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THE EFFECTIVENESS OF DIFFERENT METHODS FOR DETECTING EARLY DENTAL CARIES

Hanan Omar Basmeer, Aishah Hassan Magrashi , Aminah Ali Al Yami , Ashwaq Awad Mayuf Alanazi, Mohammad Haif Saeed Alqhtani, Abdulaziz Naser Abdulaziz Al Munyif, Mohammed Muflih Mohammed Alrabie, Alaa Ibrahim Aldhuwalia, Maryam Mohammed Ahmed Alqabi, Hassan Hussain Alnasser, Hussain Khalid Alattiah, Dalal Nasser Alharbi, Mosheera Suliman Salman Almutairi, Akram Hussein Marzouki, Aminah Saeed Hamad Almutairi

Abstract

The objective was to evaluate the data about the effectiveness of several methods for detecting early tooth decay in living organisms. A systematic search was conducted across five databases, including published research. The search phrases used were "early caries" and "caries detection." The inclusion criteria were studies that examined the accuracy of diagnostic tests for early diagnosis of caries in both permanent and primary teeth. An evaluation of potential bias was conducted using the QUADAS-2 instrument. We conducted the process of research selection, data extraction, and risk-of-bias evaluation in duplicate. The review process was filed in advance in the Open Science Framework. When examining the occlusal surfaces of permanent teeth, the DIAGNOdent Pen (DD Pen) showed a high sensitivity range of 0.81-0.89, as determined by histologic examination. This was followed by ICDAS-II with a sensitivity range of 0.62-1, DIAGNOdent (DD) with a sensitivity range of 0.48-1, and bitewing radiography (BW) with a sensitivity range of 0-0.29. The Se and Sp values exhibited variability, which may be attributed to the diversity in the settings of separate investigations. Clearly, definitive judgments cannot be made, and other diagnostic methods should be used in addition to clinical evaluation. For permanent teeth, the use of digital radiography (DD) on the biting surfaces and bitewing radiography (BW) on the areas between teeth may improve visual assessment. DD Pen may be used as an additional tool on all surfaces of primary teeth.

Keywords: Caries identification, Initial caries, Developing caries, Adult teeth, Baby teeth

1. Introduction

The frequency of dental caries has been decreasing in recent decades [Jones et al., 2017]. Nevertheless, the prevalence and effect of the condition remain significant, affecting a majority of individuals to varying degrees, despite the increasing knowledge about the advantages of dental hygiene and fluoride use, particularly in relation to certain kinds of teeth and surfaces [Ekstrand and Qvist 2015]. In 2015, more than 10% of the global population was afflicted by dental caries, highlighting the widespread nature of this illness across people of all ages and emphasizing its significant societal consequences [Vos et al., 2016]. Caries not only causes tooth decay, but also leads to discomfort, insomnia, and absenteeism from school and work [Goodwin et al., 2015; Kassebaum et al., 2015].

A significant contributing element to the high incidence is the potential for caries to remain unnoticed during the early stages and then grow into cavities. Hence, it is essential to concentrate research efforts on the timely and precise identification of initial caries. In addition, reducing caries incidence and associated socio-economic cost will further strengthen the fundamental premise of minimally invasive dentistry. The primary methods used to diagnose caries are clinical examination and radiography, as described by Gomez (2015), Lino et al. (2015), Diniz et al. (2016), and Lenzi et al. (2016). However, these approaches do have their limitations. Direct visual evaluation of caries development is difficult, primarily because of its limited repeatability [Hintze et al., 1998].

Dentists cannot consistently discern the subtle visual and tactile distinctions between active and inactive enamel lesions through a single clinical examination [Ekstrand et al., 2005], as caries is a dynamic and variable process that involves the demineralization and remineralization of teeth over time [Fejerskov 1997]. Moreover, radiography has the potential to underestimate the extent of the decayed area and has a notably poor sensitivity rate, particularly when it comes to identifying early-stage cavities [Souza et al., 2013; Menem et al., 2017]. Furthermore, there is variation in the clinical criteria used to classify caries across various systems.

In light of the information provided, there has been a growing desire in the dental industry for novel diagnostic instruments with distinct features, which have shown to be helpful in detecting caries at an early stage. According to Gomez (2015), these approaches are widely known for their high sensitivity and strong repeatability. However, they have poor specificity and may be influenced by various confounding variables. In 2001, the National Institutes of Health (NIH) Consensus Development Conference on Diagnosis and Management of Dental Caries through Life determined that the available evidence for the methods used to detect and assess non-cavitated carious lesions was insufficient to support any formal recommendation for their adoption [Bader et al., 2002].

