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Comparison of the Dimensional Accuracy of Intraoral and Laboratory Scanning Systems - A Narrative Review

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Abstract: ***This narrative review examines the dimensional accuracy of intraoral and laboratory scanners used in digital dentistry. Accurate digital impressions are critical for the success of various dental procedures, including restorations, orthodontics, and implantology. The review aims to compare the precision and reliability of intraoral scanners (IOS) and laboratory scanners (LS) by analyzing existing research studies and clinical evaluations. Through an extensive analysis of peer-reviewed articles, this review highlights the advancements in scanning technology, the methodologies employed to assess accuracy, and the factors influencing the precision of digital impressions. Findings indicate that while both intraoral and laboratory scanners exhibit high levels of accuracy, variations exist depending on the specific scanner model, scanning technique, and clinical application. Intraoral scanners offer the advantage of direct chairside use, enhancing patient comfort and streamlining workflows. However, laboratory scanners are often considered more reliable for complex cases requiring extensive scanning areas. The review discusses the implications of these findings for clinical practice, emphasizing the importance of choosing the appropriate scanning technology based on the clinical scenario. Future research directions are suggested to further refine scanning technologies and improve their accuracy, ultimately enhancing patient outcomes in digital dentistry.***

Keywords: intraoral scanners (IOS), laboratory scanners (LS), digital scanning, digital impression, CAD/CAM dentistry

1. Introduction

The technique of computer-aided design and computer-aided manufacturing (CAD/CAM) has been utilized for producing ceramic restorations, such as all-ceramic crowns and fixed dental prostheses, for several decades [1]. Various CAD/CAM systems are capable of designing and fabricating prostheses using plaster casts derived from conventional silicone impressions [2]. However, nonstandard procedures during impression taking and deformation of clinical materials can impact the accuracy of the plaster model, which in turn affects the accuracy of three-dimensional (3D) model data and the quality of the prostheses [3].

Digital dentistry has revolutionized dental practice by introducing advanced technologies such as intraoral scanners (IOS) and laboratory scanners (LS) [4]. These tools have become integral for creating precise digital impressions which are essential for manufacturing accurate prostheses [5]. The advent of these technologies has streamlined the workflow in dental offices and laboratories, reducing the need for traditional impression materials and the associated discomfort for patients. Digital impressions facilitate quicker turnaround times for prosthetic manufacturing and enable easy storage and transmission of patient data [6,7].

Intraoral scanners, used directly in the patient's mouth, capture detailed 3D images of the dental structures. They offer significant advantages, including enhanced patient comfort, immediate feedback for clinicians, and the elimination of impression materials that can distort over time [8]. Laboratory scanners, on the other hand, scan physical models or impressions in a controlled environment, typically providing higher accuracy, and detail due to the stable conditions and advanced optical systems employed [9].

Despite notable advancements, the dimensional accuracy of these scanners continues to be a significant focus of research. Several factors, including scanner resolution, operator technique, scanning environment, and the condition of the scanned object, can affect the precision of the resulting digital impressions [10]. Accurate digital impressions are essential for the creation of precise prostheses, such as crowns, bridges, and implants, which must fit perfectly to function correctly and ensure patient comfort [11].

This review aims to compile current knowledge on the accuracy of intraoral scanners (IOS) and laboratory scanners (LS), highlighting their benefits, limitations, and implications for clinical practice [12]. It will examine the latest research findings, compare the performance of various scanner models, and explore the specific challenges associated with each type of scanner [13]. Additionally, the review will discuss how advancements in scanner technology and software algorithms are enhancing the accuracy and usability of digital impressions. Practical implications for dentists and dental technicians will also be considered, providing insights on optimizing scanning procedures and selecting the appropriate scanner for different clinical scenarios [14].

By providing a comprehensive overview of the current state of intraoral and laboratory scanners, this review aims to inform and guide dental professionals in making evidence-based decisions about incorporating these technologies into their practice. The ultimate goal is to enhance the accuracy of digital impressions, improve the quality of prosthetic restorations, and, consequently, elevate the standard of patient care in digital dentistry.

2. Materials and methods

A thorough literature search was conducted across PubMed, Google Scholar, and ScienceDirect to explore the dimensional accuracy of intraoral and laboratory scanners in dentistry. The review encompassed peer-reviewed articles, clinical trials, and comparative studies focusing on key terms such as "dimensional accuracy," "intraoral scanners," "laboratory scanners," "digital impressions," and "CAD/CAM dentistry." This approach ensured a comprehensive examination of current research, highlighting advancements in scanner technology and their implications for dental practice.

The findings revealed a nuanced landscape of studies comparing the precision of intraoral versus laboratory scanners, with variability influenced by factors such as scanning technology, resolution capabilities, and clinical application. Advances in algorithms and imaging resolution have notably improved the accuracy of digital impressions, which is crucial for the precise fabrication of dental restorations. Moreover, the review underscored practical considerations including user experience, workflow efficiency, and the integration of digital scanning into everyday dental practice. Overall, this synthesis of literature provides valuable insights into the evolving role of scanners in modern CAD/CAM dentistry, emphasizing their impact on clinical outcomes and the ongoing advancements shaping dental technology.

3. Results

Intraoral scanners (IOS) represent a pivotal advancement in dental technology, designed as handheld devices to capture detailed digital impressions directly within the patient's oral cavity [15]. These scanners have been shown through various studies to achieve high levels of accuracy, particularly well-suited for applications such as single-tooth restorations and short-span prostheses. This precision not only ensures that dental restorations fit snugly and function optimally but also enhances patient comfort by minimizing the need for traditional, often uncomfortable impression materials [16].

