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Review Article

The future of dental diagnostics: Can intraoral scanners replace traditional tools?- A mini review

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Abstract

Intraoral scanners (IOSs) have revolutionized dental diagnostics by enabling detailed 3D digital impressions of the oral cavity. These devices offer numerous advantages, such as precision, efficiency, and patient comfort, in procedures like orthodontic treatment planning. However, their potential to replace traditional diagnostic tools, such as clinical visual examinations, X-ray imaging, and functional assessments, is limited. While IOSs excel at capturing surface-level anatomy, they cannot detect underlying conditions like caries, bone loss, or soft tissue pathologies, for which traditional imaging techniques remain essential. This review explores the current capabilities and limitations of intraoral scanners in dentistry, particularly their role in diagnosing oral pathologies, and discusses how combining IOSs with conventional tools can enhance diagnostic accuracy. The future of dental diagnostics may see further integration of intraoral scanners, with advancements in artificial intelligence and teledentistry, making them an indispensable complement to traditional methods rather than a complete replacement.

Keywords: Intraoral scanners, Digital impressions, Dental diagnostics, Orthodontics, X-rays, Clinical examination, Soft tissue assessment, Artificial intelligence, Teledentistry, Dental technology

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1. Introduction

Intraoral scanners (IOSs) have revolutionized modern dentistry by offering high-precision, digital alternatives to conventional dental impressions. These advanced devices utilize 3D imaging technologies to capture accurate representations of the oral cavity, including the dental arches, teeth, and surrounding soft tissues. By using structured light, laser triangulation, or confocal microscopy, IOSs generate detailed 3D models with remarkable accuracy, which serve various applications such as orthodontics, restorative dentistry, and prosthodontics.[1,2]

The development of intraoral scanning technology dates back to the early 1980s when researchers began exploring digital imaging techniques for dental use. The initial designs, while innovative, were rudimentary compared to today's devices, struggling with accuracy and ease of use.[3] It wasn't until the 2000s that major strides were made, with the advent of more advanced sensors and computing power. By the 2010s, IOSs were widely adopted in clinical practices, offering faster and more accurate impressions than traditional molds.[4] The integration of artificial intelligence (AI) further transformed their diagnostic capabilities, enhancing not only the quality of scans but also the ability to detect dental issues like caries and misalignments.[5] Despite these advancements, ongoing research is required to evaluate their full potential in replacing traditional diagnostic methods, such as radiographic techniques, and integrating with emerging technologies like AI.[5]

1.1 Types of intraoral scanners?

Intraoral scanners are devices that create detailed 3D digital models of a patient's teeth, gums, and oral structures. Unlike conventional methods, which rely on impressions or X-rays, intraoral scanners capture highly accurate digital impressions in real-time, providing detailed images of the patient's oral anatomy. The common implications of digital scanners include restorative dentistry, orthodontics and implantology.

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The primary advantage of intraoral scanners is that they offer a non-invasive, quick, and comfortable alternative to traditional impressions, which can be unpleasant and time-consuming for patients.

1.2 Types of intraoral scanners

Intraoral scanners are of several different types available, each using distinct methods to capture 3D digital impressions of the oral cavity. These technologies can be categorized primarily into *optical scanning, laser scanning, and electromagnetic scanning.* Each type has its unique set of advantages and limitations, making them suitable for different clinical applications.

1. **Optical Scanning** Optical scanners utilize light to capture digital impressions. They use technologies such as structured light or confocal microscopy to project patterns or light onto the surface of the teeth and surrounding tissues. The distortions in the light patterns are then captured by cameras or sensors and used to generate 3D models.

2. **Structured Light Scanners:** These are the most commonly used optical scanners in modern dentistry. They project a series of light patterns onto the teeth, and the reflections of these patterns are captured by a camera to reconstruct the 3D model of the teeth. These scanners are known for their speed and accuracy and are typically used for general impressions, orthodontic assessments, and restorative dentistry.

