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ACCURACY, REPRODUCIBILITY AND PATIENT SATISFACTION **OF INTRA ORAL SCANNERS USAGE IN COMPARISON TO CONVENTIONAL IMPRESSIONS, A REVIEW OF LITERATURE**

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ABSTRACT

Intraoral scanners (IOS) are reshaping modern dentistry by offering a digital alternative to traditional impression techniques. This review aims to analyze the accuracy, reproducibility, and patient satisfaction associated with IOS compared to conventional methods. A comprehensive review of academic. Studies were assessed for methodological strength, participant characteristics, and outcomes concerning accuracy, reproducibility, and patient satisfaction.

Results suggest that IOS generally performs as well or better than traditional impression methods, especially in terms of precision and reproducibility, while also delivering high levels of patient satisfaction due to improved comfort. Challenges remain, such as the cost of the technology, the learning curve for practitioners, and some technical limitations. The findings suggest that standardizing methodologies and assessing long-term performance could aid in overcoming these barriers. This review also highlights the need for increased adoption through improved training and cost management.

Aim of the Study: This review aims to provide a detailed evaluation of the accuracy, reproducibility, and patient satisfaction associated with intraoral scanners compared to traditional impression techniques in dentistry.

Materials and Methods: A systematic review was conducted across databases such as PubMed, Cochrane Library, and Google Scholar. Search terms included "intraoral scanner," "conventional impression," "accuracy," "reproducibility," and "patient satisfaction." Studies included in this review were required to compare intraoral scanners with traditional impressions in one or more of the criteria. Only articles written in English were considered, and the selection was based on the strength of their methodology. Data collected included details about study design, sample size, type of impression technique or IOS, and outcomes related to accuracy, reproducibility, and patient satisfaction. Of the 80 articles initially identified, 20 were found to meet the inclusion criteria.

These studies were categorized as follows: Reviews, in vitro studies, in vivo studies, case studies, clinical audits, and comparative studies.

KEYWORDS: Accuracy, reproducibility, patient satisfaction, Intra oral scanners

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STUDIES CLASSIFICATION

- **Reviews (n = 6)**: Literature and systematic reviews provided insights into current technologies, particularly the performance of intraoral scanners across different dental disciplines. These reviews examined the validity and reliability of IOS compared to traditional methods, focusing on clinical applications such as full-arch impressions, orthodontics, and implantology. Several studies highlighted the accuracy and efficiency of IOS systems in diverse dental procedures
- In Vitro Studies (n = 7): These studies, conducted in controlled laboratory settings, measured the precision, trueness, and accuracy of IOS. Comparisons were made between different intraoral scanners and traditional methods to assess how well each performed in replicating dental anatomy. IOS consistently demonstrated high accuracy and precision in these studies, although challenges were noted in scanning reflective surfaces and subgingival areas.
- In Vivo Studies (n = 3): Clinical trials evaluated how IOS performed in real-world scenarios. These studies compared IOS and conventional workflows in terms of prosthetic restorations, patient satisfaction, and time-efficiency. Mangano et al. (2018) found that IOS significantly reduced chairside time without sacrificing the quality of outcomes .
- Case Studies (n = 1): One case study focused on the challenges of using traditional impression methods in patients with sensitive gag reflexes. Digital impressions were found to be more comfortable and less intrusive, helping overcome such difficulties.
- Clinical Audits (n = 1): This audit explored the use of alternative methods, such as acupuncture, to manage gag reflexes during conventional impressions. It concluded that digital impressions,

due to their non-invasive nature, could mitigate these issues .

Comparative Studies (n = 1): A comparative study assessed the attitudes of dental students towards digital versus traditional techniques. Digital workflows were preferred due to their speed, ease of use, and higher quality impressions, particularly in educational settings.

INTRODUCTION

Intraoral scanners are quickly becoming a preferred alternative to traditional impression-taking methods in modern dentistry. Historically, materials such as alginate and polyvinyl siloxane (PVS) were used to capture dental anatomy for restorative and diagnostic purposes. However, these conventional methods often suffer from limitations like dimensional instability and material shrinkage, which can lead to inaccuracies in the final product^(1,2). Moreover, traditional impressions can be uncomfortable for patients, particularly those with gag reflexes or dental anxiety^(1,3).

