OPEN ACCESS

Volume: 12

Special Issue: 2

Month: October

Year: 2024

P-ISSN: 2321-788X

E-ISSN: 2582-0397

Received: 24.09.2024

Accepted: 10.10.2024

Published: 22.10.2024

Citation:
Divya, R., Diva Dharani, R., Rathna Piriyanga, RS., & Anand Sherwood, I. (2024). Digital Impressions in Dentistry - A Comprehensive Review. *Shanlax International Journal of Arts, Science and Humanities*, *12*(S2), 1-7

DOI:
https://doi.org/10.34293/sijash.v12iS2-Oct.8201

Digital Impressions in Dentistry - A Comprehensive Review

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Abstract

Digital impressions have revolutionized the practice of prosthodontics. Conventional methods often resulted in bulky impressions that caused gagging and lack of patient compliance which negatively impacted upon the treatment outcomes. The advent of digital impression utilizes the intraoral scanner to construct three-dimensional (3D) digital images of teeth, with no need for the conventional impression tray or material being used. This paper is designed to overview on performance, advantages and obstacles related to dental impression around. Digital Impressions using intra-oral scanners based on CAD/CAM technology has become a modern approach substitute for traditional method of taking dental impressions as it provides better accuracy during clinical trials when making various types of prosthetic restorations including: Inlays, Onlays, Veneers, Crowns, Bridges as well as Removable Partial Dentures and also be recognized as one kind of additional component in Digital Smile Design concept procedure due to Global Increasing aesthetic requirements. This present study aimed at describing different perspectives regarding digital interpretation technique over patient education; clinicians work dependent on author's own experience with increasing demand year after year prospective indicating dynamics development. In conclusion, the advantages of digital impressions in terms of patient comfort and clinical workflow are evident but not without challenges related to clinician learning curve and system integration that must be met for successful implementation within dentistry. The adoption of patient-friendly and sophisticated dental technology will likely continue unabated as long as these challenges are effectively addressed.

Introduction

For years, impression techniques have been central to dental practice, and historically made use of materials such as alginate, polyether and polyvinyl siloxane to cast the fine details of a patient's oral structures. These materials are essential for procedures like crowns, bridges, dentures, and orthodontic appliances. However, traditional methods often present challenges, including patient discomfort, potential inaccuracies from material shrinkage or expansion, and the time-consuming process of preparing and pouring dental casts (Husein et al., 2022).

The introduction of computer-aided design/computer-aided manufacturing (CAD/CAM) systems in the 1980s marked a pivotal shift in dentistry, allowing for the precise fabrication of inlays, onlays, crowns, bridges, and implants (Davidowitz & Kotick, 2011). This was succeeded in the early 21st century by digital impressions, which were created to overcome many of the constraints of traditional impression methodology. By using intraoral scanners (IOS) to capture precise, three-dimensional images of the teeth and oral structures, digital impressions eliminate the need for traditional impression materials and the associated issues such as discomfort, gag reflexes, and inaccuracies due to environmental factors (Husein et al., 2022).

Since then, the use of digital impressions in dental practices has only gained more popularity as it helps in increasing workflow efficiency and precision level when treating patient or fabricating prosthetics. Real-time visualization of the oral cavity, providing immediate feedback such that clinicians can view captured data and know if any modifications are required. This increases accuracy and minimises the patient visits (Rutkūnas et al., 2020).

However, capturing detailed images in hard-to-reach areas can still pose a challenge with intraoral scanners, as their relatively larger size compared to traditional impression trays makes it difficult to access certain distal areas of the mouth (Sacher et al., 2021). Despite this, studies indicate that digital impression techniques are associated with improved occlusal contact accuracy and overall superior results compared to traditional methods (Yuzbasioglu et al., 2014).

As part of the broader trend towards digital dentistry, digital impressions are transforming clinical workflows and enhancing the patient experience. From diagnostics to treatment planning and execution, the integration of digital tools such as intraoral scanners and 3D printing is improving accuracy, reducing human error, and providing faster, more personalized care. This shift is streamlining communication between dentists and laboratories, reducing turnaround times, and delivering predictable, high-quality outcomes.

