Quality Resource Guide

First Edition

Overview of Digital Restorative and Prosthetic Dentistry

Author Acknowledgements

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Educational Objectives

Following this unit of instruction, the learner should be able to:

1. To conceptualize using intraoral scanning technology to create virtual representations to develop fixed and removable prostheses.
2. To compare and contrast the analog and digital workflows recommended for fixed and removable prostheses.
3. To discuss the advantages and disadvantages of analog and digital fixed and removable prosthetic techniques and protocols.
4. To discuss the advantages and disadvantages of subtractive (milling) and additive (3D printing) technologies.

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The following commentary highlights fundamental and commonly accepted practices on the subject matter. The information is intended as a general overview and is for educational purposes only. This information does not constitute legal advice, which can only be provided by an attorney.

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Introduction

In general terms, digital dentistry commonly refers to the process of undertaking patient care by using at least one tool or process from the digital workflow in the digital environment. The digital environment has expanded to add to or even replace some of our analog processes and devices (**Table 1**). Today, a dental prosthesis can be produced solely using a digital workflow.

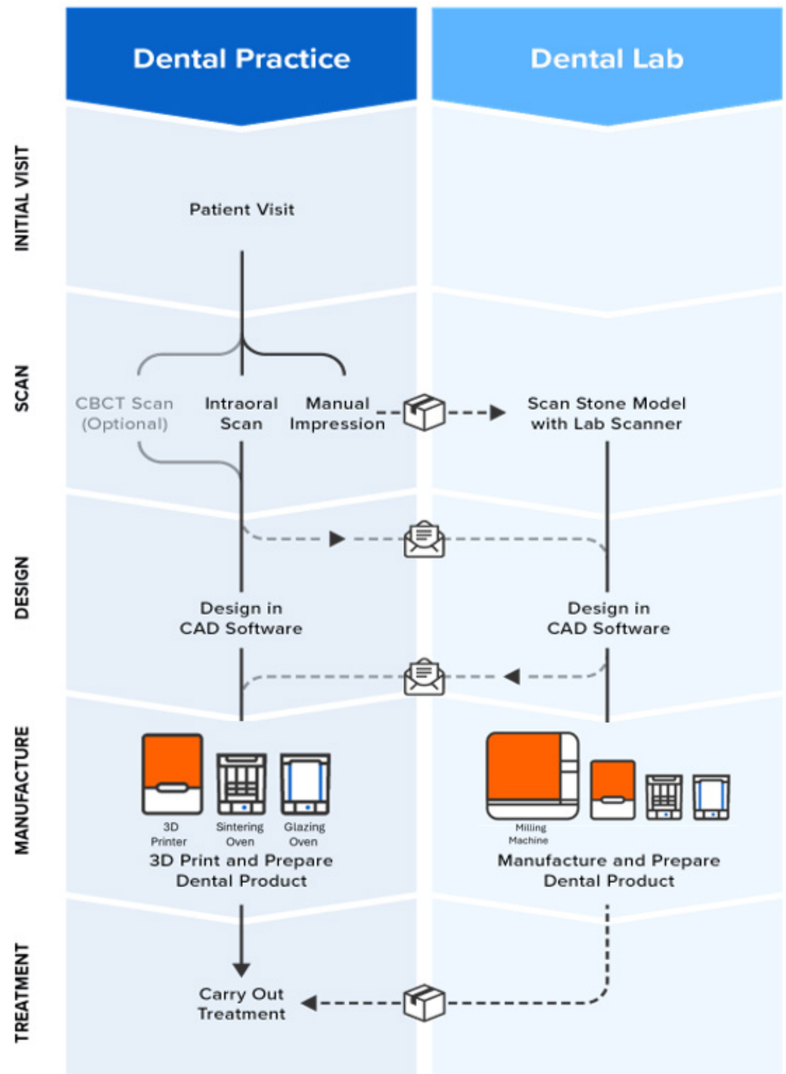
Each digital process or device uses specific file types for interaction and communication and continues to evolve to incorporate aspects of AR (Augmented Reality) and AI (Artificial Intelligence). The computer-aided design and computer-aided manufacturing (CAD/CAM) systems available for dentistry range from complete systems that scan, design, and mill to those that only perform certain functions, such as digital scanning only, exclusively designing restorations, or milling/printing restorations. The fabrication and production of restorations occur in three environments: chairside in the dental practice, dental laboratories, and milling centers.

