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A Contemporary Approach to Intraoral Optical Scanning and In-Office 3-D Printing

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Learning Objectives: After reading this article, the individual will learn: (1) clinical applications of current intraoral optical scanning and in-office 3-D printing technologies, and (2) literature-supported accuracy of these technologies for replicating the dentition and oral tissues compared to conventional techniques.

About the Author

Dr. Scherer is an assistant clinical professor at Loma Linda University, a clinical instructor at University of Nevada-Las Vegas (UNLV), and maintains a practice limited to prosthodontics and implant dentistry in Sonora, Calif. He is a Fellow of the American College of Prosthodontists and has published articles related to implant dentistry, clinical prosthodontics, and digital technology with a special emphasis on implant overdentures. As an avid technology and computer hobbyist, Dr. Scherer's involvement in digital implant dentistry has led him to develop and utilize new technology with CAD/CAM surgical systems, implement student facilitated CBCT implant planning, and outside-of-the-box radiographic imaging concepts. He has served as the director of the implant dentistry curriculum at UNLV and is actively engaged in guided surgical placement and prosthetic restoration of implants in private practice. Dr. Scherer also maintains "LearnLODI" and "LearnLOCATOR" interactive YouTube channels on standard- and narrow-diameter dental implant procedures. He can be reached via email at mds@scherer.net.

Disclosure: Dr. Scherer is a clinical consultant to 3M ESPE.

The traditional methods of replication of the dentition or oral tissues in clinical practice revolve around the use of various impression materials combined with dental laboratory techniques. These methods utilize materials such as reversible or irreversible hydrocolloid, vinyl polysiloxane, or polyether to record a detailed and accurate representation of hard and soft tissues and gypsum stone to fabricate a dental cast. Utilizing these materials and related techniques to fabricate indirect restorations has a long track record of proven accuracy for teeth, oral tissues, and dental implants.[1-4] While this research has shown repeatable accuracy, the traditional workflow is subject to potential errors throughout the process to fabricate a cast representation of the oral structures. Some of these potential errors can be derived from the following: improper humidity and temperature of the clinical, laboratory, or shipping areas; excessive or insufficient water-to-powder or base-to-catalyst ratio of the impression material or gypsum stone; mechanical undercuts and elastic deformation; excessive pressure applied during impression procedures, improper sterilization procedures; incompatible tray adhesives; incompatibilities of impression materials with gypsum and refractory materials; and inconsistent technique.[5-6]

Digital technology has rapidly become embraced by dentists and dental technicians alike to assist in CAD/CAM. In-office CAD/CAM technology such as CEREC (Sirona Dental) has been available to private practitioners since 1987.[7] While relatively cumbersome and inefficient at the time, this technology was exciting because it represented a watershed moment in clinical dentistry as it allowed for a sequential method of making impressions and restorations in a single clinical appointment. A clinician could make an optical impression of a tooth preparation and, minutes later, fabricate an aesthetic ceramic restoration. Almost 30 years later, it is interesting that approximately 14,000 American and 24,000 worldwide dentists utilize this technology within their offices.[8] While this may seem like a large figure, when comparing the total number of dentists in each respective group, these figures represent an implementation of 8% in America (186,000 total dentists) and 1% worldwide (1.8 million total dentists).[9,10] The most likely reason for this low implementation rate is the high initial cost. At approximately $100,000 USD, the high cost of this technology can be a substantial barrier to implementation. Additionally, many clinicians may not be comfortable with the philosophy and workflow to fabricate indirect ceramic restorations in their offices. Currently, in-office CAD/CAM machines are limited to ceramic restorations and are unable to produce metal-ceramic or full-cast restorations using the in-office CAD/CAM production unit. This type of change in technique is termed "disruptive technology" because the innovation results in complete change in the method and type of restoration the clinician fabricates.

