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Digital Dental Workflow- How Far We Know?

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ABSTRACT

Digital dentistry has fundamentally transformed patient care by incorporating digital technologies into every aspect of dental practice, from diagnosis and treatment planning to restoration. This comprehensive approach utilizes a variety of technologies, such as CAD/CAM, 3D printing, AI, AR, and tele dentistry, making it a swiftly evolving and highly transformative field. In recent years, CAD/CAM technology has made significant strides, leading to new techniques in oral rehabilitation. These innovations often differ from traditional methods in how impressions are taken (e.g., traditional impressions versus intraoral scanning) and how restorations are created (e.g., conventional waxing and casting versus CAD/CAM). The integration of digital technologies in dentistry has significantly enhanced the precision, accuracy, and efficiency of dental procedures, leading to better patient outcomes. Digital dentistry has reshaped how dental professionals diagnose, plan, and treat their patients, making processes more efficient and outcomes more predictable. The digital dental workflow represents a major advancement in modern dentistry by combining various digital technologies to improve accuracy and efficiency. This workflow not only streamlines the treatment process but also minimizes the potential for errors, enhances communication among dental professionals, and increases overall patient satisfaction. As technology continues to advance, the digital dental workflow is expected to bring further transformations to dental practice, providing new opportunities for innovation and improved oral healthcare. The ongoing development in digital dentistry promises to continuously elevate the quality of dental care, making it more precise, efficient, and patient-centered.

Keywords: digital dentistry, workflow, CAD/CAM, 3D printing, artificial intelligence, intraoral scanning

INTRODUCTION

Digital workflow in dentistry involves several stages, including digital impression taking, computer-aided design (CAD), and computer-aided manufacturing (CAM). Digital impressions, captured through intraoral scanners, eliminate the need for traditional impression materials, offering a more comfortable experience for patients and precise data for clinicians. CAD software enables the design of dental restorations with high precision, allowing for customized solutions tailored to individual patient needs. Subsequently, CAM technology facilitates the fabrication of these restorations using advanced materials and milling machines, ensuring superior fit and durability. [1]

Evolution of Digital dental workflow

The evolution of digital workflow in dentistry has been marked by significant advancements in technology and practices, transforming traditional methods into highly efficient and precise digital processes. [2]

1. Early Beginnings (1980s-1990s)

Introduction of CAD/CAM Technology: Companies like Sirona (now Dentsply Sirona) introduced early CAD/CAM systems, such as CEREC, which allowed dentists to design and mill restorations in-office. [3-7]

2. Technological Advancements (2000s)

Introduction of Digital Impressions: The development of intraoral scanners allowed for the capture of precise digital impressions, reducing the need for traditional impression materials and methods. Companies like 3M introduced the Lava Chairside Oral Scanner (C.O.S.) and later the True Definition Scanner. [8]

3. Integration and Expansion (2010s)

Software Integration: Improved integration of CAD software with intraoral scanners allowed for seamless workflows from digital impression to design. Dental practices could now easily collaborate with laboratories and specialists using shared digital files. [9]

4. Modern Era (2020s-Present)

Artificial Intelligence and Machine Learning: AI and machine learning algorithms are increasingly being integrated into dental software, enhancing diagnostic capabilities, treatment planning, and design accuracy. [10]

Cloud-Based Solutions: Cloud computing allows for real-time collaboration, data storage, and sharing among dental professionals, improving efficiency and patient care.

Patient-Centric Care: Digital workflows enable a more patient-centric approach, offering faster turnaround times, enhanced comfort, and personalized treatment options. Virtual consultations and tele-dentistry are also becoming more prevalent.

