Utilization of Digital Technologies for Fabrication of Definitive Implant-Supported Restorations

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ABSTRACT

The introduction 7 years ago of specially coded healing abutments dramatically simplified the task of obtaining implant impressions. Such coded abutments eliminated the need for impression copings, instead enabling supragingival impressions to be made and sent to the laboratory for fabrication of patient-specific abutments and restorations. Combining this technology with digital oral scanning has the potential to further simplify the time between impression-making and delivery of a definitive restoration, and it offers additional benefits to both patients and clinicians. This article explains how oral scanners can be used to obtain digital impressions of encoded healing abutments. A case report illustrating this approach is also presented.

CLINICAL SIGNIFICANCE

This article describes a new technological approach to implant dentistry utilizing intraoral scanning modalities. The clinical workflow will highlight the digital transfer of necessary information to fabricate a patient-specific implant abutment and final prosthesis.

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INTRODUCTION

Over the last 100 years, techniques and materials for restoring compromised teeth have evolved dramatically. Nowhere has this been more pronounced than in the field of implant dentistry. From its inception as a protracted and unesthetic treatment of last resort for individuals who had lost all their mandibular dentition, implant dentistry has been transformed into the standard of care for many individuals with hopeless or missing teeth. Clinicians now can provide patients with highly esthetic restorations, often in a significantly compressed time frame. As a result, the implant-dental sector today is one of the fastest growing areas within dentistry.

Computer-aided design and computer-aided manufacturing (CAD/CAM) techniques have been transforming the dental field in parallel with these developments. Introduced to dentists in 1971, CAD/CAM techniques were used to create the first dental prototype in 1983, and the first crown was milled and installed in a mouth without any laboratory involvement in 1985.[1] By 1998, customized implant abutments were being created with CAD/CAM technology.[2] Because these are patient-specific, such abutments, like cast custom abutments, have the potential to provide improved peri-implant soft-tissue support, essential to achieving an optimal esthetic result.[3] The CAD/CAM process moreover eliminates the inherent dimensional inaccuracies of waxing,

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investing, and casting, as well as the subsequent need for manipulation after machining. Such abutments thus fit more precisely than stock or cast ones.

For several years, all CAD/CAM abutment fabrication began with removal of the healing abutment. An impression coping then was connected to the implant and an implant-level impression was made along with an impression of the opposing arch. In 2004, a method for simplifying this part of the abutment-fabrication process was developed; it involved the use of specially coded healing abutments (BellaTek™ Encode® Impression System, BIOMET ***3i***, Palm Beach Gardens, FL, USA). Various arrangements of facets on the occlusal surfaces of the abutments identify the implant-platform diameter, the healing abutment height, the hex position of the implant, and the diameter of the emergence profile.[4] The use of such an abutment eliminates the need for impression copings. Instead, a supragingival impression can be made and sent to the laboratory for fabrication of a customized abutment and crown.

Although the conventional elastomeric impression materials used for such impressions have been documented to be accurate and safe,[5–7] they still may present opportunities for error.[8] When done improperly, tray selection, separation of the impression material from the tray, and material handling and/or storage can compromise the restorative outcome. Materials such as polyvinylsiloxane and polyether require messy mixing and clean-up, and many patients find the impression process unpleasant.

An alternative to making a conventional elastomeric impression is to record the intraoral geometry with a digital scanner. For at least 5 years, commercially available intraoral scanning systems have made it possible to capture digital information about the prepared teeth. From that data, three-dimensional computer models can be created. The models then can be quickly, safely, and inexpensively conveyed to the laboratory electronically,[9,10] or they alternatively may be used to design and mill crowns within the dental office.

Up to now, digital sensor technology has not been applied to the fabrication of implant restorations. However, in March of 2011, two manufacturers received 510 K Approval from the US Food and Drug Administration for their intraoral scanners to be used in making digital impressions of coded implant healing abutments. Obtaining such impressions digitally offers benefits to both clinicians and patients. Patients are spared from the need for any contact with messy impression material. Those with strong gag reflexes may particularly benefit from the digital technology because the scanners do not touch the soft palate. These are used for a briefer interval than impression trays and allow patients to take a break, if necessary. Most scanners are comparable in size with other common devices such as curing lights and electric handpieces.

Having a digital model of the BellaTek Encode Healing Abutment in the patient's mouth also has the potential to reduce treatment expenses and compress the interval between the making of the impression and the delivery of the definitive restoration. The data from the three-dimensional digital model is sent electronically to the BellaTek™ Production Center (Palm Beach Gardens, FL, USA). A dedicated technician designs a virtual abutment with subgingival margins that conform precisely to the patient's soft-tissue architecture. The steps of shipping a physical impression of the Encode Healing Abutment to the dental laboratory, having the laboratory pour master casts, mounting them on an articulator with special plates, shipping the casts to BIOMET ***3i***, and having a technician scan the casts, are eliminated.