CONTEMPORARY INTRAORAL OPTICAL SCANNING

In an effort to bring the digital approach that began with in-office CAD/CAM into routine clinical practice, manufacturers have developed stand-alone intraoral optical impression units and CAD/CAM restoration milling units. This approach is a departure from an "all-in-one" philosophy into one of an "a la carte," an approach that has resulted in growth of the digital dentistry

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Figure 1. Chairside intraoral optical impression scanner (True Definition Scanner [3M ESPE]).

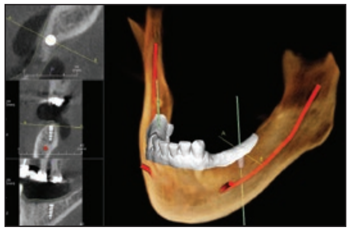

Figure 2. The CBCT reconstruction with an optical impression of a patient superimposed over the virtual rendering of the patient's jawbone structure (Invivo [Anatomage]).

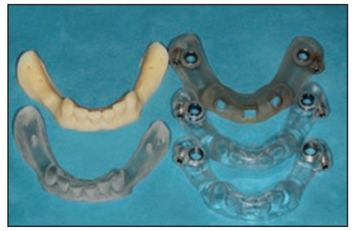

Figure 3. The 3-D printed replica of teeth and soft tissues allows for integration with dental implant surgical plans and creation of surgical guides (Anatomage Guide [Anatomage]).

Figure 4. A patient presents with an interim restoration in tooth No. 20.

workflow because of the substantially reduced cost. At approximately $15,000 USD for an intraoral optical scanning unit and $40,000 for a CAD/CAM restoration milling unit, the costs to implement this technology rapidly become more affordable. In addition, it allows clinicians to delegate responsibilities for fabrication of traditional indirect restorations to a technician in a similar manner to existing workflow. This type of change in technique is termed "adaptive technology" because the innovation results in slight modification in the method the clinician utilizes to create a similar restoration, which he or she would normally produce. The stand-alone optical impression units allow operators to simply modify their existing impression technique rather than change their complete clinical workflow.

Intraoral optical scanning has evolved into a contemporary method of replication of the dentition and oral tissues. The iTero Scanner (Align Technology), introduced in early 2006, was the first stand-alone optical scanner widely available to dentists. The technology utilizes a still image acquisition method using a red laser projected onto an object with "parallel confocal" technology similar to taking several photographs and stitching them together to form a panorama.[11] Introduced soon after the iTero, the True Definition Scanner (3M ESPE) (Figure 1), formerly known as the Lava C.O.S. scanner, uses an image beam led through a lens and projected onto a sensor to allow the image to go in and out of focus. A simple mathematical formula calculates the difference between the 2 and forms a solid object. This method allows capture of 3-D objects with video capture techniques and processing with "active wavefront sampling."[11] Other optical impression systems use a variety of image capture techniques including image triangulation (CEREC) and a proprietary reflected focal spot confocal image capture (TRIOS [3Shape]).[11] Intraoral optical scanning began with limited applications, including single-unit crowns, and has slowly evolved into partial-coverage restorations, full arches, and dental implants. More recently, open-source exporting of impressions allows for integration onto CBCT radiographs and for use with 3-D printing to fabricate a replica of the dentition and/or soft tissues (Figures 2 and 3). Digital impression systems allow the clinician to create a virtual 3-D image of a tooth preparation, adjacent teeth, opposing dentition, and other oral structures. After the 3-D image has been made, a laboratory prescription is created and is digitally signed. The 3-D image is uploaded to the dental laboratory, where the technicians can process the file using software programs to indicate restorative margins, preparation quality control, and to verify occlusion.

