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Digital Impressions in Prosthodontics: Contemporary Concepts, Technologies, and Clinical Methodologies: A Narrative Review

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ABSTRACT:

Digital impression technology has revolutionized prosthodontic practice by providing a reliable and efficient alternative to conventional impression techniques. Through accurate three-dimensional recording of intraoral structures, digital impressions have facilitated seamless integration with computer-aided design and computer-aided manufacturing (CAD/CAM) systems, thereby enhancing diagnostic accuracy, treatment planning, and prosthesis fabrication. This narrative review explores the fundamental concepts, technological principles, clinical workflows, scanner systems, accuracy, advantages, limitations, and future prospects of digital impression techniques in prosthodontics, with an emphasis on their expanding clinical relevance.

Introduction

Impression making is a critical procedural step in prosthodontics, as the dimensional accuracy of the definitive prosthesis is directly dependent on the precision with which oral tissues are recorded. Conventional elastomeric impression materials have long been regarded as the standard approach; however, they are associated with several inherent limitations, including polymerization shrinkage, dimensional instability, technique sensitivity, patient discomfort, and increased clinical and laboratory time requirements[1,2]. Advances in digital dentistry have led to the development of digital impression systems that enable direct intraoral data acquisition without the use of impression materials or gypsum casts. These systems employ optical scanning technologies to generate virtual three-dimensional representations of teeth, soft tissues, and implant components[3]. Over the last two decades, continuous improvements in scanner hardware, image-processing algorithms, and software integration have resulted in widespread adoption of digital impressions in prosthodontic workflows[3,4]. The growing emphasis on precision-driven, time-efficient, and patient-centered care has further accelerated the transition toward digital workflows. Consequently, digital impression systems are now

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considered an essential component of contemporary prosthodontic practice[5,6].

Evolution of Impression Techniques: From Conventional To Digital

The historical development of dental impression techniques reflects progressive attempts to improve accuracy and material stability. In 1856, Dr. Charles Stent introduced gutta-percha as an alternative to wax-based materials. The late 1950s witnessed the introduction of polysulfide rubber impression materials, which offered improved elasticity and detail reproduction compared to hydrocolloids. A major milestone occurred in 1965 with the introduction of polyether impression materials (Impregum™, ESPE GmbH), which demonstrated favourable flow, dimensional accuracy, and minimal polymerization shrinkage [7]. Condensation silicones were subsequently developed but exhibited limitations related to by-product release and dimensional instability. The advent of addition silicone or vinyl polysiloxane (VPS) materials addressed many of these concerns, providing excellent dimensional stability, tear resistance, and delayed pouring capability [8]. Despite these advancements, conventional impressions remain susceptible to errors related to tray selection, material handling, impression removal, transport, and environmental factors during cast fabrication. Digital impression technology represents a paradigm shift by eliminating many of these error-prone steps. Modern three-dimensional scanning systems enable direct data acquisition and integration into CAD/CAM workflows, facilitating the fabrication of restorations without physical impressions or stone models [9].

Principles of Digital Impression Technology

Digital impression systems function by capturing optical information from intraoral surfaces and converting it into a three-dimensional digital model. During scanning, a light source is projected onto the object, and the reflected light is analyzed by sensors using advanced computational algorithms [10]. Multiple images are captured sequentially and digitally stitched to generate a continuous virtual representation of the scanned area [11]. Different optical principles are employed in intraoral scanning, including structured light projection, confocal microscopy, and laser triangulation [12]. The accuracy of the final digital impression is influenced by scanner resolution, scanning strategy, surface reflectivity, ambient lighting conditions, and operator proficiency [13]. The processed data are exported in standardized digital formats that enable compatibility with CAD/CAM systems.

Standard Tessellation Language (STL) In Digital Dentistry

Standard Tessellation Language (STL) is the most commonly used file format in digital dentistry for representing three-dimensional surface geometry obtained from intraoral scans. STL files describe objects as a mesh of interconnected triangular facets that accurately reproduce the surface morphology of dental and peri-oral structures. In prosthodontics, STL files serve as the digital equivalent of conventional impressions and facilitate seamless data exchange between scanners, design software, and manufacturing devices. Although STL files contain only geometric information and lack color or texture data, their simplicity ensures broad interoperability across CAD/CAM platforms. As a result, STL remains the preferred format for subtractive and additive manufacturing processes such as milling and stereolithography[14,15].

Digital Impression Systems and Workflow

Intraoral scanners are the primary devices used for recording digital impressions in prosthodontics. These handheld systems allow direct scanning of intraoral structures while providing real-time visualization of captured data [16]. Proper isolation and moisture control are essential for optimal scan quality. A significant advantage of digital impressions is the ability to immediately assess scan accuracy and correct deficiencies without repeating the entire procedure [17]. Digital workflows may be entirely digital or hybrid. Fully digital workflows involve intraoral scanning followed by virtual prosthesis design and CAD/CAM fabrication. Hybrid workflows combine digital impressions with selected conventional laboratory procedures. Both approaches aim to improve accuracy, reduce errors, and enhance clinical efficiency compared with traditional techniques[18].

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Functional Components of Digital Impression Systems

Digital impression systems consist of optical components, image sensors, and sophisticated software algorithms. High-precision lenses and mirrors enable detailed image capture of hard and soft tissues . Light projection technologies such as structured light and confocal imaging project defined patterns onto scanned surfaces, and variations in reflected light are analyzed to generate three-dimensional data[19]. Advanced software processes the captured images, corrects motion artifacts and reflections, and merges multiple frames into a unified digital model. Multi-axis scanner tips facilitate access to posterior and anatomically challenging regions of the oral cavity. Modern scanners often feature wireless connectivity and compact designs, improving ergonomics and clinical workflow.