Additional time savings are achieved by sending the abutment design simultaneously to the BellaTek Production Center for milling of the abutment(s) and to a separate facility for fabrication of a rapid prototype model. The monolithic model, which includes a removable die of a replica of the CAD/CAM abutment, is used by the lab to fabricate the restoration. As the definitive abutment or abutments are being milled (from zirconia or titanium), the rapid prototype model is simultaneously sent to the dental laboratory for use in fabricating the definitive restoration. The restoration

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TABLE 1. Steps required to take digital impressions versus conventional ones

	Traditional impressions	Digital impressions
Remove healing abutment	✔	
Place impression copings	✔	
Radiographic verification of abutment seating	✔	✔
Make VPS impressions (of both arches)	✔	
Obtain an occlusal registration	✔	
Replace healing abutment	✔	
Send (mail) VPS impressions to laboratory	✔	
Lab fabricates a master cast and opposing arch	✔	
Lab mounts the casts on a Stratos articulator with Adesso plates	✔	
Lab sends mounted casts to BellaTek Production Center	✔	
Casts are scanned to create three-dimensional models	✔	
The definitive BellaTek Abutment is designed virtually	✔	✔
Abutment milling	✔	✔
Robocast is fabricated from master cast	✔	
Milled abutment is placed on the Robocast	✔	
Robocast or SLA model and the definitive abutment(s) are sent to the lab	✔	✔
Lab fabricates the restoration and sends it to the restorative dentist	✔	✔

SLA = stereolithographic; VPS = vinyl polysiloxane.

and definitive abutment can be shipped directly to the restorative office. Table 1 compares the workflow in fabricating a definitive abutment and crown from a traditional impression versus a digital one.

The following clinical case illustrates the use of digital impression technology to obtain implant impressions in order to fabricate a definitive implant-supported restoration.

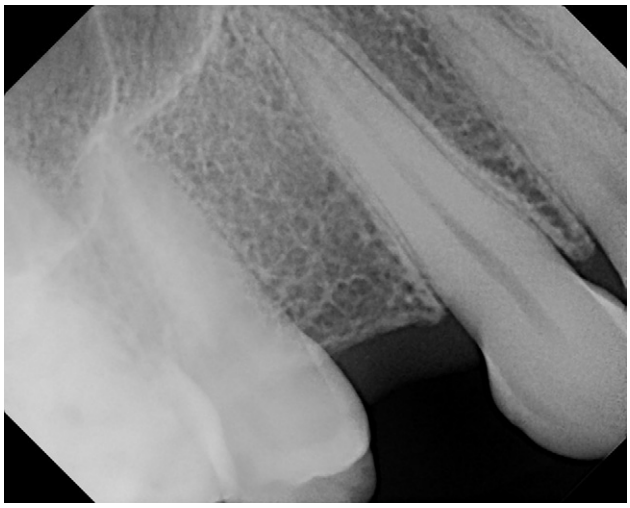

FIGURE 1. The initial radiograph shows the site of the missing maxillary right first bicuspid, which had failed endodontically before being extracted.

CASE REPORT

A 34-year-old female presented with a missing maxillary right first bicuspid, which had been previously extracted in the wake of failed endodontic therapy (Figure 1). A dental assistant, she was completing orthodontic therapy (Invisalign® System, Align Technologies, Inc., San Jose, CA, USA) and was ready to replace the missing tooth. A Certain® FOSS Tapered Implant (BIOMET ***3i***) (5.0 mm diameter × 11.0 mm length) was placed into the edentulous site, and primary closure was obtained. The patient's final aligner/retainer was used to provide temporization to replace the missing tooth during healing.

Six months after implant placement, the patient returned for second-stage surgery. A tissue punch was used to expose the implant, and a BellaTek Encode Healing Abutment (5 mm diameter × 3 mm height) was placed into the internal interface of the implant. Two weeks later, the patient was seen for digital intraoral scanning (Lava™ Chairside Oral Scanner [C.O.S.], 3M, St. Paul, MN, USA).

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FIGURE 2. The digital oral scan captured the codes on the surface of the Encode Healing Abutment, as well as the contours of the surrounding soft tissue and adjacent teeth.

FIGURE 3. Occlusal view of the digitally scanned BellaTek Encode Healing Abutment.