Types of digital workflow

According to the state of the art, there are three kinds of workflows in restorative dentistry- traditional, former and rapid. [11]

1. **Traditional digital workflow:** The dentist takes a conventional impression using trays and materials, sending it to a dental lab where a plaster model is scanned to create a 3D digital model of the full arch. Using CAD/CAM systems, the technician designs the prosthesis and sends the file to a milling machine for fabrication. The dentist then applies and refines the prosthesis in the patient's mouth to verify and adjust occlusion. This process involves traditional impression-taking, digital design, and milling technology, culminating in a customized prosthesis fitted to the patient's needs (Figure 1). [11]

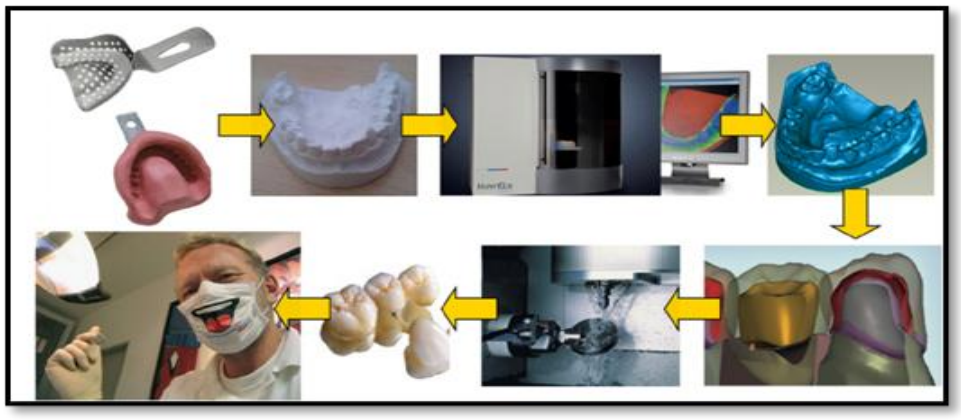

Figure 1 - Traditional Digital Workflow

2. **Former digital workflow:** The term "former" denotes a method distinct from the newer "rapid digital workflow." In the "former" digital workflow, a clinician without a milling-equipped intraoral scanner captures a digital impression using a standalone device. This impression is sent to a lab where a SLA model is created via CAD/CAM systems. The final restoration is then delivered to the clinician for seating. This contrasts with the "rapid digital workflow," which implies a streamlined process where the clinician owns an intraoral scanner with an in-office milling unit, enabling immediate restoration creation and placement (Figure 2). [11]

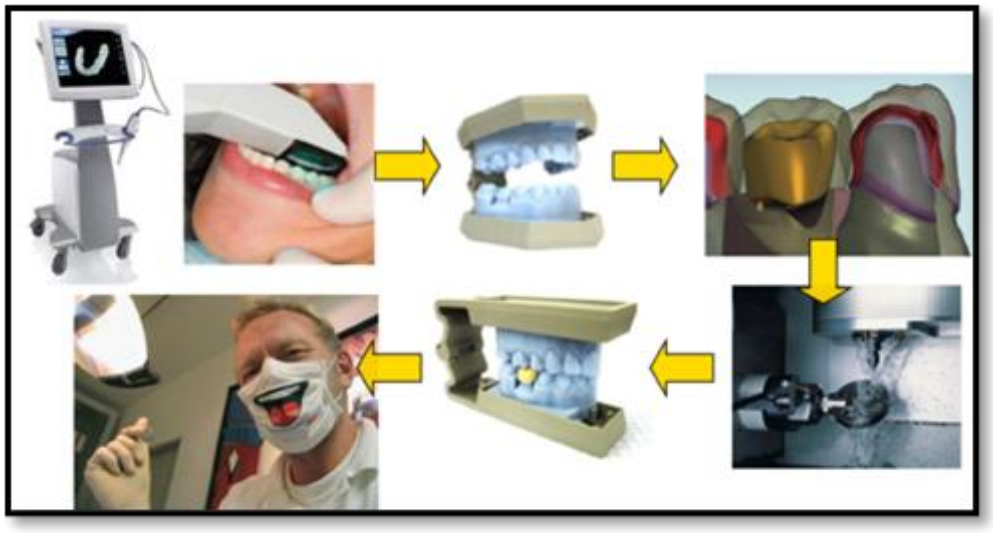

Figure 2- Former Digital Workflow

3. **Rapid digital workflow:** This workflow can be followed when the clinician possesses an intraoral scanner paired with an in-office milling unit. The dentist first takes a digital impression using the intraoral scanning device, then designs the restoration, and the software automatically generates the milling unit's program. The final restoration is milled within minutes, after which the dentist applies it (Figure 3). [11]