Two methods exist for the laboratory and clinician to utilize with optical impressions to fabricate an indirect restoration: the first technique fabricates a restoration using a die-trimmed 3-D printed model, and in the second, a technician uses the 3-D images generated from the optical impression to manipulate a virtual restoration and mill the restoration from a digital file. The first method, known as a "digital model" approach, uses 3-D printed models that look similar to conventional casts generated from elastomeric impression materials. A similar workflow to the conventional laboratory approach is utilized as the technician simply replaces the die-trimmed gypsum cast with a die-trimmed 3-D printed model. Conventional metal-ceramic restorations, all-ceramic crowns, implant restorations, removable partial dentures, and complete dentures can all be fabricated using this approach. Advantages over conventional gypsum casts include high-density 3-D printed models that are much more resistant to distortion, damage, and technician errors during laboratory fabrication techniques. Additionally, if a model is damaged or lost, an additional 3-D printed model can be fabricated with the same quality and accuracy as the original. The digital model approach allows for clinicians and laboratories to fabricate restorations using adaptive technology, such as

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intraoral optical scanning, to augment their normal techniques. This approach allows for conventional laboratory techniques to be performed in an established workflow currently in place in many clinical practices and laboratories.

The second approach to utilize optical scanning to fabricate restorations is known as a "digital modeless" approach. The modeless approach is typically used to fabricate ceramic restorations produced from a solid block of material using a reductive technique known as "milling." After the virtual restoration has been created, the restoration is sent to the milling machine and is milled using diamond burs to create a detailed restoration from a larger block of material. After completion of the milling process, the laboratory technician can finish and polish the restoration and is able to cut back some of the ceramic layer to allow for layering of highly aesthetic porcelain over the superior surface. The modeless approach is currently limited to all-ceramic restorations such as lithium disilicate or zirconia that can be produced with milling techniques. While the modeless approach is currently limited to ceramic restorations, research and development is being explored to expand technological applications for other restorations such as removable partial dentures, complete dentures, and metal-ceramic restorations.

Accuracy of optical scanning and investigation into the replication of tooth and oral tissues with both virtual and physical models has been a topic of active research and literature. Several authors have evaluated and compared the accuracy of conventional and digital impressions and have concluded that optical impressions are as accurate, if not more accurate, than conventional impression techniques.[12-15] Many hypotheses have been purported as the reasons for equal or increased accuracy of the digital techniques, but are typically attributed to the meticulous clinical or laboratory technique required for the conventional approach. While optical impressions are also subject to variations in accuracy due to technique, the numerous amounts of potential errors are reduced because of the digital approach.[15,16]

Efficiency and reproducibility of conventional technique and optical scanning have also been investigated in the literature. Authors have found that digital impression techniques are consistently faster than conventional techniques.[17,18] When investigating the total time for an impression, including setup, mixing (for conventional), making impressions, and processing (either digitally or in the laboratory with pouring casts), Lee and Gallucci[18] found that digital impression techniques reduced the total time by almost half. Other authors have found that digital

Figure 5. The tooth was prepared and a foundational restoration was placed (CLEARFIL DC CORE PLUS [Kuraray America]). Retraction cord (Ultrapak [Ultradent Products]) was placed and the patient remained closed on gauze for 2 minutes.

Figure 6. Contrast spray powder was applied and intraoral optical impressions were made using an intraoral scanner (True Definition Scanner).

Figure 7. Virtual rendering of optical impression shows instantaneous feedback of preparation details, allowing the clinician to make corrections if needed.

Figure 8. Provisional restoration (Luxatemp [DMG America]) was fabricated and cemented using a provisional luting agent (RelyX Temporary Cement [3M ESPE]).

Figure 9. The digital files of the preparation impression, opposing arch, and bite were sent to the laboratory. A metal-ceramic crown was fabricated on 3-D printed models.

Figure 10. The 3-D printed models mounted on a hinge articulator allow the laboratory and clinician to verify margin adaptation, occlusion, and aesthetics.

Figure 11. The provisional restoration was removed and cement cleaned from the preparation prior to trying in the definitive crown.

Figure 12. Adaptation of the crown was evaluated and very little adjustment was needed. The crown was cemented using a definitive luting agent (RelyX Luting Plus [3M ESPE]).

Figure 13. Reasonably priced, consumer-grade, 3-D printers (Form 1+ [Formlabs]) can be utilized in dental offices to fabricate models of teeth, edentulous ridges, and alveolar surfaces.