The restorative clinician confirmed that the BellaTek Encode Healing Abutment was securely connected to the implant and properly seated, extending at least 1 mm supragingival circumferentially. This is essential for the codes on the occlusal surface of the healing abutment to be transferred accurately. A periapical radiograph was taken to confirm full seating of the abutment. An OptraGate® (Ivoclar Vivadent, Inc., Amherst, NY, USA) retractor was placed to isolate the site for scanning and create a dry field. A light dusting of a titanium dioxide powder was applied to the healing abutment and the adjacent teeth in the quadrant to afford higher resolution when scanning. The intraoral scanner was used to digitally capture the codes on the occlusal surface of the BellaTek Encode Healing Abutment, the surrounding soft tissue, and the adjacent teeth (Figures 2–4). The virtual image on the C.O.S. Monitor was evaluated for accuracy and accepted (Figure 5). Then the opposing arch was sprayed and scanned in similar fashion, followed by a scan of the buccal aspect of the patient's dentition in maximum intercuspation (Figure 6). The virtual images were evaluated for accuracy of detail and correct occlusal relationship.

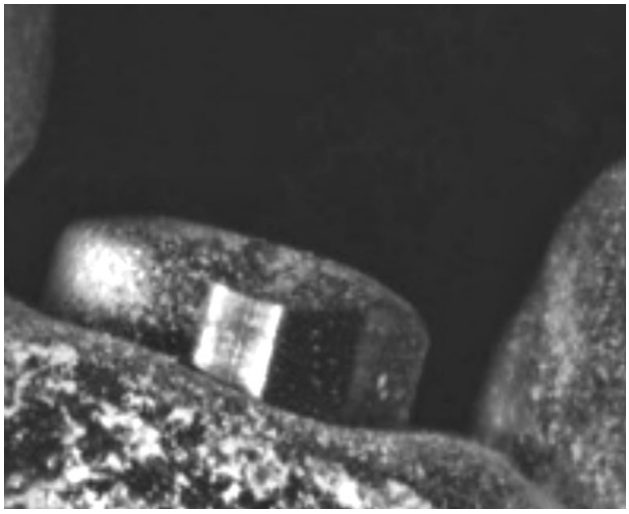

FIGURE 4. View of the digitally scanned BellaTek Encode Healing Abutment demonstrating that a minimum height of 1 mm is supragingival, circumferentially.

Using the Lava C.O.S software, the appropriate laboratory work order was completed and submitted electronically to the BellaTek Production Center. A technician imported the data into a 3Shape three-dimensional scanner (3Shape A/S, Copenhagen,

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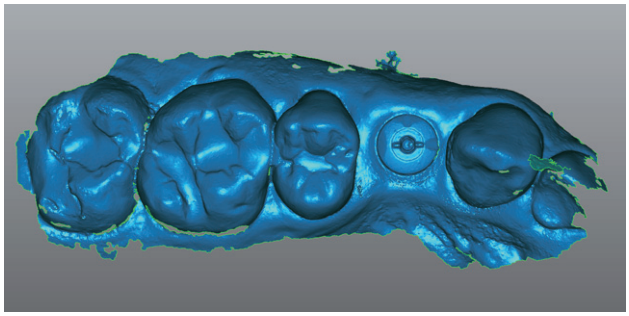

FIGURE 5. Digital three-dimensional model of the maxillary arch.

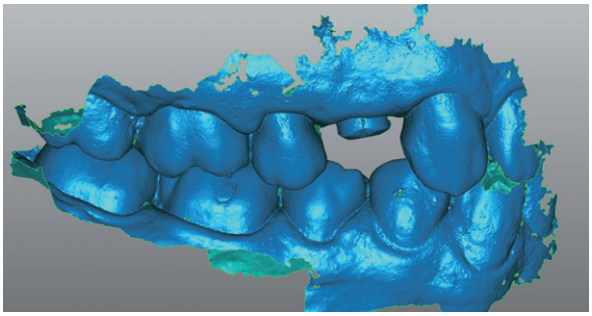

FIGURE 6. Buccal view of the BellaTek Encode Healing Abutment in place along with the opposing dentition in maximum intercuspation.

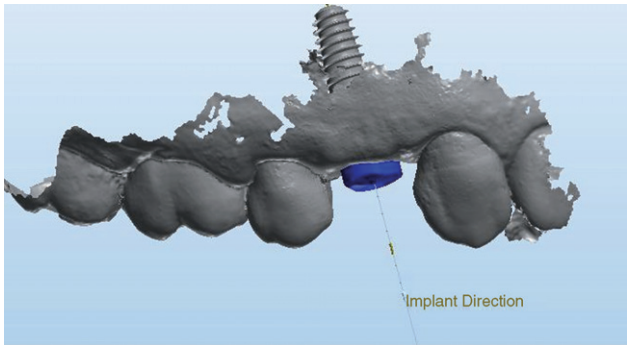

FIGURE 7. After being transmitted electronically to the BellaTek Production Center, the digital scan data was imported into a 3Shape three-dimensional scanner, in which special software was used to design the definitive abutment.

