent dental software companies. After the clinician/laboratory generates an optical image, the software aligns the digitized model of the patient's dentition on top of the virtual dentition portrayed on the CBCT scan. This process, termed image fusion, utilizes computerized software to join similar points on each of the scans and aligns them together onto the same position on a singular 3-D image (Figure 5).

After image fusion procedures are completed, implant planning procedures are done using a restoratively driven treatment philosophy. This technique, termed "crown-down treatment planning," positions dental implants for restorative contours and then fits the implant position within the bone volume to correspond with the restorative plan.[4,9] Once the implant plan and positions are completed and approved by the clinician, the template can be designed by the software and fabricated by industrial techniques. While milling or subtractive manufacturing techniques have historically been employed with production in the dental laboratory, many advocate 3-D printing or additive manufacturing techniques as the preferred method for the production of surgical guides. Most 3-D printing techniques are broken down into 4 main categories: hobbyist, desktop, laboratory-industrial, and large-scale industrial (Figure 6).

Recently, an increase in interest has been shown by clinicians regarding in-office methods to fabricate surgical guides. Historically, surgical guide production relied upon the laboratory utilizing proprietary software with moderately expensive production methods. While these methods have proven reliable, desktop-level 3-D printing has also been shown to be a reliable and precise method for the production of physical models. Additionally, recent research indicates that desktop-level printers are capable of producing model prints and surgical guides that are similar to that of large-scale industrial units.[10,11]

The incorporation of a 3-D printer into clinical practice has become much simpler and easier than in the past. Three-dimensional printing companies, along with a growing network of innovative clinicians, are evaluating and establishing workflows. There is a variety of reasons for incorporating a 3-D printer into a practice and multiple rationales for doing so; however, in this author's opinion, it is wise to start small—and with a desired direction and goal in mind (Table 4). For example, if a clinician wishes to incorporate a 3-D printer to produce models and surgical guides only, a desktop-level 3-D printer (such as a Form 2 [Formlabs]) is an appropriate choice. If a clinician, however, wishes to rapidly produce printed models, guides, provisional restorations, and/or denture bases, then a laboratory or industrial printer (such as a NextDent 5100 printer [3D Systems]) would be a preferred choice.

While multiple considerations for technology and options for surgi-

Table 4. Features To Look for in a 3-D Printer

- **Applications:** Consider if the printer supports the applications a clinician/laboratory team wishes to provide
- **Materials:** Consider the appropriate material options—models, surgical guides, denture bases, tooth colored resins, and biocompatible resins, etc.
- **Size of unit:** Desktop vs laboratory-industrial
- **Costs:** Consider the initial costs and then the cost per mL of resin

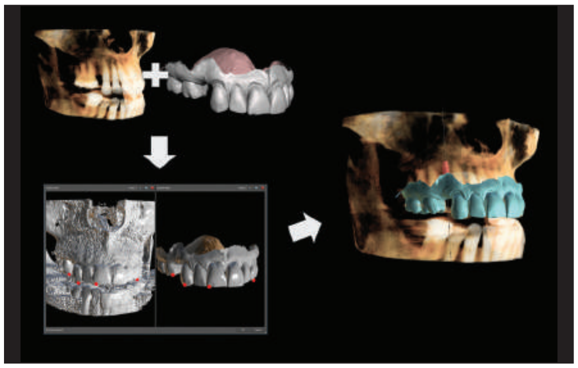

Figure 5. An image fusion was done by taking **(upper left)** individual CBCT Digital Imaging and Communications in Medicine (DICOM) files, merging them with **(lower left)** optical STL scan files, and using anatomical landmarks so they could be **(right)** visualized in the same image.

Figure 6. Three-dimensional printers are available in several configurations: (1) hobbyist (eg, Replicator [Makerbot] and Robox [CEL]), (2) desktop (eg, Moonray S [Sprintray] and Form 2 [Formlabs]), (3) laboratory-industrial (eg, Nextdent 5100 printer [3D Systems] and Carbon M1 [Carbon3D]), and (4) large-scale industrial (eg, Projet [3D Systems]).