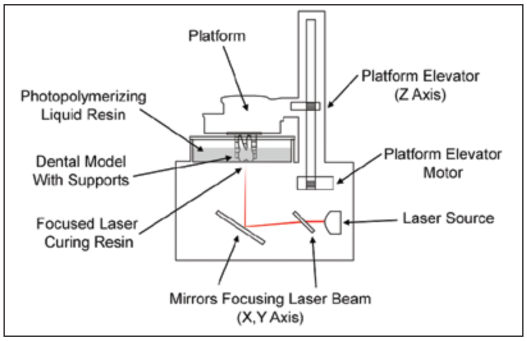

Figure 14. Schematic representation of a stereolithographic additive manufacturing printer. After uploading the stereolithography (STL) image file, the laser source emits an ultraviolet laser beam that is focused and reflected on a series of mirrors until it contacts photopolymerizing liquid resin within a container. Upon contact with the laser, the resin cures, forming a hard object. A platform elevates with the assistance of a motor, creating a full-sized physical object in small, incremental layers.

Figure 15. 3-D printed dental model with a traditional base replicating the teeth and oral tissues printed with a consumer-grade 3-D printer (Form 1+).

Figure 16. A A 3-D printed mandible of a patient missing all of his teeth was created using a CBCT radiograph and a consumer grade printer (Form 1+).

impression techniques are more reproducible, more consistent, and less technique sensitive than conventional techniques.[19,20] Finally, when evaluating patient perceptions of conventional versus digital techniques, patients often prefer the digital approach because of increased comfort and efficiency.[20]

CASE REPORT NO. 1

A patient presented to the author's clinical practice on an emergency basis with a concern regarding a fractured tooth. The patient reported that, one day prior, he closed down into a hard piece of candy, fracturing the existing restoration in tooth No. 20. Because the fracture was extensive, a full-coverage restoration was recommended, and the patient requested a laboratory fabricated restoration for tooth No. 20. An interim restoration was placed and the patient was appointed for a crown procedure (Figure 4).

After applying local anesthesia, the interim restoration was removed, a foundation restoration was placed (CLEARFIL DC CORE PLUS [Kuraray America]), and the tooth was prepared for a metal-ceramic crown. Retraction cord (Ultrapak [Ultradent Products]) impregnated with aluminum chloride (Hemodent [Premier Dental Products]) was placed around the tooth preparation and a light dusting of titanium dioxide contrast spray was applied (Figure 5). The cord was removed and an impression was made using an intraoral optical scanner (True Definition Scanner) (Figure 6). The impression of the quadrant with the tooth preparation was made in approximately 40 seconds and the complete capture of the axial walls and marginal surfaces was verified on the computer screen (Figure 7). Optical scans of the opposing teeth and a bite registration were subsequently captured with the intraoral scanner. A provisional restoration was fabricated (Luxatemp [DMG America]) and was cemented with a provisional luting agent (RelyX Temporary Cement [3M ESPE]) (Figure 8).

The digital impression scans were submitted to the laboratory with detailed instructions entered in the computer system. A request for a PFM restoration with aesthetic occlusal anatomy was specified. With this technique, the digital impression is received by the dental laboratory and margins are marked and models are built using planning software. The die-marked models are printed using an industrial-grade laboratory 3-D printer (Viper Pro [3D Systems]) and crowns are fabricated using conventional waxing and ceramic application techniques. Additionally, a secondary solid model is printed along with the die-marked models to provide a way for the laboratory to confirm contact points of the restoration.

One week after the submitting the impression files, the completed crown was received with the models used to fabricate the restoration (Figure 9). The crown was removed and inserted on the die-marked model to confirm marginal adaptation, occlusion, and aesthetics (Figure 10). The provisional restoration was removed and any residual provisional luting agent was removed from the preparation (Figure 11). The final restoration was tried in and required only a few minor adjustments. The restoration was cemented using a definitive luting agent (RelyX Luting Plus [3M ESPE]) (Figure 12).

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Figure 17. A patient presents with periodontally involved mandibular incisors.


Figure 18. Because of extreme mobility and concerns regarding traditional impression material from prematurely extracting teeth upon removal, an intraoral optical impression was made of the patient's dentition.