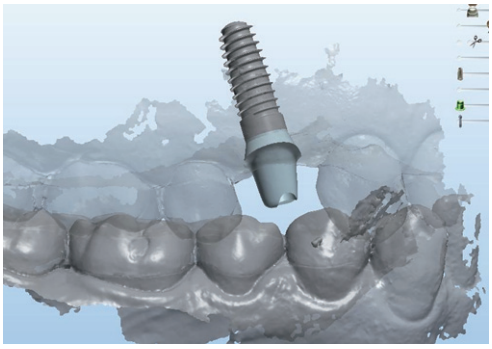

FIGURE 8. Buccal view of the virtual abutment design.

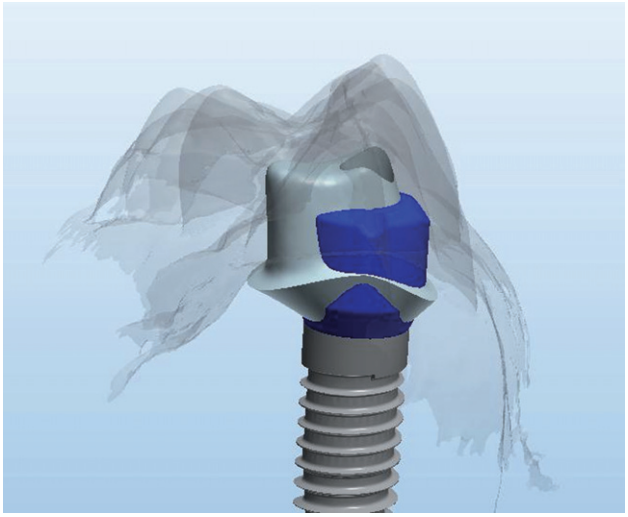

FIGURE 9. This cutaway view of the virtual abutment design shows that the abutment fits within the contours of the planned definitive restoration.

FIGURE 10. The patient-specific abutment was milled in zirconia, reproducing the dimensions of the virtual abutment design.

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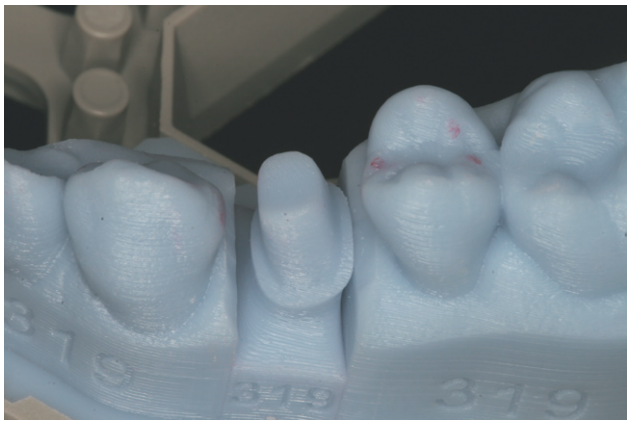

FIGURE 11. A stereolithographic model was fabricated at 3M from the digital data.

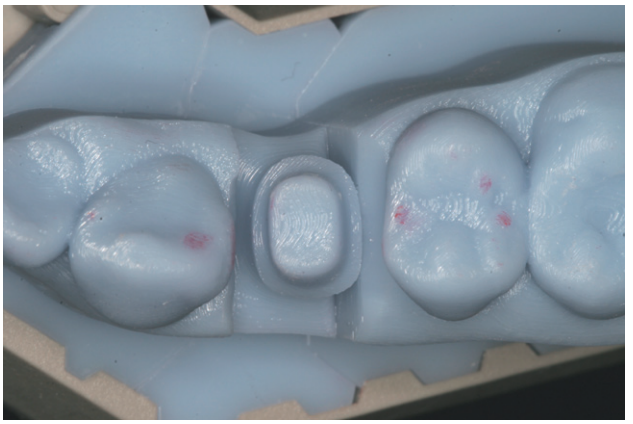

FIGURE 12. Occlusal view of the stereolithographic model.