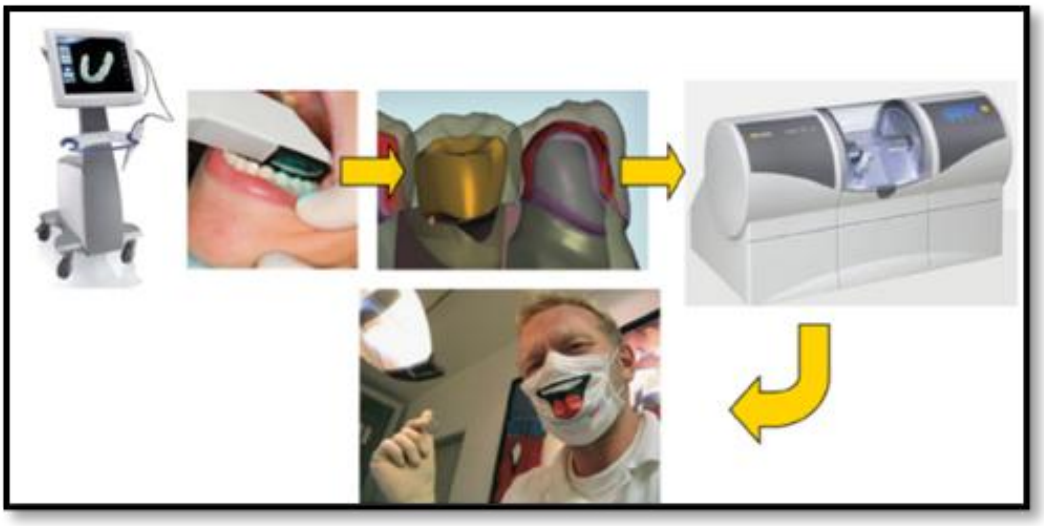

Figure 3- Rapid Digital Workflow

Steps of complete digital workflow-

1. Patient Examination and Initial Consultation

- Conduct a comprehensive oral examination using digital diagnostic tools (e.g., digital X-rays, CBCT scans).
- Discuss the patient's dental concerns and desired outcomes.
- Formulate a treatment plan using digital treatment planning software. [12]

2. Digital Impression Taking

- Use an intraoral scanner to capture detailed digital impressions of the patient's teeth and oral structures.
- Create a 3D digital model of the patient's mouth, ensuring high precision and comfort. [7]

3. Data Processing and Model Optimization

- Transfer the digital impression data to a computer.
- Utilize software to clean, refine, and optimize the 3D digital model, correcting any anomalies. [12]

4. Computer-Aided Design (CAD)

- Import the optimized digital model into CAD software.
- Design the dental restoration (e.g., crown, bridge, inlay, onlay, veneer, implant, denture) with precise customization for the patient's anatomy.
- Perform virtual simulations and adjustments to ensure optimal fit and aesthetics. [13]

5. Treatment Simulation and Patient Approval

- Use digital tools to simulate the treatment outcome and share the virtual results with the patient.
- Obtain patient approval for the proposed design and modifications, if necessary. [12]

6. Computer-Aided Manufacturing (CAM)

- Export the final design to a CAM device such as a milling machine or 3D printer.
- Manufacture the restoration using appropriate materials (e.g., ceramic, resin, metal), ensuring high precision and durability. [12]

Benefits of Digital Workflow over conventional workflow-

1. Precision and Accuracy

- Intraoral scanners deliver high-resolution scans, producing precise and detailed 3D models of a patient's oral structures.
- This digital approach significantly reduces errors compared to traditional impression materials and manual fabrication methods, enhancing the accuracy and reliability of dental impressions and overall treatment outcomes. [14]

2. Efficiency and Time Savings

- Faster Process: Digital impressions and CAD/CAM technologies significantly reduce the time required for impression taking, design, and fabrication of restorations.
- Instant Data Transfer: Digital files can be instantly shared with dental laboratories and specialists, speeding up the overall treatment process. [14]
- Several studies have shown that optical impressions are time-efficient (12 min 24 sec), as they enable reduction of the working times (and therefore costs) when compared to conventional impressions (24 min 42 sec). [15] According to *Yuzbasioglu et al.* time for conventional impression making was found to be 605 sec and for digital scanning it was approximately 248 sec. [18]

3. Improved Patient Experience

- Comfort: Intraoral scanning is less invasive and more comfortable for patients compared to traditional impression materials that can cause gagging and discomfort.
- Reduced Appointments: Faster turnaround times for restorations can reduce the number of patient visits needed to complete a treatment. [14]

4. Enhanced Collaboration

- Seamless Communication: Digital workflows enable easy sharing of digital models and treatment plans with dental labs and specialists, improving collaboration and consistency.
- Real-Time Adjustments: Adjustments to designs can be made quickly and communicated instantly, enhancing treatment planning and execution.