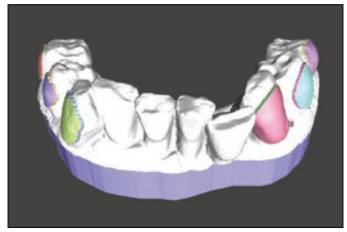
Figure 19. Using open-source software, a virtual model of the patient's teeth was created with a base for printing, and recesses were prepared on the facial aspects of the teeth for bleaching material.


Figure 20. The STL file was uploaded to the printer and a 3-D printed model was fabricated (Form 1+).

In-Office 3-D Printing: A Clinical Reality

Fabricating indirect restorations is a primary interest of clinicians who are new to, or considering incorporating, the digital workflow and intraoral optical impressions. Many clinicians, however, may also have the desire to fabricate study models for orthodontic treatment evaluation, diagnostic tooth arrangement prior to restorative therapy, and for dental implant procedures. While 3-D modeling is a relatively new and emerging technology within dentistry, its has been used for approximately 30 years within the field of mechanical engineering to produce a rapid model of a CAD drawing.[21]

The original 3-D printing technology is called "stereolithography" and was invented in 1986 by Charles Hull. The stereolithograph apparatus technology, commonly referred to as *SLA*, uses an additive manufacturing processing which utilizes a container of liquid ultraviolet (UV) photo-polymerizing resin and a UV laser to build parts one layer at a time until a solid object is formed out of the liquid resin container. Most commercially available printers are designed for use in large-scale production; however, recent development of consumer-grade SLA printers has made possible desktop 3-D printing within dental offices (Form 1+ [Formlabs]) (Figure 13). These newer consumer-grade printers have costs that are substantially lower than industrial grade 3-D printers traditionally available only to large dental laboratories.

SLA printing technology is a relatively simple production process that requires a significant precision and detailed control to produce replicas of teeth and oral tissues. Most SLA printers utilize liquid photo-polymerizing resin suspended in a container with a laser source emitted into the container to cure the resin in precise positions (Figure 14). The resin is a liquid mixture of methacrylate acid esters, acrylic acid esters, and photoinitiators that upon exposure to UV light, hardens. The most common method is using a UV light source from a laser focused upon a series of moving mirrors that control the *x* and *y* positions of the laser beam on a target source within the resin container. A horizontal platform is suspended in the resin and is controlled by a platform elevator moving the platform up out of the resin as the object is polymerized. This vertical movement controls the *z*-axis dimension (height) of the object. The object is created using a CAD software program, and a "print" command is issued, similar to what is done with a word processing document and an inkjet or laser printer. The 3-D models are created by converting optical images into stereolithography files—or STL files—which can be considered a 3-D .jpg or .gif image file for 3-D printing. The principal difference between 3-D and 2-D printing is the *z*-axis, allowing for a fully formed 3-D object that replicates teeth and oral tissues (Figure 15). Accuracy of the 3-D printed model is dependent upon the thickness of each incremental *z*-axis layer that is cured by the resin.

3-D printing allows for a fully formed 3-D object that replicates teeth and oral tissues.

Laboratories currently utilize 3-D printing technology in several applications. The most common is the "indirect method" of fabricating restorations by using models of teeth and tissues based upon the intraoral optical scans. After receiving the scan from the clinician, the laboratory utilizes a variety of computer software programs to produce a model that has a base and resembles our current gypsum dental casts. The model is fabricated out of the liquid resin to produce a hard resin model that corresponds to the shape of the virtual model. After printing, the model is cleaned and processed of the remaining liquid resin and can be utilized for a variety of applications, including fabricating simple study models provided to the clinician, indirect fixed restorations, orthodontic retainers, removable partial dentures, and

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Figure 21. The supports were removed and the model was processed with isopropyl alcohol. The model was placed in a vacuum-forming machine (MiniSTAR S [Great Lakes Orthodontics]) and a sheet of polyethylene was vacuum formed over the model (Bioplast [Great Lakes Orthodontics]).