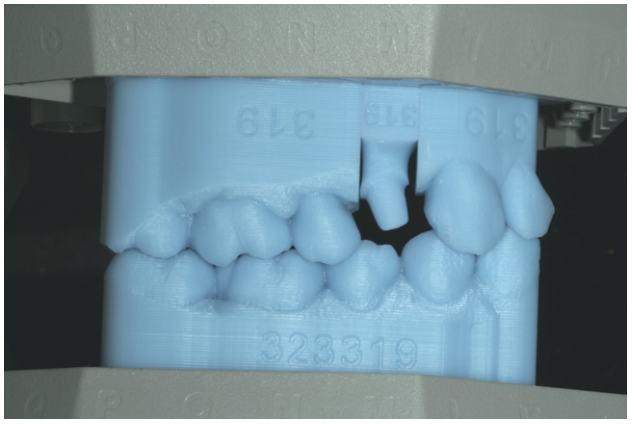

FIGURE 13. Buccal view of the articulated stereolithographic model.

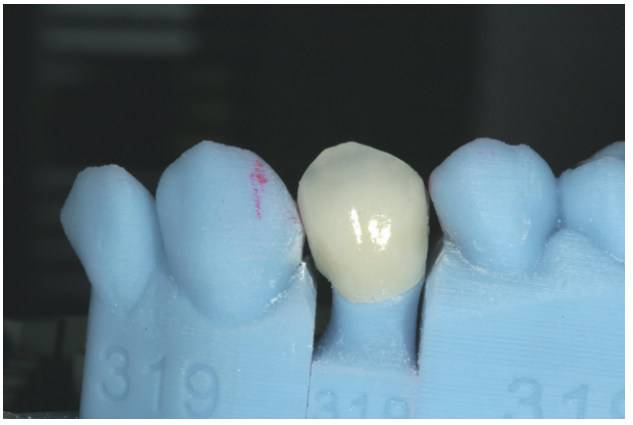

FIGURE 14. The definitive all-ceramic restoration on the stereolithographic model.

Denmark) (Figure 7), and the definitive abutment was designed virtually to fit within the confines of the planned definitive restoration (Figures 8 and 9).

Once the abutment design was completed, the data was transmitted to the milling machine for fabrication of a BellaTek Abutment in zirconia (Figure 10). Simultaneously, the data file was sent to 3M for fabrication of a stereolithographic (SLA) model (Figures 11–13). 3M sent the SLA model to the laboratory, which concurrently received the zirconia abutment from BIOMET ***3i***. Using the SLA model, the laboratory fabricated an all-ceramic restoration (Figure 14). Upon completion, the SLA model was sent to the restorative clinician, along with the abutment and restoration.

On the day of delivery, the precision of fit of the restoration to the abutment was verified (Figure 15). The BellaTek Encode Healing Abutment was removed, and the definitive zirconia abutment was placed into the implant and secured with an abutment screw. A periapical radiograph was taken to confirm complete seating, and the screw was tightened to 20 Ncm of torque (Figure 16). The restoration was tried in to verify contacts and occlusion. The screw-access opening was blocked with a cotton pellet. To ensure adequate bonding of the abutment to the restoration, zirconium primer (Monobond Plus, Ivoclar Vivadent)

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FIGURE 15. The definitive all-ceramic restoration fits precisely on the zirconia BellaTek Abutment.

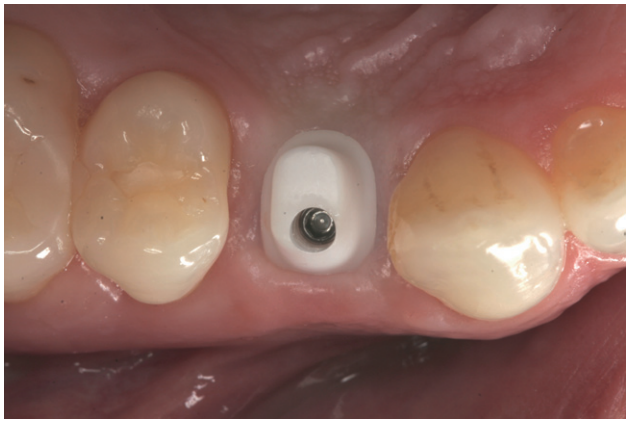

FIGURE 16. The zirconia abutment was seated and secured with the specific abutment screw and tightened to 20 Ncm of torque.