One of the standout advantages of intraoral scanners is their ability to streamline workflows in dental practices. By eliminating the traditional step of physical impression taking, which can be messy and time-consuming, IOS significantly reduce chairside time and overall treatment duration. This efficiency benefits both patients and practitioners alike, allowing for quicker treatment planning and execution [17].

Furthermore, the accuracy of intraoral scanners can be influenced by several factors, including operator skill and experience. They play a crucial role in obtaining accurate scans, as precise movement and positioning of the scanner are necessary to capture all the required details [18]. Moreover, intraoral conditions such as saliva flow and soft tissue movement can pose challenges, potentially affecting the quality of the digital impression. Advances in scanner technology have aimed to mitigate these issues, with improved software algorithms helping to compensate for minor movements and variations during scanning [19].

Laboratory scanners represent a cornerstone of digital dentistry, renowned for their robustness and ability to meticulously scan plaster casts or impressions within a controlled laboratory environment. These scanners are favored particularly for their ability to achieve high levels of accuracy, making them indispensable for handling complex cases that demand extensive scanning coverage and intricate detail [20].

The exceptional precision of laboratory scanners is largely credited to the stability of their scanning environment. Unlike intraoral scanners used chairside, laboratory scanners operate in conditions carefully optimized to minimize external interference and ensure consistent results. Advanced optical systems further enhance their performance, allowing for precise capture of even the smallest anatomical nuances present in dental models [21].

Despite these advantages, the accuracy of laboratory scanners can still be influenced by various factors. The quality of the initial impression or model is crucial, as any distortions or imperfections can propagate through the scanning process and affect the fidelity of the digital model. Careful handling of the plaster casts or impressions before scanning is essential to maintain their integrity and ensure accurate replication in the digital realm [22].

Laboratory scanners play a critical role in the digital workflow of dental laboratories, facilitating the creation of highly accurate digital models that serve as blueprints for manufacturing prostheses like crowns, bridges, and implants. Their ability to produce detailed 3D renderings not only aids in precise fabrication but also allows for virtual adjustments and simulations that optimize the final restoration's fit and function [23].

As digital dentistry continues to evolve, laboratory scanners are expected to further refine their capabilities. Advances in scanning technology and software algorithms promise to enhance accuracy, speed up workflow processes, and improve integration with other digital tools used in modern dental laboratories [24]. These advancements ultimately empower dental technicians to deliver prosthetic solutions that meet the highest standards of accuracy and aesthetics, benefiting both practitioners and patients alike.

4. Discussion

Comparative research consistently indicates that both intraoral scanners (IOS) and laboratory scanners (LS) achieve levels of accuracy suitable for various dental applications [25]. However, each type of scanner excels in different clinical contexts due to its specific capabilities. Laboratory scanners are known for their superior precision, particularly when handling extensive prosthetic work like large-span prostheses or full-arch impressions. This enhanced accuracy is attributed to the controlled settings of dental laboratories, where conditions such as lighting, stability, and calibration are meticulously maintained to optimize scanning outcomes [26]. Advanced optical systems further contribute to the ability of laboratory scanners to capture intricate anatomical details with exceptional fidelity [27].

Conversely, intraoral scanners are valued for their convenience and patient-centric approach. These devices capture digital impressions directly within the patient's mouth, eliminating the discomfort associated with traditional impression materials and reducing chairside time. They provide immediate visual feedback to dentists, enabling real-time adjustments and enhancing overall treatment efficiency [28].

Despite these advantages, intraoral scanners may encounter challenges when scanning larger areas or handling complex cases. Multiple scans may be necessary to adequately cover expansive surfaces, and the merging of these scans into a cohesive digital model can occasionally introduce minor discrepancies [29]. Factors such as patient movement, saliva presence, and soft tissue dynamics can also affect the accuracy of intraoral scans, necessitating careful technique and skilled operation to mitigate potential errors. The selection between intraoral and laboratory scanners depends primarily on the specific requirements of each clinical scenario. Intraoral scanners are typically preferred for straightforward restorations or single-unit prostheses due to their speed and immediate feedback capabilities [30]. In contrast, laboratory scanners excel in scenarios that demand meticulous accuracy, such as comprehensive rehabilitations or cases involving complex bridgework [31].

Looking forward, ongoing advancements in scanner technology aim to narrow the performance gap between intraoral and laboratory scanners. Continued developments in scanning algorithms, enhanced sensor capabilities, and intuitive software interfaces are anticipated to further improve the precision and reliability of digital impressions across all facets of dental practice. As these technologies evolve, they are expected to play a pivotal role in advancing standards of accuracy and enhancing patient care in the realm of digital dentistry [32].

5. Conclusion

In conclusion, intraoral scanning technology represents a significant advancement in modern dentistry, particularly in the realm of prosthetic dentistry and removable prosthodontics. The technology's ability to provide highly accurate digital impressions, enhance patient comfort, streamline workflow efficiency, and improve communication with dental laboratories underscores its transformative potential. Despite initial costs and implementation challenges, the long-term benefits of intraoral scanners in terms of precision, time savings, and patient satisfaction make them a valuable investment for dental practices aiming to deliver superior prosthetic outcomes. Future research and development efforts should continue to focus on optimizing scanning protocols, enhancing software capabilities, and evaluating long-term clinical outcomes to further refine and expand the application of intraoral scanning technology in prosthodontic care. As adoption rates increase and technology continues to evolve, intraoral scanners are poised to become integral tools in achieving predictable, patient-centered prosthodontic treatments.

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