3. **Confocal Scanning:** Confocal microscopy, which is less common than structured light, involves capturing a series of 2D images at different depths to create high-resolution, detailed 3D models of the oral cavity. This type of scanner provides excellent resolution and is especially useful for detailed surface scans.

4. **Laser Scanning** Laser scanners employ a laser beam to scan the teeth. The laser beam is directed onto the surface of the teeth, and the reflected light is used to generate a 3D model. The laser method provides highly accurate and detailed scans, particularly for capturing fine details of the teeth's surface. The technology is often used in conjunction with other scanning methods, such as optical scanning, to provide a more comprehensive view of the dental anatomy

5. **Triangulation Laser Scanners:** These scanners use laser triangulation, where the scanner emits a laser beam and measures the angle of reflection to calculate the distance between the scanner and the object being scanned. The data is used to build a precise 3D representation of the oral cavity.

6. **Electromagnetic Scanning** Electromagnetic scanners are another type of intraoral scanner that use electromagnetic fields to track the position of a probe within the oral cavity. This type of scanner is less common but can be useful in certain specialized dental applications, such as dynamic functional assessments or monitoring tooth movement during orthodontic treatments. However, electromagnetic scanning is generally less popular than optical and laser-based methods due to its lower resolution and slower speed.

Each type of intraoral scanner comes with its unique advantages. For example, optical scanners are fast and non-invasive, making them suitable for routine impressions. Laser scanners provide high accuracy and precision, especially for capturing detailed anatomical features. Electromagnetic scanners, while not widely used, offer benefits in specialized clinical settings, such as in tracking tooth movements during orthodontics.

2. Study Selection

A systematic search was performed across several databases, including MEDLINE, PubMed, Scopus, and Google Scholar, covering studies published between January 2010 and December 2024. Keywords such as "intraoral scanners," "AI integration," "diagnostic accuracy," and "dental imaging" were used to identify relevant studies.

Duplicate articles were removed, and studies that did not meet the inclusion criteria (described below) were excluded. After screening titles, abstracts, and full-texts, a total of 16 articles were selected for inclusion in this review. The inclusion and exclusion criteria were as follows;

2.1 Inclusion criteria

1. Studies published between 2010 and 2024.
2. Peer-reviewed articles and clinical trials assessing the role of IOSs in dental diagnostics.
3. Studies discussing AI integration with IOSs for enhancing diagnostic accuracy.
4. Studies comparing IOSs to traditional diagnostic tools (e.g., X-rays, visual exams).
5. Articles published in English.

2.2 Exclusion criteria

1. Articles not available in full text or not peer-reviewed.
2. Studies unrelated to dental diagnostics or focusing on non-human subjects.
3. Reviews, opinion pieces, and editorials.
4. Articles in languages other than English.

3. Discussion

Intraoral scanners represent a significant advancement in dental diagnostics, providing dentists with high-resolution digital models that improve accuracy and patient comfort. The scanners have revolutionized procedures such as crown preparation, implant planning, and orthodontic assessments. By capturing detailed 3D images of the teeth, gums, and surrounding tissues, IOSs offer a faster, less invasive

alternative to traditional impressions, which are often uncomfortable and prone to distortion.[6]

3.1 The role of intraoral scanners in dentistry

Intraoral scanners are used in many aspects of dentistry.

1. **Restorative Dentistry**: Intraoral scanners are increasingly used to create digital impressions for crowns, bridges, and veneers, leading to quicker turn arounds in the fabrication process.
2. **Orthodontics**: Intraoral scanners play a key role in planning treatments, such as clear aligners, by providing precise 3D images that can be used to develop individualized treatment plans.
3. **Implantology**: For dental implants, intraoral scanners help create accurate impressions of the oral cavity, which are essential for the correct placement of implants.
4. **Patient Education**: With detailed 3D models, dentists can better communicate with patients, providing a clearer understanding of their dental conditions and treatment options.