Figure 22. The vacuum-formed matrix was trimmed and prepared.

Figure 23. Complete adaptation of the vacuum-formed matrix was confirmed and the patient was given instructions to properly utilize peroxide bleaching material prior to restorative therapy.

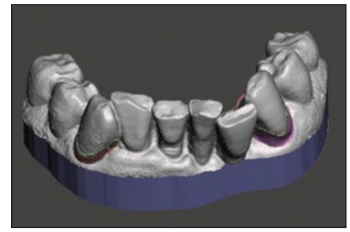

Figure 24. The virtual model used in **Figure 19** was modified by removing the bleaching reservoirs, and areas around the gingival margin were slightly enlarged to compensate for shrinkage of provisional restoration material.

complete dentures. The second method of using 3-D printing is the "direct method" of fabricating restorations by utilizing the intraoral optical scans using the modeless approach and directly printing the desired restoration. While this method seems relatively simple, it is largely encumbered by the research and development of the resin materials utilized in 3-D printing technology. Many of the currently available resins are not biocompatible and may not have ISO 10993-1 certification, which would allow them to be used within the mouth. The principal reason the resins are not used directly in the mouth is the unknown cytotoxicity, long-term stability, and functionality; as a result, if 3-D printing resins do have the proper ISO certification, they are still rated only for temporary use within the mouth. Ultimately, it is the goal of 3-D printing to be able to directly produce final and temporary fixed restorations, complete dentures, and orthodontic appliances. Ultimately, as the materials and systems develop, it will open multiple additional opportunities for dental applications.

Consumer grade resins can currently print layer thickness ranging from 25 to 250 µm, allowing for a tremendous amount of accuracy control. It is important to note, however, that higher accuracy prints require an increased number of layers, thus making for longer printing times. For example, if an object that a clinician wishes to print is 1.0 mm tall, printing at 100 µm accuracy means that a total of 10 print layers are required, whereas printing at 25 µm, 40 print layers are required. Considering that each layer requires an equal amount of time per layer, printing at the higher resolution will require approximately 4 times more printing time. Therefore, average dental models without large bases that a clinician wishes to print at 100 µm typically require one to 2 hours of printing time.

While intraoral optical impression workflows have been fairly well studied, less is known about the accuracy, precision, and reproducibility of models produced with the additive manufacturing process. One study determined that orthodontic study models produced with various different types of 3-D printing technologies produce models that are clinically accurate with a high degree of reproducibility.[22] Other studies have determined that there is a moderate amount of variability in 3-D printing technology and methods of printing.[23-24] While research with dental 3-D printing has been limited, it has been eagerly investigated in the medical literature. Authors have determined that industrial grade 3-D printers in conjunction with 3-D medical CT imaging reconstruction can produce highly accurate models prior to craniofacial surgery.[25] Further study has revealed that consumer-grade printers can produce highly accurate and reproducible models for the same surgical procedures that have a proven track record with industrial grade printers.[26] With the use of some relatively simple computer software programs and digital imaging and communications in medicine (known as DICOM) data from CBCT scans, similar models of the head and neck can be produced for use in in oral surgery and implant dentistry procedures with consumer-grade 3-D printers (Figure 16).

CASE REPORT NO. 2

A patient presented to the author's clinical practice for evaluation regarding the mobility of her mandibular incisors. The patient reported that she had a long-term history of having loose mandibular incisors due to a history of extensive periodontal disease and scaling and root planing procedures (Figure 17). Upon evaluation, periodontal measurements were within normal limits for teeth Nos. 22 and 27 but pocket depths for teeth Nos. 23 to 26 ranged from 5 to 10 mm; additionally, teeth Nos. 23 to 26 had Class III+ mobility. Several treatment options were presented, including an implant-supported fixed partial denture and removable partial denture options; the patient elected to have a conventional fixed partial denture fabricated between teeth Nos. 22 to 27 combined with conventional tooth bleaching

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prior to restorative treatment.