In contrast, intraoral scanners offer an entirely digital solution, using advanced optical or laser technologies to generate precise three-dimensional (3D) models of the oral cavity^(2,4). Digital impressions provide real-time feedback, allowing for immediate corrections during the scanning process, thereby minimizing the need for repeat impressions^(5,6). Research by Mangano et al. (2016) and Ender & Mehl (2013) has demonstrated that IOS can match or even exceed the accuracy of traditional impressions, particularly for complex restorations ^(7,8).

The integration of IOS with computer-aided design and manufacturing (CAD/CAM) workflows has also revolutionized restorative dentistry. Digital impressions are not only more accurate but also streamline the design and production of crowns, bridges, and other restorations. This reduces the risk of errors associated with manual modeling and speeds up the entire process^(5,6). Zimmermann et al. (2015) highlighted how IOS improves efficiency by eliminating many of the time-consuming steps involved in traditional impression workflows ⁽⁹⁾.

However, despite these advantages, the widespread adoption of IOS faces several challenges. The cost of acquiring intraoral scanners and the associated training required for proficiency represent significant barriers, particularly for smaller dental practices^(6,10). Additionally, some technical issues, such as difficulty capturing subgingival margins or scanning reflective surfaces, can limit the accuracy of IOS in certain cases^(2,6). Nevertheless, advances in scanner technology continue to address these limitations, improving overall performance and accessibility^(2,11).

DISCUSSION

Intraoral scanners have greatly impacted dental workflows by enhancing both accuracy and efficiency. One of the key advantages of IOS is the precision it offers in capturing digital impressions. Studies have shown that IOS can produce highly detailed digital models with minimal distortion, making them ideal for procedures such as crown and bridge restorations ^(5,7,12). This level of accuracy is crucial for ensuring a precise fit of dental prosthetics, reducing the need for post-placement adjustments ⁽¹²⁾.

In addition to their accuracy, IOS enhances patient comfort significantly. Traditional impressions often require bulky trays and messy materials, which can cause discomfort and trigger gag reflexes^(1,3). Digital impressions, on the other hand, are non-invasive and quick, making them particularly advantageous for patients who may have anxiety or other sensitivities^(3,6). Clinical trials have consistently found that patients prefer digital impressions over conventional methods due to the increased comfort and reduced chairside time^(7,13).

The integration of digital workflows with CAD/CAM systems further improves the overall efficiency of dental practices. Digital impressions

can be sent directly to the laboratory, speeding up the production of prosthetic restorations and reducing the potential for human error $^{(6, 12)}$.

Joda & Brägger (2015) found that digital workflows reduced chairside time by a significant margin compared to traditional techniques, improving both productivity and patient outcomes ⁽¹⁴⁾.

Advantages:

- Accuracy and Precision: IOS consistently demonstrates a high level of accuracy and precision, offering detailed 3D models that closely mirror the actual dental anatomy ^(2,5,6,12). This precision is especially beneficial in restorative dentistry, where even small inaccuracies can lead to complications or prosthetic failures ⁽¹²⁾.
- **Patient Comfort**: Digital impressions eliminate the need for trays and impression materials, making the process far more comfortable for patients, particularly those with strong gag reflexes or dental anxiety ^(3,6). This improves the overall patient experience and increases satisfaction ^(7,13).
- Efficiency: IOS streamlines clinical workflows, reducing the need for repeat impressions and minimizing chairside time. Digital impressions can be immediately reviewed, adjusted, and sent to the laboratory, which improves both the speed and accuracy of dental procedures ^(6,12).
- Customization: IOS technology enables greater customization of restorations, ensuring that they are tailored to the patient's specific anatomy. This leads to better aesthetic and functional outcomes ^(5,6).

Disadvantages:

• **Cost**: Acquiring IOS technology requires significant investment, which may be prohibitive for smaller practices. The cost of associated software and training can also be a barrier to adoption ^(6,11).