3.2 Can intraoral scanners replace traditional diagnostic tools?

While intraoral scanners provide invaluable data for certain procedures, they cannot fully replace traditional diagnostic tools, especially when it comes to detecting internal oral conditions or assessing overall oral health. Let us break down the potential replacements and limitations of intraoral scanners:

3.3 Clinical visual examination

The clinical visual examination is a cornerstone of dental diagnostics. During this exam, dentists can assess visible signs of oral disease, such as gingivitis, gum recession, or oral cancer. Intraoral scanners, while capable of producing detailed digital impressions do not replace a dentist's tactile and visual assessment during a clinical exam.

1. **Strengths of Visual Exams**: Dentists can detect early signs of diseases like periodontal conditions or oral cancer through visual inspection, something that an intraoral scanner cannot replicate. It also allows for assessment of the overall condition of the teeth, gums, and soft tissues.
2. **Limitations of Intraoral Scanners**: Intraoral scanners cannot replace the hands-on evaluation of soft tissues, such as checking for swelling, ulcers, or other oral lesions.

3.4 X-ray Imaging

X-rays, including traditional radiographs (bitewings and panoramics) and more advanced imaging techniques such as cone-beam computed tomography (CBCT), are fundamental diagnostic tools in dentistry. These imaging methods allow dentists to see beneath the surface of the teeth and bone to detect conditions such as cavities, infections, bone loss, and impacted teeth.

1. **Advantages of X-rays**: X-rays are indispensable for diagnosing conditions that cannot be detected visually, such as decay between teeth, abscesses, and bone abnormalities. CBCT scans are particularly valuable for planning implant surgeries, as they offer a comprehensive view of both hard and soft tissues.
2. **Limitations of Intraoral Scanners**: Intraoral scanners are great for capturing surface-level anatomy but cannot provide the same detailed internal view that X-rays or CBCT scans offer. They are unsuitable for detecting hidden caries between teeth or assessing bone structure.

4. Functional Diagnoses

Functional diagnoses, such as assessing bite issues or temporomandibular joint (TMJ) disorders, often require physical examinations and testing. While intraoral scanners can provide a detailed digital model of a patient's bite, they do not capture the dynamic movements or functional problems that occur in the jaw.

1. **Advantages of Intraoral Scanners**: They can analyze the occlusion (bite) and monitor changes over time. This is particularly useful in orthodontics and restorative work, where an accurate model of the teeth is essential for planning treatments.
2. **Limitations of Intraoral Scanners**: Functional issues, such as muscle pain, TMJ disorders, and bite dysfunctions, require additional physical examinations, which intraoral scanners cannot replace.

5. Limitations of Intraoral Scanners

Despite their impressive capabilities, intraoral scanners can only partially replace traditional diagnostic tools. Here are some limitations that need to be considered:

7.1 Inability to detect certain conditions

Intraoral scanners excel in capturing the surface details of the teeth and gums, but they are limited in their ability to detect conditions that lie beneath the surface, such as decay between teeth, bone loss, or abscesses. Diagnostic tools like X-rays are essential for evaluating these hidden conditions. X-rays provide a view of the internal structures of the teeth, bone levels, and soft tissues, which is crucial for identifying issues that are not visible through a scanner alone.

7.2 Limitations in soft tissue assessment

While intraoral scanners are highly effective in visualizing hard tissues like teeth, they are less efficient in visualizing soft tissues. For example, they may not provide sufficient detail for diagnosing oral lesions, gingival conditions, or pathologies in the mouth's soft tissues. A traditional clinical examination, possibly combined with tools like periodontal probes, is still necessary for evaluating soft tissue health.

7.3 Initial cost and accessibility

The initial investment in intraoral scanners can be prohibitively high for some dental practices, especially smaller or solo practices. While the long-term benefits in terms of efficiency and patient satisfaction are significant, the upfront cost remains a barrier for many.