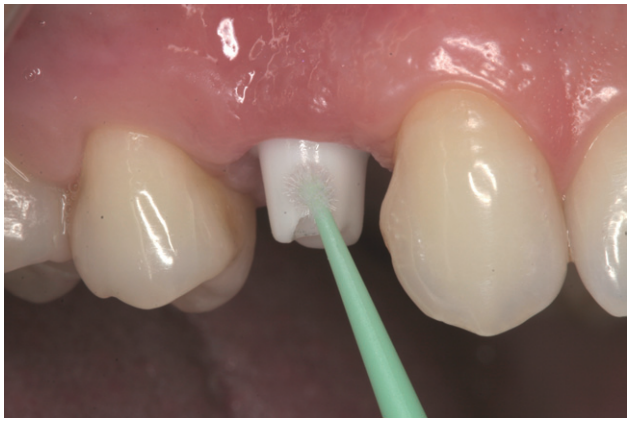

FIGURE 17. Zirconium primer was applied to the abutment.

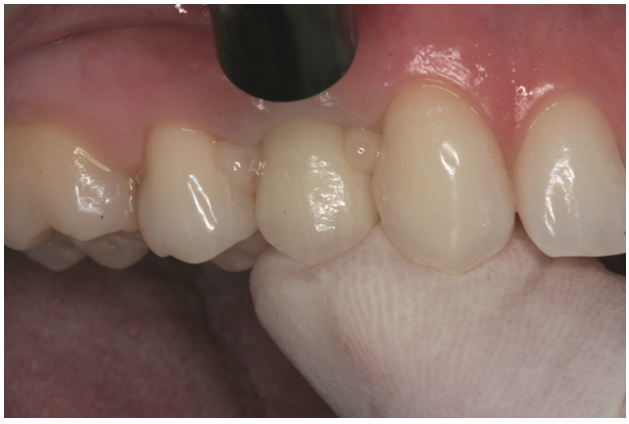

FIGURE 18. The all-ceramic restoration was cemented with resin cement.

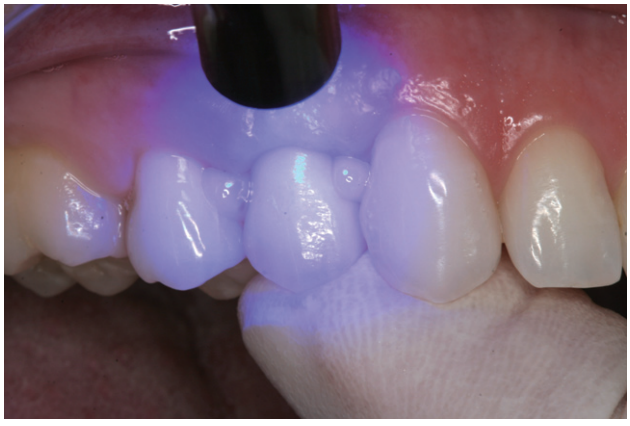

FIGURE 19. Excess cement was spot-tacked with a light-emitting diode curing light for 2 seconds on both the buccal and palatal aspects.

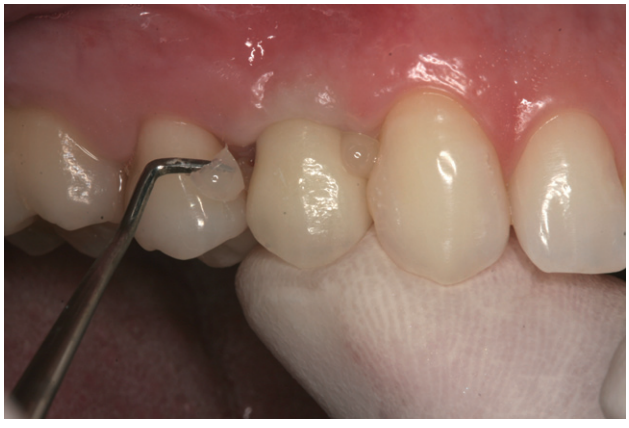

FIGURE 20. The excess cement was removed easily in the gel state.

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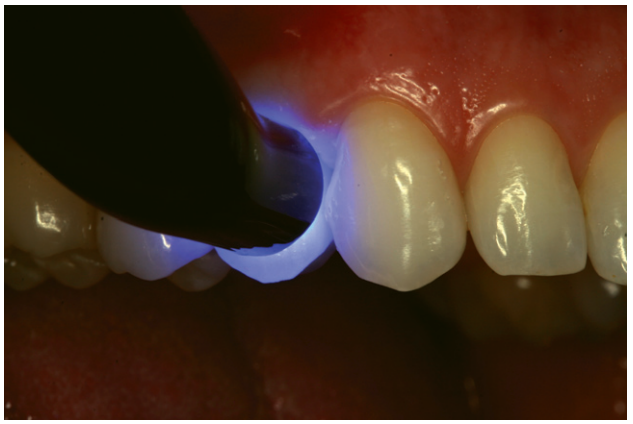

FIGURE 21. Final light-curing was accomplished.