Figure 7. An intraoral scan (True Definition Scanner [3M]) was done of a patient's arch. She was missing tooth No. 30 and wanted an implant replacement.

cal guide design have been discussed, the main decisions that the clinician needs to make related to surgical guide fabrication comes down to the following question: "Do I want to outsource some or all of the guide production, or do I want to do some or all of the guide production myself?" The following are 2 case reports in which both options are shown.

CASE 1
Outsourcing Surgical Guides

A patient presented to the author's clinical practice with a request to replace missing tooth No. 30. A CBCT scan was made (Green CT [Vatech America]) as well as an intraoral scan (True Definition Scanner [3M]) (Figure 7). The DICOM files were downloaded from the CBCT machine and imported into the implant planning software (Invivo [Anatomage]). Then the implant (T3 [Zimmer Biomet]) was planned. The STL file was downloaded from the online portal for the intraoral scanner and sent together with the tentative implant plan Invivo file to the online portal for an industrial laboratory to fabricate a surgical guide. The optical scan STL file was fused onto the Invivo file and sent back to the author for evaluation (Figure 8). Minor changes in the implant position were made to correct any discrepancies between the restorative and surgical plans. The surgical guide (Anatomage Guide [Anatomage]) was fabricated and received.

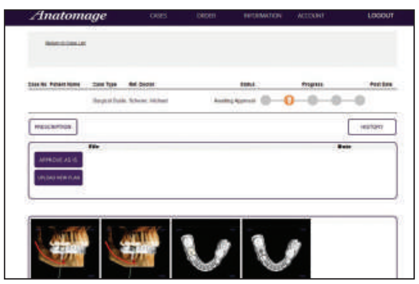

Figure 8. The CBCT planning file (Invivo [Anatomage]) was uploaded to a secure portal (Anatomodel [Anatomage]) with the optical scan file of the patient's arch.

Figure 9. A surgical guide (Anatomage Guide [Anatomage]) was designed and fabricated by a large-scale laboratory and adapted to the patient's arch. A 5/4- × 10-mm implant (T3 [Zimmer Biomet]) was placed, and then a coded healing abutment (Encode [Zimmer Biomet]) was placed.

Figure 10. An intraoral scan was made of the healing abutment, and a CAD/CAM abutment (BellaTek [Zimmer Biomet]) and PFM crown were fabricated.

The patient presented for the surgical procedure. Preoperative antibiotics (Amoxil [Moxatag]) and chlorhexidine oral rinse (Peridex [3M]) were administered. Local anesthetic was applied (2% Lidocaine [Zahn]), and the surgical guide was placed onto the mandibular dentition to confirm full adaptation of the guide (Figure 9). Minimally invasive, flapless procedures with sequential ostetotomy preparations were performed with an implant-specific surgical guide system (Navigator System for Guided Surgery [Zimmer Biomet]) through the surgical guide until full preparation was completed. A 5/4- × 10-mm implant (T3) was placed, and a 7.5- × 3-mm coded healing abutment was placed (Encode [Zimmer Biomet]). Postoperative instructions were provided to the patient.

The patient returned after an integration time period of approximately 8 weeks. A periapical radiograph was made to confirm adequate bone fill around the implant. The coded healing abutment was confirmed to be fully adapted to the implant, and an intraoral scan (True Definition Scanner) was made of the healing abutment, maxillary arch, and bite registration. The scan was sent to the laboratory, where a CAD/CAM abutment (BellaTek [Zimmer Biomet]) was fabricated. A PFM crown was fabricated at the laboratory with a screw-access channel corresponding to the abutment-screw position of the abutment. The patient returned, and the abutment was placed and torqued to 20 Ncm using a torque wrench (Low Torque Indicating Ratchet Wrench [Zimmer Biomet]) (Figure 10). The crown was adapted to the abutment and luted using a resin-modified glass ionomer luting agent (RelyX Luting [3M]). A radiograph was made to confirm complete removal of the luting agent. PTFE tape (1/2 Tape [USA Dental Tape]) was placed over the screw channel, and flexible composite resin (Fermit [Ivoclar Vivadent]) was placed and cured. The patient was satisfied with the final restoration.