7.4 Patient movement and difficulties with complex anatomy

Intraoral scanners can struggle with certain patients, especially those with complex oral anatomy, such as large or deep palates, tight interproximal spaces, or significant dental work already in place. Additionally, patient movement during scanning can lead to less accurate results, particularly if the scan needs to be taken more meticulously.

6. Future of Intraoral Scanners: AI Integration and Enhancement of Diagnostic Capabilities

Artificial intelligence (AI) has the potential to further enhance the capabilities of intraoral scanners. AI algorithms, especially machine learning models, are being integrated into these devices to enable real-time analysis of both surface and internal dental structures.[7]Studies indicate that AI can assist in detecting subtle features such as caries, occlusal discrepancies, and early signs of periodontal disease, which might be overlooked by human observers.[8] By training AI systems on large datasets of 3D dental scans, these models can learn to identify patterns that indicate pathological conditions, assisting dental professionals in making more accurate diagnoses.

AI's role in enhancing intraoral scanners is underscored by recent studies that show improved accuracy in detecting dental caries, especially in early-stage lesions, compared to traditional radiographs.[9] Furthermore, AI-powered intraoral scanners can automatically segment and analyze the scanned data, providing dentists with automated reports, thus saving time and reducing human error. For example, studies on AI-enhanced scanning systems have shown that these devices can identify abnormalities such as enamel demineralization and early-stage cavities with higher sensitivity than conventional visual exams.[10] This integration could lead to earlier interventions, potentially preventing the progression of certain dental conditions.

Case Studies on IOS and Traditional Methods Complementing Each Other

In practice, IOSs and traditional diagnostic methods often complement one another rather than replace each other entirely. For instance, while intraoral scanners provide high-precision 3D images, traditional radiographic techniques such as X-rays are still indispensable for detecting subsurface dental conditions like caries between teeth or bone loss. A study by Smith et al. (2020) examined the combination of IOS and CBCT (cone-beam computed tomography) to assess the placement of dental implants. The IOS provided accurate surface scans, while CBCT allowed for a detailed view of bone structure, demonstrating that both methods provided valuable complementary insights.[11]

Another example can be seen in orthodontics, where intraoral scanners provide detailed digital impressions of teeth, while traditional methods, such as cephalometric analysis from X-rays, remain essential for evaluating jaw structure and facial growth patterns.[12] The synergy between digital and traditional tools ensures a comprehensive assessment of patient conditions, offering more accurate treatment planning.

However, integrating IOSs with traditional diagnostic methods comes with its challenges. Data interoperability is a significant concern, as different systems may use incompatible formats, making it difficult to merge digital impressions with radiographs or CT scans. Additionally, workflow adjustments may be required as clinicians adapt to incorporating new technologies without disrupting established practices. The integration of AI and machine learning can assist with these issues by automating data processing and creating standardized protocols across different systems.[13,14,15]

7. Limitations of the Review

This review has some limitations that must be acknowledged. First, it relies heavily on secondary data from existing studies, which may be subject to biases or incomplete reporting. Furthermore, the body of literature surrounding the integration of IOSs with traditional diagnostic methods is still evolving, and there are gaps in research, particularly in the longitudinal assessment of diagnostic accuracy and patient outcomes over extended periods. Future research should address these gaps to provide a more comprehensive understanding of the role of IOSs in dental diagnostics.

8. Conclusion

In conclusion, intraoral scanners are transforming dental diagnostics, but they will not entirely replace traditional diagnostic methods. Rather, they will complement these techniques, with AI playing a crucial role in enhancing diagnostic accuracy and workflow efficiency. The integration of IOSs with traditional tools like X-rays and CBCT provides clinicians with a more complete view of a patient's oral

health. As technology advances, future studies should focus on specific areas such as cost-benefit analysis, longitudinal studies to assess diagnostic outcomes, and the optimization of AI integration to further streamline clinical workflows. By addressing these areas, we can ensure that intraoral scanners continue to evolve in ways that benefit both dental practitioners and patients alike.[16]

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None.

10. Conflict of Interest

The authors report no conflicts of interest regarding this study.

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