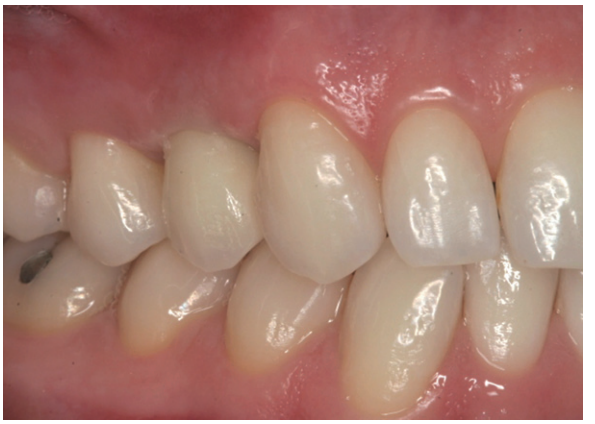

FIGURE 22. The restoration immediately after delivery and light-curing.

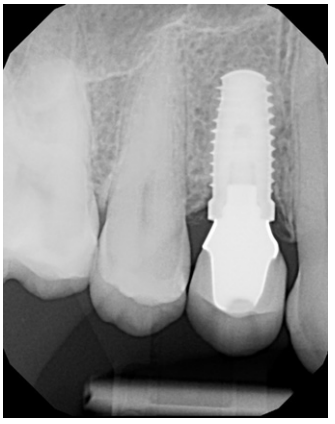

FIGURE 23. Radiograph taken immediately after delivery of the definitive restoration.

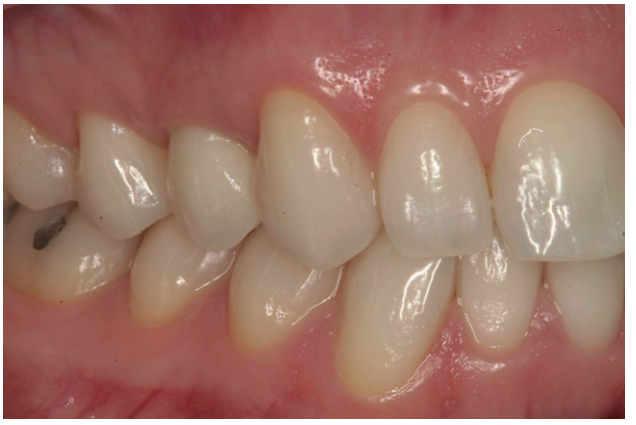

FIGURE 24. The restoration 6 months after delivery.

was applied to the abutment (Figure 17), and the restoration was secured with resin cement (Figure 18). Excess cement was spot-tacked with a light-emitting diode curing light for 2 seconds on the buccal and palatal aspects (Figure 19) and then removed (Figure 20). Final light-curing was accomplished (40 seconds buccal and palatal) (Figures 21 and 22). A periapical radiograph was taken (Figure 23), and the patient was given oral hygiene instructions, then released. Figures 24 and 25, taken at the 6-month follow-up appointment, demonstrate an esthetic and functional result. The patient was not only very satisfied with the result of treatment, but as a dental professional, she was excited to have benefited from the merging of these advanced technologies.

DISCUSSION

Since the first systems strictly intended for capturing digital impressions appeared in 2006,[11] several competing products have emerged. They include the Lava C.O.S, the Cadent™ iTero™ (Cadent, Inc., Carlstadt, NJ, USA), the CEREC Connect (Sirona Dental Systems, Charlotte, NC, USA), and the E4D Dentist® IntraOral Digitizer (D4D Technologies, Richardson, TX, USA). Whereas the CEREC and E4D scanners were introduced for chairside ceramic restoration fabrication, both the Lava and iTero Systems were created to electronically transmit digital data to the dental laboratory.[12] These systems use different technologies, but either can be used to scan BellaTek Encode Healing Abutments.