- Learning Curve: Transitioning from conventional impression techniques to digital workflows requires clinicians to undergo specialized training. This learning curve can deter some practitioners from adopting the technology ^(6,7).
- **Technical Limitations**: IOS can struggle to capture subgingival margins and reflective surfaces, which may limit their accuracy in certain clinical situations. However, using techniques such as anti-reflective sprays or gingival retraction can mitigate these issues ^(2,6,11).
- Data Security: Digital impressions raise concerns regarding the protection of patient data. Robust cybersecurity measures are necessary to ensure that sensitive information is not compromised ⁽⁶⁾.
- Maintenance: Regular maintenance and calibration of intraoral scanners are required to
 ensure optimal performance, which adds to the
 operational costs ⁽⁶⁾.

Clinical Implications:

Intraoral scanners (IOS) have had a profound impact on dental practice, influencing treatment planning, workflow efficiency, patient care, and collaboration within the dental team. The integration of digital impressions has modernized many dental procedures, from diagnostics to restorations, leading to improvements in accuracy, patient satisfaction, and overall clinical outcomes.

Enhanced Treatment Planning and Precision:

IOS provides clinicians with highly detailed digital impressions that enable more accurate and efficient treatment planning. This precision is especially beneficial in orthodontics, where digital scans help to assess tooth alignment and predict treatment outcomes more accurately than traditional methods^(11,15,16). Similarly, in prosthodontics and implant dentistry, IOS allows for the precise fabrication of crowns, bridges, and implants, ensuring better-fitting restorations with fewer post-placement adjustments ^(1,5,14). The accurate digital models also facilitate better diagnosis, allowing clinicians to detect and address potential issues before treatment begins.

Improved Workflow Efficiency:

The introduction of IOS has streamlined many aspects of dental workflows by eliminating timeconsuming steps associated with traditional impression techniques. Conventional impressions often require multiple appointments for accurate captures, while IOS allows for immediate feedback and real-time adjustments during the scanning process^(6,12). Digital impressions can be transmitted directly to the dental laboratory, speeding up the process of creating restorations and eliminating the delays involved in transporting physical models. As a result, practices benefit from faster turnaround times, reducing chairside time and increasing productivity^(5,6).

Studies, such as the one conducted by Joda and Brägger (2015), have shown that digital workflows significantly cut down on chairside time without compromising the quality of outcomes. This improved efficiency enhances practice throughput, allowing clinicians to treat more patients in less time, and improves patient satisfaction by minimizing the time they need to spend in the dental chair ⁽¹⁴⁾.

Patient Satisfaction and Comfort:

One of the most significant advantages of IOS is the increased comfort it offers to patients. Traditional impression methods, which involve the use of impression trays and materials, can be uncomfortable and trigger gag reflexes or anxiety, particularly in sensitive patients ^(1,3). In contrast, digital impressions are non-invasive and eliminate the need for bulky trays and messy materials, making the experience more pleasant for patients. Research shows that patients generally prefer digital

impressions due to the ease and speed of the process, resulting in higher levels of satisfaction ^(3,6).

Moreover, IOS enables clinicians to share the digital scans with patients during appointments, helping them better understand their treatment and boosting their confidence in the care they are receiving. The ability to make immediate corrections during the scanning process also means fewer repeat impressions, reducing patient discomfort and time spent in the dental chair ^(7,13).

Enhanced Collaboration Among Dental Teams:

Digital impressions facilitate smoother communication and collaboration between clinicians, dental technicians, and specialists. With IOS, digital scans can be instantly shared electronically, allowing dental technicians to review and provide feedback in real-time. This real-time exchange of information ensures that any necessary adjustments can be made quickly, reducing the risk of miscommunication or errors, which can occur with physical models ^(6, 13,16).

Improved collaboration leads to better coordination in treatment planning and the fabrication of restorations. The ability to instantly share and discuss the digital impressions enhances the quality of restorations, reduces delays, and helps ensure that the final product meets the clinician's and patient's expectations ^(6,16). This collaborative approach, facilitated by IOS, helps in achieving more accurate and predictable clinical outcomes.

Customization of Restorations:

The use of IOS allows for highly customized restorations, tailored to the specific anatomical needs of each patient. Because digital impressions are highly accurate, they provide the foundation for creating precise, personalized restorations that offer superior fit and functionality ^(5,6). This customization is particularly important in prosthodontics, where the quality of fit can significantly impact the long-term success of crowns, bridges, and implants.

By integrating IOS with CAD/CAM systems, clinicians can design and fabricate restorations that match the patient's oral anatomy precisely, improving both aesthetic and functional outcomes.