The patient expressed significant concern and visible dental anxiety when advised that inadvertent tooth extraction was possible with using traditional irreversible hydrocolloid impression materials. As a result of the high degree of mobility of the mandibular incisors, an intraoral optical impression scan with an intraoral optical scanner (True Definition Scanner) was made to avoid having to use conventional impression techniques (Figure 18). Using readily available, open source software, the 3-D image virtual model generated from the intraoral optical scan was manipulated to form a base to facilitate printing, and recesses were prepared on the facial aspects of teeth to hold peroxide bleaching material in place (Figure 19). After completion of the virtual model manipulation, an STL file was exported and placed into the printer software for printing and a 3-D printed model was fabricated (Figure 20).

After processing in isopropyl alcohol and curing in a light-curing oven, the model supports were removed and a matrix was created over the model using a vacuum-forming machine (MiniSTAR S [Great Lakes Orthodontics]) (Figure 21). The patient returned for evaluation of fit of her bleaching trays fabricated from the 3-D printed models (Bioplast [Great Lakes Orthodontics]) (Figure 22). The bleaching trays were tried in and full adaptation was confirmed (Figure 23). Instructions were provided for bleaching prior to restorative therapy and the patient was appointed for fixed partial denture preparation and provisional placement. After 2 weeks of bleaching, the patient was satisfied with the improvement in color of her teeth.

Prior to returning for restorative treatment, the original 3-D virtual model from the optical impression made previously was manipulated and prepared for fabricating a vacuum-formed template. In the open source software, the bleaching reservoirs were removed, and gingival tooth structure was slightly extruded to provide a slightly enlarged area corresponding to the proposed gingival margin of the tooth preparation (Figure 24). An STL file of the virtual model was exported and placed into the printer software for 3-D printing, and a 3-D printed model was generated (Figure 25).

The patient returned to the office for restorative treatment. After anesthesia was achieved, teeth Nos. 22 and 27 were prepared for PFM restorations and teeth Nos. 23 to 26 were prepared to the gingival margin to facilitate provisional procedures. A provisional vacuum-formed matrix was prepared using the 3-D printed model without bleaching reservoirs and tried in, confirming complete adaptation to the teeth (Figure 26).

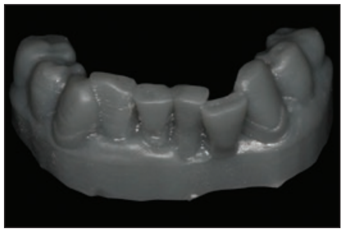

Figure 25. A 3-D printed model was fabricated and a vacuum-formed matrix was prepared on the model.

Figure 26. Two weeks after confirmation of bleaching shade preference, preparation PFM restorations were completed on teeth Nos. 22 and 27. Teeth Nos. 23 to 26 were trimmed to the gingival margin and a provisional was fabricated (Luxatemp).

Figure 27. Teeth Nos. 23 to 26 were extracted and the provisional was cemented using an interim luting agent (RelyX Temporary Cement).

A provisional restoration was fabricated using a bis-acryl provisional material (Luxatemp) injected into the vacuum-formed matrix produced with the 3-D printed model. During finishing and polishing procedures for the provisional restoration, teeth Nos. 23 to 26 were extracted. The provisional was cemented using a provisional luting agent (RelyX Temporary Cement) (Figure 27).

A limitation of conventional techniques for creating provisional and final indirect restorations is the need for impression materials that are stiff, and using gypsum casts that are prone to breakage and damage. This case report represents utilizing an intraoral digital impression technique to complement conventional techniques rather than completely replace them. Currently, at the time of publication of this article, directly printing provisional restorations using virtual models and STL files is in development; however, it is not currently widely used in dentistry. This case report aims to describe the blending of digital technology with conventional techniques, thus making the conventional approach simpler and more efficient.