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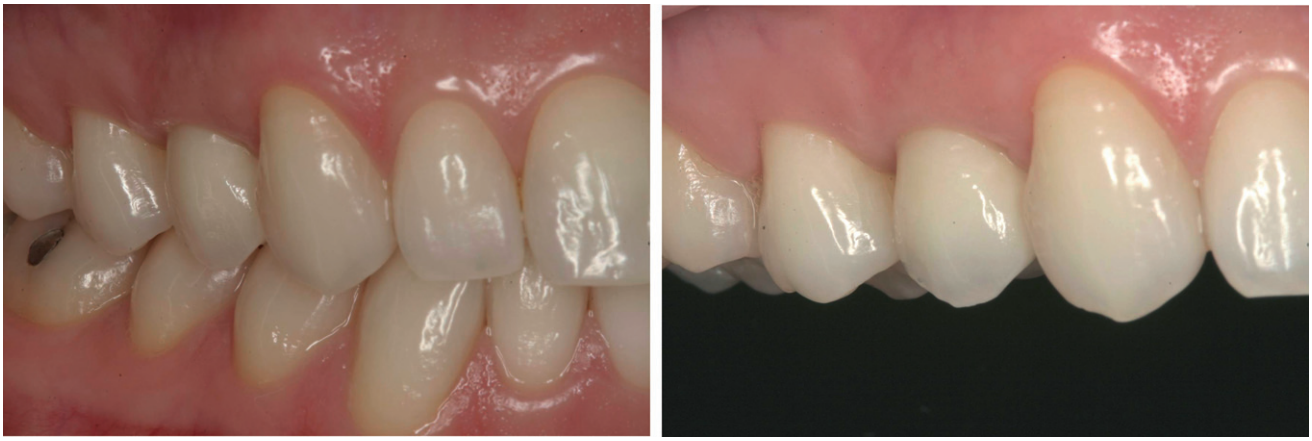

FIGURE 25. An excellent esthetic result was achieved.

As is the case when making traditional impressions, digital impression scanners cannot capture images through the soft tissue. In order to ensure direct visual access for the scanner, the Encode Healing Abutments must be at least 1 mm supragingival circumferentially. Otherwise, the codes will not be transferred accurately. Adequate control of the oral fluids also is essential as heavy saliva or blood can impair accurate capture of the digital image.

CONCLUSION

Recent approval by the US Food and Drug Administration of the use of intraoral digital scanners for making digital impressions of coded implant healing abutments has the potential to simplify the task of obtaining implant impressions. Combining digital scans of coded implant healing abutments with CAD/CAM technology enables a dramatic compression of the time required to deliver definitive crowns, bridges, and full-arch restorations supported by implants and patient-specific abutments that fit more precisely than those fabricated by traditional methods. The merging of advanced dental technologies eliminates the need for conventional elastomeric impression materials, the use of which is subject to error. Such materials also require messy mixing and clean-up and are repugnant to many patients.

DISCLOSURE AND ACKNOWLEDGEMENTS

The authors have no financial interest in any of the companies whose products are included in this article.

Both Dr. Ramsey and Dr. Ritter have received honoraria in the past as lecturers for BIOMET ***3i***.

Surgical colleague: Karina Leal, DMD, West Palm Beach, FL. Laboratory colleague: Frank Lavonia, CDT, Biotech Dental Prosthetics, Palm Beach Gardens, FL.

REFERENCES

1. Duret F, Blouin J-L, Duret B. CAD-CAM in dentistry. J Am Dent Assoc 1988;117:715–20.
2. Kucey BK, Fraser DC. The Procera abutment—the fifth generation abutment for dental implants. J Can Dent Assoc 2000;66:445–9.
3. Papazian S, Morgano SM. A laboratory procedure to facilitate the development of an emergence profile with a custom implant abutment. J Prosthet Dent 1998;79(2):232–4.
4. Priest GF. Virtual-designed and computer-milled implant abutments. J Oral Maxillofac Surg 2005;63(Suppl 2):22–32.
5. Clancy JM, Scandrett FR, Ettinger RL. Long-term dimensional stability of three current elastomers. J Oral Rehabil 1983;10(4):325–33.

 DOI 10.1111/j.1708-8240.2011.00481.x

6. Hondrum SO. Changes in properties of nonaqueous elastomeric impression materials after storage of components. J Prosthet Dent 2001;85(1):73–81.
7. Thongthammachat S, Moore BK, Barco MT, et al. Dimensional accuracy of dental casts: influence of tray material, impression material, and time. J Prosthodont 2002;11(2):98–108.
8. Christensen GJ. The state of fixed prosthodontic impressions. J Am Dent Assoc 2007;138(4):527–9.
9. Christensen GJ. Will digital impressions eliminate the current problems with conventional impressions? J Am Dent Assoc 2008;139(6):761–3.
10. Christensen GJ. Impressions are changing. J Am Dent Assoc 2009;140(10):1301–4.
11. Avery DR. The maturation of CAD/CAM. Compend Contin Educ Dent 2010;31(5):391–8.
12. Fasbinder DJ. Digital dentistry: innovation for restorative treatment. Compend Contin Educ Dent 2010;31 Spec No 4:2–11.

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