The dental digital experience can be divided into three major processes: (1) Scanning (Data acquisition), (2) Designing, and (3) Manufacturing (**Figure 1**). As an example, CAD/CAM technology is essentially a combination of the three processes mentioned: data or image acquisition, image/information analysis and manipulation or computer-aided design, and fabrication or computer-assisted manufacturing. Data is acquired through a variety of techniques that capture relevant images (digital intra-oral / extra-oral scanning and /or digital extra-oral photography). Software is then used to render, analyze, and manipulate the images. Milling units (3 or 5 axes) or three dimensional (3D) printers are then used to fabricate the CAD created restorations or treatment components. Like all aspects of healthcare, as technology continues to improve/advance, the workflow, specific equipment, and materials may be upgraded or replaced to better meet the needs of patient care.

Table 1 - Some Digital Processes and Devices

Digital articulators	Digital facebows
Digital casts	Digital models
Digital imaging and communications in medicine (DICOM)	Digital impressions
Digital light processing	Digital printing
Digitally fabricated dentures	Digital scans
Digital sculpting	Digital surgical planning

Figure 1



Basic steps required for dental prosthesis production using digital technology. The left column illustrates an in-house workflow, while the right column illustrates the use of an off-site dental laboratory. The horizontal dashed lines indicate the various shipping and communication steps necessary between the dental practice and the dental laboratory.

Data Acquisition (Intraoral Scan)

An intraoral scanner (IOS) is an optical scanner (a type of image scanner) that is usually comprised of a handheld camera (hardware), computer, and software, that captures and analyzes reflected light to generate 3D images that represent the intraoral environment.

Data formats include standard tessellation language (STL) and polygon file format (PLY). An intraoral scan is the process of using an IOS inside the mouth to capture and digitally record 3D data that represents the qualities of objects within the field of view, including size, color, and texture. Currently, there are many different manufacturers of quality intraoral scanners, and many employ an open software design that allows the opportunity to use other brands of design software and hardware to best meet the needs of the practice. The decision as to which IOS is best should be based on comparing different manufacturers to determine which best fits your practice needs. There are numerous YouTube videos available that compare many IOS devices. One such example is "Top Intraoral Scanner Comparison," which may help inform you of what IOS best meets your practice needs.[1] Most quality manufacturers offer training packages for you and your staff so the team can be efficient in the early stages of adoption, which ultimately benefits patient care.

When scanning for fixed or removable restorative care, the same techniques used in the traditional (analog) impression-making procedure are necessary, as intraoral scanning is intended only to replace the use of an impression tray filled with impression material. Proper isolation and appropriate retraction techniques are still required to expose margins.

Fixed Restorative Care

There is sufficient evidence validating the accuracy of intraoral scanning to support it as a treatment of choice for all routine and complex fixed restorative care.[2] This would include natural teeth, implants, or a combination of both. Typically, the clinician scans the arch being treated and the opposing arch, and then obtains a third buccal scan with the teeth in maximum intercuspation (MI). This allows the individual scans to be oriented much like on an articulator for design and fabrication. When dental implants are a part of the treatment, in a fully digital workflow, scan bodies that represent the specific brand implant(s) are placed after the healing abutments are removed to record the exact position(s) in three dimensions. The scans are sent to a laboratory equipped to accept the files to design the final restoration(s). A proposed design would then be sent to the provider for approval and/or recommended changes. In a hybrid digital workflow, the impression and bite registration can be made by the conventional method (analog) and sent to the lab for scanning and design. If implants are involved, implant analogs, not scan bodies, would be placed after removal of the healing abutments and before the final impression is taken. The proposed final restoration(s) design is sent to the provider for approval and/or recommended changes.

Dental ceramics have become increasingly popular as restorative materials because of their esthetics and biocompatibility.[3] Today, all ceramic restorations represent more than 80% of fixed restorations produced in the United States, and this number is increasing due to the higher demand for esthetics and the availability of new ceramic materials with superior properties.[3,4] The invention of new ceramics such as high alumina-dense ceramics[5,6], high leucite,[6] lithium disilicate, and zirconia have expanded the indications of all ceramics in restorative dentistry.[3,6,7]

Digital dentistry has changed the fixed restorative field dramatically since 1985, with most ceramic materials being compatible with CAD/CAM methods.[8] Digital workflow, in combination with advanced milling technologies, results in the fabrication of ceramic restorations that are superior in marginal and internal fit, when compared to equivalent analog restorations[8] and provide a better clinical outcome and durability due to being more homogeneous with fewer internal defects.[3,9]

Although today, milling is the gold standard for manufacturing ceramics in digital dentistry with a proven track record,[10] there are shortcomings and limitations. These mainly consist of consuming excessive materials, producing unusable waste, and not being able to produce complex geometries and details.[11] Also, machining processes such as milling or grinding cause high tool wear, leading to high production costs.[12]

Additive Manufacturing (AM) is a new manufacturing technique introduced in dentistry. AM has advantages over subtractive or milling technologies by avoiding material waste and producing complex geometries with greater accuracy.[9] More importantly, it allows for more product customization.[9,12] Although AM is a valid manufacturing process for metals and polymers, its use in the fabrication of ceramic restorations remains to be established and validated.