In summary, digital impressions represent a significant advancement in dental practice, addressing the limitations of traditional techniques and paving the way for further innovation in patient care.

Conventional vs. Digital Impressions

Aspect	Conventional Impressions	Digital Impressions
Materials	Uses physical impression materials such as alginate, polyether, or polyvinyl siloxane.	Utilizes intraoral scanners to capture 3D images without physical materials.
Patient Comfort	Can cause discomfort, gagging, and require time for material setting.	Generally more comfortable, reduces gag reflex, and eliminates the need for material setting.
Accuracy	Prone to errors due to material shrinkage or distortion.	Typically more accurate with less risk of distortion and better fitting restorations.
Procedure Time	Time-consuming; involves multiple steps including material preparation and setting.	Faster with real-time feedback and immediate adjustments.
Error Rate	Higher potential for inaccuracies due to manual handling and material issues.	Lower error rate with advanced scanning technology and real-time corrections.
Initial Cost	Lower initial cost; requires only traditional impression materials and trays.	Higher initial cost due to the price of intraoral scanners and software.
Learning Curve	Minimal; based on established techniques familiar to most practitioners.	Requires training and adaptation to new technology and software.
Research Variability	Variability in methods and results can make comprehensive comparisons difficult.	Growing body of research supports benefits, but comparisons with conventional methods can be inconsistent.

This table summarizes key differences between conventional and digital impressions, emphasizing the advantages of digital methods in terms of accuracy, patient comfort, and efficiency, despite higher initial costs and the need for ongoing training.

Intraoral Scanners

Intraoral scanners (IOS) CEREC, 3Shape TRIOS and iTero are backbone of digital dentistry among which each has its own advantages in terms of accuracy, efficiency and user-friendliness. CEREC is a chairside CAD/CAM system pioneer, however, is less effective for ful- arth impressions as the reported minor compromised accuracy. The rapidity and best-in-the-market accuracy of the 3Shape TRIOS for full-arch scans significantly better than other IOS, coupled with color scanning and a potential real-time bite registration clinched it superior to other IOS. The iTero works best for orthodontics as it can capture an accurate relationship in a complex occlusion along with full-arch data, while also its good compatibility with multiple aligners system. Latest studies comment that both TRIOS and iTero offer better performance as compared to other intraoral scanners on account of their excellent accuracy and effectiveness, whereby iTero offers further significance due to its ease of soft-tissue details (for implant-supported restorations) (Segundo et al., 2023).

Additionally, trends in the application of advanced technologies such as artificial intelligence (AI) and machine learning in IOS to automate margin detection, caries diagnosis and procedure alignment have been reported. For instance, the Dental System (3Shape) AI engine provides real-time suggestions and an accuracy warning system, while the application of a machine learning algorithm to determine predictable treatment options based on patients' needs is employed (Mayta-Toualino et al., 2023). In general, considering that both Open-Sourced and Closed-Sourced IOS have positive aspects as previously presented, most of various CAD/CAM platforms for prosthodontic use accept STL files. Thus, open-sourced IOS are assumed to be more useful than closed-sourced IOC.

Working Principle of Digital Impressions

Digital Impression Systems can be Classified into Two Categories: Open and Closed Systems

Open Systems: These systems use standardized file formats, such as the stereolithography (STL) format, which is a common standard in dental CAD/CAM systems. Open systems allow for easier integration and data exchange between different software and hardware platforms. They typically use intraoral cameras that capture three-dimensional data using techniques such as triangulation or parallel confocal laser scanning. For example, systems like the 3Shape TRIOS and the iTero are known for their compatibility with various CAD/CAM platforms, facilitating seamless workflow integration (Lin, 2018).

Closed Systems: These systems utilize proprietary file formats and are designed to work within a specific manufacturer's ecosystem. They may not support standard file formats like STL, making it more challenging to share or integrate data with other systems or software. Closed systems often come with limitations regarding compatibility and flexibility, as the data generated is optimized for use only within the manufacturer's system. For instance, the CEREC system operates within its proprietary framework, which can limit the ease of data exchange with other platforms (Leinfelder et al., 1989).

The scanning process involves intraoral cameras that use either video or still photo techniques. Still images rely on triangulation or parallel confocal laser scanning.