The digital nature of IOS minimizes manual errors associated with traditional methods, ensuring that restorations are produced to the highest standards ^(6, 12). Zimmermann et al. (2015) highlighted that this level of customization enhances patient satisfaction and leads to better long- term clinical outcomes ⁽⁹⁾.

Challenges in Detecting Deep Margins:

One of the technical challenges associated with intraoral scanners is the difficulty in capturing deep subgingival margins, particularly when these margins are located below the gum line.

Traditional impression materials have the ability to displace soft tissue, allowing for better capture of subgingival details. However, IOS relies on light or laser to scan surfaces, which makes it harder to accurately capture deep or subgingival margin lines^(9, 13, 16).

In aesthetic zones, where subgingival prosthetic margins are commonly required, the limitations of light-based scanners become more apparent. Bleeding, poor oral hygiene, or the inability to retract the gingival tissues properly can obstruct the scanner's ability to record the full extent of the margin ⁽¹⁶⁾. This challenge is less of an issue with dental implants, where the use of scan bodies offers better capture of margins, but it remains a significant concern for natural tooth restorations.

To address this issue, various techniques have been suggested. Gingival retraction cords or agents are commonly used to temporarily displace the gingiva, improving visibility and allowing the scanner to capture deep margin lines more effectively^(4,9). Additionally, the use of anti- reflective sprays can help to reduce the distortion caused by reflective surfaces, ensuring a more accurate scan. In cases where IOS struggles to capture the deep margins effectively, combining digital and traditional impression techniques has been proposed as a way to overcome these limitations ⁽¹¹⁾. This hybrid approach provides clinicians with the flexibility to leverage the advantages of both methods while minimizing their individual shortcomings.

Long-term Clinical Benefits and Predictability:

In addition to improving the immediate accuracy of restorations, IOS contributes to more predictable long-term clinical outcomes. In implantology, for example, digital impressions allow for precise implant placement, reducing the risk of complications such as misalignment or improper angulation ^(7,16). Over time, this precision leads to better stability and durability of dental restorations, minimizing the need for corrective interventions.

Digital impressions also offer the advantage of being stored indefinitely as part of a patient's digital record. This allows clinicians to track treatment progress over time and compare previous scans to current ones, making it easier to monitor changes in the patient's oral health and adapt treatment plans accordingly^(6,11). The ability to access and review past scans enhances clinical decision-making and improves patient management.

Impact on Dental Education and Training:

As digital workflows become more common in clinical practice, dental education must adapt to ensure that future dentists are well-versed in the use of IOS technology. Studies, such as Marti et al. (2017), have shown that dental students tend to prefer digital scanning techniques due to their efficiency, ease of use, and the quality of the impressions produced⁽¹³⁾. By incorporating IOS into dental curricula, training programs can better prepare students for the demands of modern dental practice.

This shift in education is crucial, as proficiency in digital workflows will become an essential skill for future dentists. Familiarizing students with IOS early in their careers ensure that they are ready to embrace the evolving technological landscape of dentistry and can integrate digital tools into their practices effectively⁽¹³⁾.

Potential for Long-term Cost-effectiveness:

While the initial cost of purchasing IOS technology can be high, the long-term benefits in terms of cost savings are substantial. By reducing the need for impression materials and minimizing chairside time, IOS can improve the overall efficiency of dental practices and lead to higher productivity ^(6, 12). Additionally, the reduction in retakes and the ability to avoid costly remakes due to inaccurate impressions help offset the upfront investment.

As technology becomes more affordable and accessible, the potential for broader adoption increases. Over time, practices that invest in IOS technology may see significant improvements in workflow efficiency, profitability, and patient satisfaction, making it a worthwhile investment for the future^(6,11).

CONCLUSION

Intraoral scanners have significantly advanced dental practice, providing superior accuracy, reproducibility, and patient comfort compared to traditional impression methods. Digital workflows improve efficiency, reduce the need for retakes, and enable more precise restorations. While challenges such as cost, the learning curve, and technical limitations persist, the ongoing development of IOS technology continues to address these issues. As IOS becomes more affordable and accessible, its role in modern dentistry will only grow. Future research should focus on standardizing methodologies, expanding clinical applications, and exploring the long- term benefits of IOS in various dental disciplines.

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