5. Customization and Aesthetics

- Tailored Solutions: CAD software allows for highly customized and precise designs tailored to the individual patient's anatomy and needs.
- Improved Aesthetics: Digital design tools enable the creation of restorations with superior fit and aesthetics, enhancing the final outcome.

6. Data Storage and Retrieval

- Digital Records: All digital impressions, designs, and patient records can be stored electronically, making data management and retrieval efficient and secure.
- Easy Access: Stored digital data can be easily accessed for future reference, modifications, or repeat treatments.

7. Material Efficiency and Environmental Impact

- Reduced Waste: Digital workflows reduce the need for physical impression materials and plaster models, minimizing waste and environmental impact.
- Efficient Use of Materials: Advanced manufacturing techniques like milling and 3D printing ensure precise use of restorative materials, reducing excess and waste. [12]

8. Quality Control

- Consistency: Digital workflows provide consistent and reproducible results, enhancing the quality of dental restorations.
- Verification: Digital tools allow for thorough inspection and verification of designs and final products before they are implemented, ensuring high standards are met.

9. Virtual treatment planning-

- It has the capability to combine and overlay 3D meshes from various imaging exams to construct a virtual patient enhances treatment planning and patient communication. [16]

10. Advanced Capabilities

- Innovative Treatments: Digital workflows enable advanced treatments and techniques that are difficult or impossible with conventional methods, such as guided implant surgery and orthodontic aligners.
- Patient Education: Digital tools and visualizations can enhance patient education and communication, helping patients understand their treatment options and expected outcomes. [17,18]

11. Reduce the risk of infection-

- In traditional precision impressions, the tray for impression material needs sterilization, followed by cleaning post-removal of modeling materials.
- Contamination of this material by oral pathogens poses infection risks in dental environments, necessitating time-consuming and expensive risk mitigation measures.
- Contrastingly, the scanning tip of an Intraoral Scanner (IOS) is autoclavable, ensuring sterilization. Additionally, the digitally acquired 3D images from optical impressions are transmittable data, eliminating the need for handling impression materials or conventional models, which could potentially spread infections. This technological advancement not only reduces infection risks but also simplifies the dental workflow. [14]

12. Analysis of abutment tooth formation or restoration-

- The intraoral scanner (IOS) allows users to view abutment tooth formation in three dimensions on a computer screen, offering analysis options such as assessing the abutment tooth surface,

clearance with opposing teeth, and margin or undercut shapes.

- Users can also measure restoration thickness and perform morphological and functional structural designs for restorations. [19]

13. Tooth and gum color-tone assessment-

- Digital models replicate the structural color tone of the tooth or gum-surface formation using a virtual color representation, which the users can utilize in shade taking or prognosis observation. [20]

14. Merging with maxillofacial data-

- Combining intraoral digital models with 3D facial scans, jaw motion data, or other 3D imaging like CT scans allows for thorough examinations and diagnoses.
- There are ongoing developments in open-architecture systems that process data in the widely used STL file format, crucial for guided dentistry's treatment planning and implementation.

15. No more plaster casts/ repeated impressions-

- Optical impressions eliminate the need for a time-consuming step in traditional impressions, where physical impressions are detected and gypsum models are cast.
- This efficiency saves clinicians time and reduces costs by eliminating the use of conventional impression materials, leading to direct savings on consumables. [15]

16. Improved communication the dental laboratory technician

- An intraoral scanner enables real-time assessment of impression quality by both the clinician and dental technician. Following the scan, the dentist can swiftly send the impression via email to the lab, where the technician can conduct a precise evaluation.
- If the technician deems the optical impression insufficient, they can promptly request a new scan from the clinician, avoiding delays or the need for a second patient visit.
- This capability not only streamlines communication between the dentist and technician but also enhances efficiency by addressing potential issues immediately.
- It strengthens the collaborative workflow, allowing for seamless adjustments and ensuring that high-quality impressions are obtained without inconveniencing the patient with additional appointments. [21]