Technological Advancements

Technological innovations have greatly improved digital impression systems for faster, more accurate, and patient-friendly dental treatment. AI in the form of machine learning has streamlined workflow efficiencies by allowing an intraoral scanner to self-detect and diagnose errors with real-time feedback for self-correction; analyze patients' data together with the vast amount of clinical data available to enhance predictability of treatment outcomes; (Babu et al., 2021; Mayta-Tovalino et al., 2023) and integrate seamlessly with haptic robotic devices (Liu et al., 2023). The amalgamation of AI and 3D printing technology allows 4D imaging for dynamic analysis over time, which will revolutionize the fields of orthodontics and prosthodontics, providing timely feedback on tooth movement or restoration wear (Lee, 2018).

Applications in Various Fields of Dentistry

Restorative Dentistry

Digital impressions have transformed restorative dentistry with the ability to generate 3D models for designing and manufacturing dental prosthetics. Using this technology, it is possible to produce accurate inlays, onlays, crowns, bridges, and dentures. Digital impressions can be easily incorporated with CAD/CAM systems which enable the production of chair-side customized restorations with superior fit and occlusion. Additionally, digital impressions enhance workflow efficiencies for both single-unit restorations and full-arch rehabilitations resulting in more predictable results, as well as increased patient satisfaction (Rutkunas et al., 2020).

Dental Surgery

In dental surgery, digital impressions play a vital role in the accurate planning and execution of implant placement. High-resolution 3D models are constructed using these impressions to fabricate surgical guides for guided implant placement facilitating minimal error and maximum output surgeries. Furthermore, it aids in developing patient specific abutments and prosthesis leading to an improved results owing to precise fit of implants in case of both fully or immediately loaded implants (Hong & Oh, 2017).

Orthodontics

Digital impressions have been a game-changer in orthodontics. They simplify the diagnosis of dental problems and the development of a treatment plan. The digital models that can be fabricated from digital impressions are extremely accurate and are used for making dentures, custom aligners, brackets, as well as wires. In fact, Invisalign cannot make clear aligners using conventional (intraoral) impressions; they have to be taken using an intra-oral scanner. Digital impression technology also makes it possible to monitor and make changes to orthodontic treatments if necessary on regular interval basis (Morton et al., 2017; Baxi et al., 2022).

Forensic Dentistry

In the field of forensic dentistry, digital impressions are essential in the identification and comparative analysis of individuals based on dental evidence. The increased accuracy provided by digital models allows for the creation of highly descriptive dental profiles that can be used during forensic casework. Unidentified human remains can be matched to a potential identity by comparing antemortem dental records with postmortem data, or bite marks can be analyzed using enamel casts generated from digital impressions for more credible results (Khanna & Dhaimade, 2017).

Teledentistry

Digital impressions can also improve teledentistry. With them, a dentist can take and forward a digital impression to another dentist, specialist or dental laboratory without the need for a physical referral. This is particularly beneficial to patients who cannot easily get to the dental office themselves. Teledentistry with digital impressions enables an efficient and effective access to care that allows for early identification of problems and minimally invasive early intervention (Jampani et al., 2011).

Pre-Surgical Planning

Complex oral surgery cases, such as reconstructive procedures or extensive implant placement cases, require digital impressions in order to obtain proper pre-surgical planning. The 3D model allows the surgeon to see the anatomy of the patient and plan the case accordingly using this technology. By doing so, it helps simulate what can be achieved with surgery and design custom surgical guides/prosthetics which ultimately leads to a better result for patients. In addition, this type of planning helps improve safety by having a

complete understanding of where vital anatomic structures are located prior to entering into surgery (Afroz et al., 2021).

Implant Dentistry

The use of digital impressions is particularly important in implant dentistry for the planning and placement of dental implants. They can provide accurate 3D models of the oral cavity for designing implant placement and fabricating surgical guides. Digital impressions can be used to design and manufacture custom implant components and prostheses that fit more accurately, are easier to maintain, and function better (Hong & Oh, 2017; Marques et al., 2021).