Powered and Non-Powered Digital Impression Systems

Digital impressions may be obtained using powered (active) or non-powered (passive) scanning systems. Powered intraoral scanners rely on external energy sources to emit structured light or laser beams and capture reflected data using sensors. These systems provide real-time visualization, automated image stitching, and immediate error detection, making them suitable for fixed and implant prosthodontics [20]. Powered scanners are widely used for capturing preparation margins, occlusal morphology, and implant scan bodies. However, their accuracy in complete-arch and edentulous cases may be influenced by cumulative stitching errors and operator technique. Non-powered systems, such as photogrammetry-based technologies, rely on ambient light and high-resolution photographic capture rather than active light emission. These systems are particularly advantageous in full-arch implant prosthodontics, as they minimize stitching errors and provide highly accurate implant position data. Their primary limitation is restricted applicability, often requiring supplementary scans from intraoral or laboratory scanners [21].

Classification of Digital Scanners

Digital scanners used in prosthodontics include intraoral scanners, laboratory scanners, and imaging-based systems. Laboratory scanners are further classified as contact (mechanical) or non-contact (optical) scanners. Contact scanners employ a physical probe to trace surface contours and are primarily used in industrial and laboratory settings. Non-contact optical scanners utilize laser or light-based triangulation and form the basis of most contemporary CAD/CAM systems. Commercially available digital impression systems include chairside acquisition units such as CEREC and E4D, as well as dedicated intraoral scanners like TRIOS, iTero, and Lava™ C.O.S. [22].

Available Digital Impression Systems

Digital Impression System	Manufacturer	Scanning Technology	Key Clinical Applications
CEREC Primescan	Dentsply Sirona	Structured light	Chairside restorations
TRIOS	3Shape	Confocal microscopy	Fixed & implant prosthodontics
iTero Element	Align Technology	Parallel confocal imaging	Prosthodontics & orthodontics
Medit i500/i600/i700	Medit Corp	Structured light	Open digital workflows
CS 3600/3800	Carestream	Structured light	Wireless scanning
Planmeca Emerald	Planmeca	Structured light	Compact chairside use
PIC Dental	PIC Dental	Photogrammetry	Full-arch implant accuracy

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Digital Impression System	Manufacturer	Scanning Technology	Key Clinical Applications
iCam4D	**iCam4D**	**Photogrammetry**	**Passive implant scanning**

Figure 1: Various Intraoral Scanners Available

Clinical Applications in Prosthodontics

Digital impressions are widely used in fixed prosthodontics for the fabrication of crowns, inlays, onlays, and fixed dental prostheses. Accurate margin detection and occlusal analysis contribute to improved restoration fit and longevity. Digital data transfer also enhances communication between clinicians and dental laboratories [23].m In implant prosthodontics, scan bodies are used to accurately record implant position and angulation, reducing errors associated with impression coping displacement and material distortion [4]. While digital impressions demonstrate high accuracy for single-implant and short-span restorations, photogrammetry-based systems are increasingly preferred for full-arch implant cases. Applications in removable prosthodontics are expanding; however, challenges remain in accurately recording functional soft tissue dynamics [1]. In maxillofacial prosthodontics, integration of intraoral scanning with facial scanning improves prosthesis esthetics and precision.

Accuracy of Digital Impressions

Accuracy of digital impressions is evaluated in terms of trueness and precision. Multiple studies have demonstrated that digital impressions provide accuracy comparable to conventional techniques for single-unit and short-span restorations [1,5]. By eliminating errors associated with material handling and cast fabrication, digital workflows enhance consistency and reliability [24]. In full-arch and edentulous situations, accuracy may be compromised due to cumulative stitching errors and lack of stable reference landmarks . In implant prosthodontics, factors such as implant angulation, inter-implant distance, scanner type, and scanning protocol influence accuracy. Ongoing technological improvements continue to address these limitations.

Advantages and Limitations

Digital impressions offer several advantages, including improved patient comfort, reduced chairside time, elimination of material-related distortions, and immediate verification of impression quality. Digital data storage and transmission enhance workflow efficiency and interdisciplinary collaboration. Limitations include high initial equipment costs, technique sensitivity, and the need for adequate training . Accurate recording of mobile soft tissues and edentulous arches remains challenging, necessitating conventional impression techniques in selected cases.

Future Perspectives

The future of digital impressions in prosthodontics is closely linked to advancements in scanning hardware, artificial intelligence, and digital integration. AI-based algorithms are expected to enhance real-time error detection, optimize scanning strategies, and reduce stitching inaccuracies, particularly in complete-arch cases. Technological improvements in soft tissue capture, motion-tracking, and time-based scanning are anticipated to improve functional impression recording [25]. Integration of intraoral scans with CBCT, facial scanning, and jaw-motion tracking will enable comprehensive virtual patient models. Photogrammetry is expected to gain broader clinical acceptance in implant prosthodontics due to its superior accuracy in full-arch restorations. Advances in additive manufacturing will further streamline workflows, enabling direct fabrication of definitive prostheses. Future research should focus on standardized protocols and long-term clinical validation.

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Conclusion

Digital impressions have significantly transformed prosthodontic practice by providing a precise, efficient, and patient-centered alternative to conventional impression techniques. Their successful application across fixed, implant, removable, and maxillofacial prosthodontics is well documented. Although certain limitations persist, continuous technological advancements and growing clinical evidence strongly support the expanding role of digital impressions in modern prosthodontics.[26,27]

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