CASE 2
In-Office Surgical Guides

A patient presented to the author's clinical practice with a request to replace missing teeth Nos. 12, 13, and 14. A CBCT scan was made (Green CT), and an intraoral scan (TRIOS [3Shape]) was made. The DICOM files were imported from the CBCT into the implant planning software (Blue Sky Plan [Blue Sky Bio]), and implants (Tapered Internal Plus [BioHorizons]) were planned within the software (Figure 11). The STL file was copied from the intraoral scanner and fused onto the CBCT file directly within the software prior to surgical-guide fabrication. A pilot surgical guide was designed and fabricated within the software and printed with a desktop 3-D printer (Form 2 [Formlabs]) using biocompatible dental resin (DentalSG [Formlabs]) (Figure 12). The surgical guide was UV cured in a commercially available curing unit (LC-3DPrint Box [NextDent]) with supports removed, and then it was polished.

The patient returned for the surgical procedure. Pre-op antibiotics (Amoxil [Moxatag]) and chlorhexidine oral rinse (Peridex [3M]) were administered. Local anesthetic was applied (2% Lidocaine [Zahn]), and the surgical guide was placed onto the maxillary arch to confirm full adaptation of the guide. Using the initial pilot drill, osteotomies were done through the soft tissues (Figure 13). A small periosteal flap was elevated, and sequential osteotomy preparations were done free-hand with implant-specific drills (Tapered Drills [BioHorizons]). A 5.8- × 10-mm implant (Tapered Internal Plus) was placed in the tooth No. 14 position, and a 4.6- × 10-mm implant (Tapered Internal Plus) was placed in the tooth No. 12 position. The flap was closed, and PTFE sutures (Cytoplast [Osteogenics Biomedical]) were placed. Post-op instructions were provided to the patient. The patient returned 2 weeks later for suture removal.

Ideal placement of a dental implant helps contribute to the overall health of the bone, periodontium, and implant.

The patient returned 8 weeks after implants were placed. A radiograph was made, confirming adequate bone fill around the dental implants. A special compounded topical anesthetic was applied (The Best Topical Ever [AAAcP/Nueva Vista Dental]), a small flap was elevated, and healing abutments were placed (Laser-Lok Healing Abutments [BioHorizons]). Then, 2 weeks later, the healing abutments were removed, and scannable temporary abutments were placed (PEEK Scan Abutments [BioHorizons]) (Figure 14). An intraoral scan (TRIOS) was made of the abutments, the mandibular arch, and the bite scan. Healing abutments were placed, and the scan was sent to the dental laboratory for abutment fabrication (Guided Restorative Solutions [Vulcan and BioHorizons]). CAD/CAM abutments were fabricated, and 3-D printed models (Objet [Stratasys]) were returned. A monolithic zirconia fixed partial denture (KATANA ML [Kuraray Noritake]) was fabricated with screw access channels for the abutment screws. The patient returned, healing abutments were removed, and the abutments were placed. Radiographs were made to confirm full adaptation of the abutments, and the restoration fit and occlusion were verified. The abutments were torqued to 30 Ncm, and the fixed partial denture was luted using a resin cement (RelyX Unicem 2 [3M]) (Figure 15). Radiographs were made to confirm the complete elimination of any residual cement. The patient was satisfied with the final restorative outcome.

CLOSING COMMENTS

Digital technology in dental laboratories and clinicians' offices is a rapidly growing aspect of the profession. Various systems can be applied efficiently for fabricating surgical guides for simple implant placement and ideal restorative goals. CBCT scanning is an ideal first place to get started, followed by intraoral scanning and 3-D printing techniques.✦

Acknowledgment

The author would like to thank Vulcan Custom Dental (Birmingham, Al) for their help shown in Case 2.

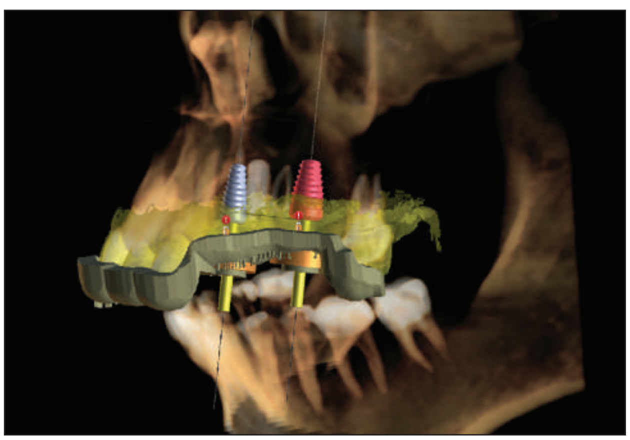

Figure 11. An intraoral scan (TRIOS) and a CBCT scan (Green CT) were made of missing teeth Nos. 12 to 14 and imported into implant planning software (Blue Sky Plan [Blue Sky Bio]), and a surgical guide was designed.