Prosthodontics

In prosthodontics, digital impressions facilitate the design and production of various prostheses such as complete dentures, removable partial dentures and fixed prostheses. They provide highly accurate and detailed models that influence the fit and esthetics of prosthetic restorations. Furthermore, digital impressions offer faster adjustments or re-designs therefore streamlining prosthodontic procedures. Numerous studies have also investigated the prospective clinical applications for digital impressions especially in the context of rehabilitation with single posterior implant supported crowns with / without 3D printed/milled casts. These reveal equal or improved accuracy by CAD/CAM systems compared to conventional techniques.

Preventive Dentistry

In preventive dentistry, the use of digital impressions provides accurate baseline data with which to monitor oral health over time. High-quality 3D models enable precise measurements of changes in tooth morphology, occlusion, and other oral conditions for early identification of potential issues and the initiation of timely preventive protocols for maintaining oral health (Lin, 2018; Baxi et al., 2022).

Cost-Benefit Analysis

The acquisition of digital impression technology is accompanied by high initial costs, including the purchase of intraoral scanners and staff training, as well as maintenance. However, many such costs can be recouped over time and far outweighed by other savings. Digital impressions decrease the use of physical materials and model production, as well as chairside assistant times in making prostheses. Also, treatment times can be decreased through immediate-load implants or same-day crowns (Chen et al., 2022)

In terms of Return on Investment (ROI), clinics can typically expect to recover expenses within a few years through increased productivity, fewer remakes of restorations, and improved patient retention. Increased accuracy and elimination of errors over time also decrease costly adjustments. Ultimately, the increase in efficiency and patient satisfaction resulting from the implementation of digital impressions will generate financial reward (Segundo et al., 2023; Tordiglione et al., 2016).

Challenges

Despite their many advantages, digital impressions present several challenges that must be addressed for optimal adoption in dental practices. One primary issue is the significant cost associated with acquiring and maintaining digital impression systems, which includes equipment, software, and ongoing training. For dental laboratories, managing digital data effectively is crucial, as intraoral scanners may struggle with accuracy when reflecting off fluids like saliva, leading to distorted models. Additionally, proper training and maintenance of scanners are essential for ensuring accurate results (Birnbaum & Aaronson, 2018; Yuzbasioglu et al., 2014).

The transition to digital impressions presents a steep learning curve for clinicians, requiring technical proficiency in scanning techniques, digital file management, and lab communication. Continuous education

and training are essential to keep up with advancing technology. Without proper training, errors in data capture or lab communication can compromise restoration quality. While courses and certifications are available, older practitioners may find it harder to adapt, making ongoing professional development crucial for fully utilizing digital technologies.

Compatibility Issues

Another challenge is the compatibility between different CAD/CAM systems and intraoral scanners. Despite claims of interoperability, not all devices and software solutions work seamlessly together. This can create workflow barriers, especially when collaborating with external labs using different equipment. Issues such as file conversion or reduced data fidelity can arise if systems from different manufacturers do not communicate effectively. Some proprietary systems may restrict users to a specific ecosystem, limiting flexibility. To address this, many clinicians opt for open-source systems to enhance compatibility. However, ensuring full interoperability requires careful selection and consultation with manufacturers (Alghazzawi, 2016; Birnbaum & Aaronson, 2018).

Patient Experience

Digital impressions greatly improve patient comfort and satisfaction over traditional methods, which often involve uncomfortable materials that cause gag reflexes and anxiety. Intraoral scanners capture detailed 3D images quickly, eliminating the need for bulky impression materials. This reduces anxiety, speeds up treatment, and minimizes the need for repeat appointments. Real-time visualization allows clinicians to make immediate adjustments, improving prosthetic fit and reducing frustration. Surveys and case studies confirm patient preference for digital impressions due to their comfort and efficiency, reflecting a positive shift towards more advanced, patient-friendly dental technologies (Cepic et al., 2023; Yuzbasioglu et al., 2014).

Conclusion

Digital impression technology in dentistry is an innovative solution that offers faster, more accurate, and more comfortable alternatives to conventional impression methods. Despite challenges such as cost and technical training, digital impressions are becoming increasingly popular for a wide range of dental applications, ensuring better patient outcomes and streamlined workflows.

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