Ceramics can be additively manufactured using direct and indirect methods. In the direct technique, the ceramic material is deposited on the building area to form a layer that is sintered immediately to densify the layer; therefore, not requiring post-processing steps. In the indirect method, the ceramic material is deposited on the building area the same way as the direct method but is not sintered and remains in the unsintered "green stage" for try-in purposes and adjustments as needed prior to final post-processing steps. The advantages of this technique are short processing times and minimized material shrinkage, but this procedure does create ceramic objects with excess porosity and high surface roughness. Although numerous AM technologies have been successfully used in manufacturing dental ceramics and there are promising preliminary in vitro studies, AM dental ceramics have not been accepted and approved for use in clinical applications yet.

Removable Restorative Care

Additive manufacturing of complete dentures normally involves fabricating the denture base and the denture teeth independently using polymer 3D printing. Both printed parts are bonded together using a light-polymerization bonding agent.[13,14] Alternatively, commercially available denture teeth can be bonded to additively manufactured denture bases. During the digital design of the complete dentures, the commercially available teeth are selected from the denture teeth library of the CAD software program.

Limited studies in the dental literature have analyzed and compared the fracture resistance[15] or wear resistance[16] of AM and commercially available denture teeth. Results suggest that AM denture teeth might exhibit adequate resistance and wear properties to support their use in clinical practice.[15,16] In the case of removable restorative care (both complete dentures (CDs) and removable partial dentures (RPDs)), intraoral scanning is possible. However, due to the design limitations of current IOS devices, they can only capture the tissues at rest. IOS devices cannot capture the critical vestibular extension obtainable through a conventional (analog) impression technique for a complete denture using the selected pressure or equal pressure impression philosophy. A hybrid technique addresses this deficiency. A conventional (analog) tray and final impression technique would be completed and then sent to the lab to be scanned. This approach accommodates maximum extension and the above-mentioned impression philosophies. There are numerous companies and labs that support a fully digital impression workflow. Each may provide their own specific bite registration tray that allows for midline orientation and is scanned to allow alignment of the individual arches at the proposed vertical dimension of occlusion (VDO). A trial denture would be sent back to the provider for review/approval/patient try-in. Once approved, the final prosthesis would then be digitally fabricated by either an additive (printing) or subtractive (milling) process.

Unlike complete dentures, removable partial dentures rely on a tooth supported framework design for retention and support, with limited tissue support depending on the edentulous Kennedy Classification. In these cases, a complete digital workflow is reasonable with intraoral scanning of both the hard and soft tissues. Specific dental CAD software programs facilitate the virtual design of RPDs, including the metal framework design. Typically, the design is initiated following the digitalization of definitive working casts. The CAD software program allows the practitioner to identify undercut locations, select the path of insertion, and design the RPD framework components. Once completed, the virtual design of the metal framework, in a STL file format, is exported and used to additively manufacture the metal framework of the dental prostheses. The teeth are prepared according to the desired framework design philosophy as in the conventional method.

If implants are a part of the treatment being rendered, scan bodies would have to replace the healing abutments before scanning for the same purposes as mentioned in a fixed restorative impression. The use of scan bodies will register the position of the implant in 3 dimensions for treatment planning and final treatment decisions. The purpose of a healing abutment is to support soft tissue during healing. An IOS is used, as previously described, for a fixed restoration to capture the necessary images. If the hybrid technique is used with the conventional impression technique, implant analogs would replace the healing abutments before the impression is made and sent to the lab for scanning. In addition, a scan of the opposing arch or conventional impression with a bite registration would be sent to the lab for orientation/design and fabrication. Individual labs may have specific workflows that support their capabilities, so it is always best to research/contact digitally capable labs that align with your practice processes and materials. It is always best to accomplish a framework try-in before final fabrication regardless of the workflow you select (fully digital or hybrid).

Summary

Digital dental technology is rapidly evolving to create workflows allowing for in-house chairside and laboratory clinical advancements. When combined with future material advancements, the use of digital dental technologies should lead to improved patient outcomes. To date, subtractive manufacturing technologies, although impressive, are limited by the tooling capabilities of the mill, which often require more tooth reduction than the additive manufacturing approach. However, the current dental materials used to support printing (metals/ceramics/acrylics) do not share the same long-term mechanical properties as milled. It is critical for the practitioner to stay informed to select the best digital workflow available for the planned patient treatment.