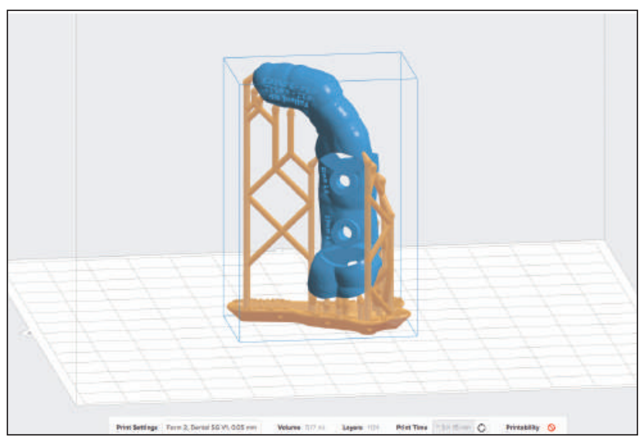

Figure 12. A surgical guide was printed with a desktop 3-D printer (Form 2) using biocompatible surgical guide resin (DentalSG [Formlabs]).

Figure 13. Pilot osteotomy procedures were done using the surgical guide, a small flap was elevated, and implants were placed (Tapered Internal Plus [BioHorizons]).

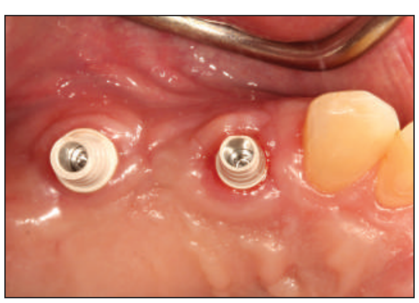

Figure 14. Healing abutments were removed, scan bodies (PEEK Scan Abutments [BioHorizons]) were placed, and an intraoral scan (TRIOS [3Shape]) was made.

Figure 15. CAD/CAM abutments (Vulcan [Biohorizons]) were designed and milled, and then a monolithic zirconia fixed partial denture (KATANA ML [Kuraray Noritake]) was fabricated and delivered.

References

1. Edge MJ. Surgical placement guide for use with osseointegrated implants. *J Prosthet Dent*. 1987;57:719-722.
2. D'Souza KM, Aras MA. Types of implant surgical guides in dentistry: a review. *J Oral Implantol.* 2012;38:643-652.
3. Rojas-Vizcaya F. Biological aspects as a rule for single implant placement. The 3A-2B rule: a clinical report. *J Prosthodont*. 2013;22:575-580.
4. Scherer MD. Presurgical implant-site assessment and restoratively driven digital planning. *Dent Clin North Am*. 2014;58:561-595.
5. Friedland B, Miles DA. Liabilities and risks of using cone beam computed tomography. *Dent Clin North Am*. 2014;58:671-685.
6. Tischler M, Ganz SD. The CT/CBCT-based team approach to care. Part I: Identifying the implant patient and prosthetic options. *Dent Today*. 2012;31:74-79.
7. Rios HF, Borgnakke WS, Benavides E. The use of cone-beam computed tomography in management of patients requiring dental implants: an American Academy of Periodontology best evidence review. *J Periodontol*. 2017;88:946-959.
8. Güth JF, Runkel C, Beuer F, et al. Accuracy of five intraoral scanners compared to indirect digitalization. *Clin Oral Investig*. 2017;21:1445-1455.
9. Scherer MD. A contemporary approach to intraoral optical scanning and in-office 3-D printing. *Dent Today*. 2015;34:46-47.
10. Bortolotto C, Eshja E, Peroni C, et al. 3D printing of CT dataset: validation of an open source and consumer-available workflow. *J Digit Imaging*. 2016;29:14-21.
11. Deeb GR, Allen RK, Hall VP, et al. How accurate are implant surgical guides produced with desktop stereolithographic 3-dimensional printers? *J Oral Maxillofac Surg*. 2017;75:2559.e1-2559.e8.

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