Limitations of digital workflow over conventional workflow-

1. High Initial Investment

- **Cost of Equipment:** Digital dental technologies, including intraoral scanners, CAD/CAM systems, and 3D printers, require a significant initial financial investment.
- **Software Expenses:** Purchasing and maintaining advanced dental software can be costly. [22,23]

2. Learning Curve

- **Training Requirements:** Dental professionals need to undergo training to become proficient in using digital tools and software, which can be time-consuming and costly.
- **Adaptation Period:** Adapting to new digital workflows may take time for dental teams accustomed to conventional methods. [24-30]

3. Technical Issues

- **Software and Hardware Reliability:** Digital systems can experience technical problems, such as software glitches, hardware malfunctions, and compatibility issues.
- **Maintenance and Repairs:** Regular maintenance and potential repairs of digital equipment can incur additional costs and downtime.

4. Data Management and Security

- **Data Storage:** Managing and storing large volumes of digital data requires robust IT infrastructure and storage solutions.

- **Cybersecurity Risks:** Digital records are vulnerable to cybersecurity threats, requiring stringent data protection measures to prevent unauthorized access and breaches.

5. Difficulty in detecting deep margins of prepared teeth

- Detecting deep margin lines of prepared teeth is challenging because, unlike conventional impression materials, light cannot physically displace the gum to capture 'non-visible' areas. Bleeding can also obscure prosthetic margins, making it difficult to register these areas accurately. [31-34]

6.Large handpiece

- Camera can be too large for patients with limited mouth opening and for paediatric patients.

Digital versus Conventional Workflow (Table 1)-

Aspect	Digital Workflow	Conventional Workflow
Impression Taking	Intraoral scanners capture digital impressions.	Physical impressions using trays and materials.
Patient Comfort	High comfort, no gag reflex, quick process.	Can be uncomfortable, potential for gag reflex.
Precision	High accuracy and reproducibility.	Dependent on material handling and technique.
Time Efficiency	Faster turnaround times for impressions and restorations.	Longer process with physical impression setting time and mailing.
Data Storage	Digital files stored electronically, easy to share.	Physical models and impressions, prone to damage and storage issues.
Design and Customization	Advanced CAD software for precise, customized restorations.	Manual design and wax-ups, less precise customization.
Manufacturing	CAM technology for milling or 3D printing.	Traditional casting, molding, and hand-finishing.
Error Reduction	Reduced errors through digital accuracy and automation.	Higher potential for human error in multiple steps.
Communication	Easy digital communication and collaboration with labs and specialists.	Physical models and impressions sent by mail, longer communication times.
Cost	Higher initial investment in technology but potential cost savings over time.	Lower initial cost but higher ongoing costs for materials and labor.
Environment Impact	Reduced waste with digital files and processes.	More waste from impression materials and physical models.

Significance

The digital dental workflow is not merely a technological advancement but a paradigm shift in dental care delivery. Its clinical significance lies in its ability to enhance diagnostic and treatment precision, improve patient comfort and satisfaction, and foster a more efficient and collaborative practice environment. By embracing digital workflows, dental professionals can provide higher quality, more personalized, and future-ready care.

CONCLUSION

The digital dental workflow represents a transformative leap in modern dentistry, offering unparalleled precision, efficiency, and patient satisfaction. By integrating advanced technologies such as intraoral scanners, computer-aided design (CAD), computer-aided manufacturing (CAM), and 3D printing, dental professionals can streamline processes from diagnosis to final restoration. This shift not only enhances the accuracy of dental treatments but also significantly reduces turnaround times, allowing for same-day solutions and minimizing patient discomfort. Furthermore, digital workflows facilitate better communication among dental teams and with patients, providing clearer visualizations and more predictable

outcomes. The ability to store and share digital records enhances collaboration and long-term patient care management. As technology continues to evolve, the digital dental workflow will likely incorporate even more sophisticated tools, such as artificial intelligence and machine learning, further refining the precision and customization of dental treatments.

Declaration by Authors

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