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1. **Digital Dentistry is:**
   a. the process of undertaking patient care by using at least one tool or process from the digital workflow in the digital environment.
   b. the process of undertaking patient care by completely using every tool or processes from the digital workflow in the digital environment.
   c. the process of undertaking patient care by completely using analog tools or processes from the conventional workflow in the analog environment.
   d. the process of undertaking patient care by using at least one tool or process from the conventional workflow in the analog environment.

2. **The dental digital experience can be broken down into three major processes:**
   a. (1) Scan (Data manipulation), (2) Design (Data acquisition) and lastly (3) manufacturing (Data processing).
   b. (1) Manufacturing (Data processing), (2) Design (Data acquisition) and lastly (3) Scan (Data processing).
   c. (1) Scan (Data acquisition), (2) Design (Data manipulation) and lastly (3) manufacturing (Data Processing).
   d. (1) Design (Data acquisition), (2) Scan and lastly (3) manufacturing.

3. **An open design system:**
   a. Allows the operator to use different manufacturers of both hardware and software throughout the digital workflow.
   b. Allows the operator to use different manufacturers for the scan and manufacturing components only of the digital workflow.
   c. Allows the operator to use different manufacturer for only the software components of the digital workflow.
   d. Allows the operator to use different software components but the hardware must be from the same manufacturer.

4. **Data acquisition:**
   a. Can be from an optical intraoral scanner (IOS) only and stores data in either standard tessellation language (STL) and polygon file format (PLY).
   b. Can be from an optical intraoral scanner (IOS) or a lab scanner and stores data in either standard tessellation language (STL) and polygon file format (PLY).
   c. Can be from an Lab scanner only and stores data in either standard tessellation language (STL) and polygon file format (PLY).
   d. Can be from an optical intraoral scanner (IOS) or a lab scanner and stores data in standard tessellation language (STL) file format only.

5. **When considering the digital workflow for complete denture dental treatment, an advantage(s) of using a hybrid technique include:**
   a. ability to extend into the vestibule
   b. ability to support multiple impression philosophies
   c. does not require the use of a traditional impression tray
   d. Both A and B are correct

6. **The manufacturing component of the digital workflow:**
   a. Can be additive (printing) or subtractive (milling), both which have the same applications and limitations for patient care.
   b. Can be additive (printing) or subtractive (milling), both which have different applications and limitations for patient care.
   c. Can be additive (printing) or subtractive (milling), both using the same materials for patient care.
   d. Can be additive (printing) or subtractive (milling), both use different materials and have the same applications and limitations for patient care.

7. **When scanning for fixed or removable restorative care:**
   a. The same techniques used in the traditional (analog) impression-making procedure are necessary.
   b. Moisture control is not necessary as the intraoral scanner is an optical scanner and will only read hard and soft tissue.
   c. Soft tissue retraction is not necessary as the intraoral scanner is an optical scanner and is able to read hard and soft tissue in very limited spaces.
   d. Both B and C are correct.

8. **When considering the digital workflow for patient care:**
   a. There is sufficient evidence now to support the accuracy of intraoral scanning for all routine and complex fixed restorative care as a treatment of choice.
   b. There is sufficient evidence now to support the accuracy of intraoral scanning for routine and complex fixed restorative care as a treatment of choice for natural teeth only.
   c. Currently there is not sufficient evidence to support the accuracy of intraoral scanning for all routine and complex fixed restorative care as a treatment of choice for natural teeth.
   d. Currently there is not sufficient evidence to support the accuracy of intraoral scanning for routine and complex fixed restorative care as a treatment of choice for implants and natural teeth combined.

9. **Currently in the digital workflow:**
   a. Intraoral scans are sent to the lab and are converted to printed casts for analog articulation and the fabrication of the final restoration, which is then scanned for milling or printing.
   b. Intraoral scans are sent to the lab for design and articulation, which are then printed in wax for fabrication by milling or printing.
   c. Intraoral scans are sent to the lab for design and articulation, then directly to the mill or printer for fabrication.
   d. Intraoral scans are sent to the lab for analog articulation, design and fabrication.

10. **Milling as compared to printing is the gold standard for manufacturing ceramics in digital dentistry. Some disadvantages include:**
    a. Excess waste of material
    b. High tool wear
    c. Unable to produce complex geometries and details
    d. All of the above

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