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Advances in Caries Detection: Analyzing Commercial Technologies and Their Limitations in Clinical Practice

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ABSTRACT

This manuscript discusses several advanced technologies currently available for detecting dental caries. Each technology already has a commercialized product that is sold and available on the market. This research also examines the limitations of each technology. Types of technologies are listed in this study are intraoral radiography, near-infrared transillumination (NIRT), light-induced fluorescence, laser fluorescence, electrical conductivity and ultrasound. Apart from these digital diagnostic instruments that are clinically available, numerous more digital diagnostic aids for the detection of dental cavities are still in the development stage and are exhibiting encouraging outcomes in lab settings.

Keywords: *Caries; technology; method; limitation; commercialize product*

1. Introduction

One of the most prevalent infectious disorders affecting people worldwide is tooth decay, or caries, which is brought on by a combination of bacteria, carbohydrates, and food. Dental caries is a serious issue for human health that is commonly observed in clinical settings, progresses slowly, and can result in severe discomfort, tooth loss, and other problems that lower quality of life [1].

The identification of dental caries has been made much easier by the development of digital diagnostic tools [2]. The purpose of this review is to emphasize on its limitation of digital diagnostic tools that have been commercialized for the clinical detection of dental caries.

Minimally invasive dentistry and preventative applications are becoming more and more popular in today's dentistry. Early detection of early caries lesions is crucial for minimally invasive dentistry. As technology advances, numerous new techniques are being developed to guarantee the early detection of dental cavities [1].

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1.1 Literature Search

This section describes several existing technologies used to detect caries, along with their limitations as outlined in the Table 1 below. Given the various shortcomings found in current technologies, particularly those involving radiation and the inability to analyze the depth of caries.

These technological diagnostic tools have advantages but also certain drawbacks. They support conventional techniques by helping doctors identify dental cavities. But none have shown to be ideal in spotting dental caries, especially when it's early observed [2]. The technologies that are being focused on include intraoral radiography, near-infrared transillumination (NIRT), light-induced fluorescence, laser fluorescence, and electrical conductivity.

1.1.1 Intraoral radiograph

Includes bitewing and periapical radiography. Periapical refers to the area around the apex of a tooth's root; as such, it encompasses the whole crown and root of a tooth, extending approximately 2 mm past the apex of the root. However, bitewing radiographs record the maxillary and mandibular teeth's crown and a third of their root, together with the interalveolar bone that surrounds them. [3].

1.1.2 Near-infrared transillumination (NIRT) devices

A photo-optical technique that uses a long-wave light to shine on the tooth's side in order to identify cavities. NIRT employs light from the invisible spectrum, which penetrates things more deeply and produces an excellent contrast between healthy and carious tissue, with the latter appearing as a darker region. This decreases light scattering and absorption in the solid tooth enamel [4].

Table 1
Current technologies used in caries detection and its limitations

Technology/ Method	A model of a commercial product	Research Gap
Intraoral radiograph	Planmeca ProXTM [2]	• 30–40% of enamel must demineralize before showing up on radiography. (missing of early stages of caries). [5] • Radiation exposure is either digital (lower radiation) or analog (high radiation). radiography [3], [7]
Near-Infrared Transillumination (NIRT) devices	DIAGNOCam™ (Kavo) [4]	• Some proximal caries may not be noticeable. [5]. • Extremely challenging to picture the first lower primary molars. [5].
Light-induced fluorescence	Spectra, 3Shape TRIOS 4 [2]	• Contamination-like blood, calculus, or plaque could mix up with carious lesions, giving a false positive signal. This might cause inexperienced personnel to overtreat, [5]
Laser-induced fluorescence	DIAGNOdent [8]	• Better at identifying the volume of a caries than its depth within the tooth. [1] • Very expensive [1]
Electrical Conductivity	Ortek ECDTM electronic device [2]	• Requires a lot of time to do routine entire mouth exams. [1] • Does not offer any proof of active or inactive caries. [1]
Ultrasound	Ultrasonic Caries Detector (UCD); Novadent	• Is only able to identify whether caries is present or not, not the severity of the caries such as initial, moderate and severe [6].

1.1.3 Light-induced fluorescence

Materials that exhibit fluorescence produce light when they are triggered. Light-induced fluorescence in dentistry makes use of teeth's inherent fluorescence to distinguish between healthy and decaying areas. These gadgets make use of green, blue, or red light. Due to energy and wavelength discrepancies, the fluorescence that is released has a distinct color from the light that causes it to occur [5].

1.1.4 Laser-induced fluorescence

Laser system technique is based on the resultant increase in the fluorescence of demineralized tooth at specific excitation wavelengths. A laser diode that generates a pulsed 655-nm red laser beam via a central fiber, which is transported to the tip of the device and into the tooth. The intensity of fluorescence is directly proportional to the degree of demineralization or bacterial concentration in the area scanned [3].

1.1.5 Electrical conductivity

The electrical conductance of a decaying tooth is measured by the electrical conductance measurement instrument using a fixed frequency alternating current. To touch a little quantity of fluid, a particular electrode inserts itself into tiny pit or fissures in the tooth. The circuit is not complete in a tooth that is in good health and has no decay, so the gadget displays a zero value. However, if there are caries, the gadget circuit is completed and provide reading [2].

1.1.6 Ultrasound

By placing the transducer on the tooth surface, this gadget detects the acoustic reflection that the tooth surface emits; the signal is instantaneously shown on the screen [6].

1.2 Discussion

In the detection of dental caries, each technology brings specific strengths that contribute to different aspects of diagnostic accuracy. Overall, while each method offers valuable insights into caries detection, research gaps remain. Many technologies struggle with early-stage detection, particularly for smaller or inaccessible carious lesions.

These limitations highlight the need for further advancements in caries detection technologies. Although the tools discussed have significantly improved diagnostic capabilities, their gaps—such as difficulty in detecting early-stage caries, challenges in quantifying lesion severity, and high costs—underscore the importance of ongoing research and innovation in this field.

This research is limited to only a few selected technologies to maintain a focused and in-depth analysis. By concentrating on these specific technologies, the study aims to critically evaluate their limitations, which are well-documented and clinically relevant. Additionally, these technologies represent a diverse range of diagnostic principles, offering a comprehensive view of the current state of caries detection tools while staying within the scope and feasibility of the research.

2. Conclusions

In conclusion, while each technology has shown promise in caries detection, the need for improvement in sensitivity, accessibility, efficiency, and accuracy remains. Addressing these gaps would enhance the effectiveness of diagnostic tools in everyday dental practice, ultimately leading to better patient outcomes. This research focuses primarily on the limitations of the selected technologies for caries detection rather than their advantages. While these technologies offer significant benefits in clinical practice, the emphasis of this study is to critically analyze their shortcomings to identify areas for improvement and highlight the need for more effective diagnostic solutions.

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