CONCLUSION

Many clinicians are reluctant to integrate digital technology because it can be challenging, cumbersome, and prohibitively expensive. A contemporary approach to routine clinical dentistry has been presented, including intraoral optical impression scanning with in-office 3-D printing. Incorporating intraoral optical digital impressions is an established and well-accepted procedure that has a track record of accuracy and precision. Its use enables clinicians to integrate a technology that does not change how they perform dentistry and the types of restorations fabricated, but merely changes the way the clinician makes an impression of the tooth or oral tissues. In conjunction with in-office 3-D printing, clinicians can skip the step of having to make a traditional impression and pour a cast by utilizing additive manufacturing techniques. These technologies seek to develop "adaptive innovation" to allow integration of digital technology to augment their clinical procedures, rather than creating "disruption innovation" by requiring clinicians to completely change the materials they use and procedures they normally perform.

Although this technology is still in its relative infancy, the outlook is very promising. With time, innovation within intraoral optical scanning and 3-D printing should continue to allow clinicians to make complex procedures simpler and more efficient.✦

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POST EXAMINATION QUESTIONS

1. In the "digital model" technique, which uses 3-D printed models, the following type(s) of restorations can be fabricated:
a. All-ceramic crowns.
b. Implant restorations.
c. Removable partial dentures.
d. All of the above.

2. When compared to conventional gypsum casts, high-density 3-D printed models are much more resistant to distortion, damage, and technician errors during laboratory fabrication procedures.
a. True.
b. False.

3. The "digital modeless" approach is typically used to fabricate ceramic restorations using a reductive technique known as milling. The modeless approach is currently limited to all-ceramic restorations such as lithuium disilicate or zirconia.
a. The first statement is true, the second is false.
b. The first statement is false, the second is true.
c. Both statements are true.
d. Both statements are false.

4. Digital impressions have been found to be as accurate as, if not more accurate than, conventional impression techniques. Studies indicate that digital impression techniques require more time than conventional impression techniques.
a. The first statement is true, the second is false.
b. The first statement is false, the second is true.
c. Both statements are true.
d. Both statements are false.

5. In case report No. 1, using an intraoral optical scanner, the time required to take a digital impression of the quadrant with the tooth preparation was approximately:
a. 40 seconds.
b. 60 seconds.
c. 90 seconds.
d. 120 seconds.

6. Stereolithography, or SLA, is the original:
a. CAD/CAM milling technology.
b. Optical scanning technology.
c. 3-D printing technology.
d. None of the above.

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7. The principal difference between 3-D and 2-D printing is:
a. *x* axis.
b. *y* axis.
c. *z* axis.
d. None of the above.

8. Many of the currently available resins used in 3-D printing technology are not biocompatible and may not have ISO 10993-1 certification.
a. True.
b. False.

9. In 3-D printing, higher accuracy prints require an increased number of layers. For example, if an object to be printed is one mm tall, printing at 100 µm accuracy means a total of 10 print layers is required.
a. The first statement is true, the second is false.
b. The first statement is false, the second is true.
c. Both statements are true.
d. Both statements are false.

10. In 3-D printing, average dental models without large bases that are printed at 100 µm accuracy typically require how much printing time?
a. 30 minutes.
b. One to 2 hours.
c. 2 to 3 hours.
d. 3 to 4 hours.

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Please check the correct box for each question below.

1.	❑ a	❑ b	❑ c	❑ d	6.	❑ a	❑ b	❑ c	❑ d
2.	❑ True		❑ False		7.	❑ a	❑ b	❑ c	❑ d
3.	❑ a	❑ b	❑ c	❑ d	8.	❑ True		❑ False	
4.	❑ a	❑ b	❑ c	❑ d	9.	❑ a	❑ b	❑ c	❑ d
5.	❑ a	❑ b	❑ c	❑ d	10.	❑ a	❑ b	❑ c	❑ d

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Please complete the following activity evaluation questions.
Rating Scale: Excellent = 5 and Poor = 0

Course objectives were achieved. ______
Content was useful and benefited your clinical practice. ______
Review questions were clear and relevant to the editorial. ______
Illustrations and photographs were clear and relevant. ______
Written presentation was informative and concise. ______
How much time did you spend reading the activity and completing the test? ______
What aspect of this course was most helpful and why? ______

What topics interest you for future *Dentistry Today* CE courses?