The net efficacy of diagnostic procedures is uncertain due to ambiguity. Conventional approaches are more specific but less sensitive, whereas newer methods are regarded more sensitive but less specific [Gimenez et al., 2015]. Within this particular setting, the delicate

equilibrium between the sensitivity (Se) and specificity (Sp) of each diagnostic approach might have an impact on the choice of therapy and therapeutic choices. This can possibly result in misclassification, leading to either excessive or insufficient treatment [Zaidi et al., 2016].

The presence of heterogeneity, unverified data, and subjectivity in diagnostic tools in present published research motivates future efforts to thoroughly evaluate the available evidence in the area. Systematic reviews and meta-analyses are very effective research methods for identifying and evaluating the highest quality data. The objective of this systematic review is to compare the accuracy of different diagnostic methods available to clinicians for early detection of tooth decay in both permanent and primary teeth, and provide insights for future research on the most effective approaches.

2. Methods

A systematic electronic search was performed on both published and unpublished literature, with two investigators (P.F. and E.O.) conducting the search separately. The primary formal databases used in this investigation were MEDLINE (accessed via PubMed) and Scopus.

3. The DIAGNOdent 2095

The first iteration of the DIAGNOdent laser fluorescence device (DD), also referred to as DIAGNOdent 2095, underwent assessment in a total of 18 trials. The sample sizes varied between 30 and 433 teeth. Nevertheless, this range was much narrower compared to the ranges seen in optical techniques and intraoral radiography. Each study had an average of two examiners. Similar to earlier approaches, operational intervention and histological validation were the most often used reference standards, appearing in 8 and 8 research, respectively. The sensitivity (Se) of the diagnostic test varied from 0.48 to 1, the specificity (Sp) ranged from 0.5 to 1, and the area under the receiver operating characteristic curve (Az) ranged from 0.55 to 0.94. The device's calibration cut-off points showed a noticeable variation.

4. The DIAGNOdent Pen

The DIAGNOdent Pen (DD Pen), a second-generation DIAGNOdent laser fluorescence device, was evaluated in 20 investigations. The range of teeth being evaluated varied from 37 to 621, with an average of two examiners per research. Validation was conducted using several reference standards, including histological validation in 6 trials and surgical intervention in 6 investigations. Additional methods such as BW, computed microtomography, and visual inspection (in some instances after the elimination of orthodontic brackets or the use of elastic orthodontic separators) were also very uniformly utilized. The range of the DD Pen was between 0.16 and 1, whereas the range of Sp was between 0.2 and 1. Although these ranges are generally comparable to the equivalent ranges of the DD, there were minor variations. The range of the DD Pen varied from 0.4 to 0.95.

5. CarieScan Pro

The CarieScan Pro equipment underwent evaluation in 5 investigations, with a somewhat lower sample size of teeth assessed, specifically ranging from 25 to 120 throughout the studies. However, all studies reported duplicate assessment screenings, which were conducted by the same number of investigators. Histological validation was used as the benchmark in three investigations, whereas surgical intervention was utilized in one study. The sensitivity (Se) of the CarieScan Pro device varied from 0.72 to 0.91, the specificity (Sp) ranged from 0 to 0.92, and the area under the receiver operating characteristic curve (Az) ranged from 0.47 to 0.92.

6. VistaProof

The performance of the VistaProof fluorescence camera was studied in four trials, with the number of teeth examined ranging from 32 to 619. These investigations also followed duplicate examination techniques. Histological validation was used as the benchmark in one investigation, whereas in another study, operational intervention was utilized as the reference standard. The range of the VistaProof fluorescence camera's sensitivity (Se) was from 0.26 to 0.92, while its specificity (Sp) was from 0.41 to 0.98. The Az value, which measures the accuracy of the camera, was only reported in one research and ranged from 0.66 to 0.97.

7. SoproLife

The diagnostic efficacy of the SoproLife fluorescence camera was evaluated in four investigations. The sample sizes varied from 37 to 433 teeth, and the inspection technique was conducted three times. In one research, histological validation was employed as the reference standard, while visual examination using ICDAS-II was used for the other studies. The sensitivity (Se) of the SoproLife fluorescence camera varied from 0.86 to 0.98, the specificity (Sp) ranged from 0.55 to 0.96, and the area under the receiver operating characteristic curve (Az) ranged from 0.89 to 0.98.

8. Diagnostic techniques

Severl researches assessed several diagnostic techniques, such as OCT, NIR, quantitative light-induced fluorescence (QLF), and variations and combinations of the aforementioned procedures. These strategies were not well-represented, and none of them were evaluated in more than two trials. The sample sizes varied widely, ranging from 25 to 1,160 teeth, which is to be anticipated given the diversity of diagnostic procedures used.

9. The impact of index tests, meta-analyses

This decision was made after evaluating the differences in research circumstances and settings. All the research included in the quantitative synthesis focused only on permanent teeth. A pooled estimate could only be obtained for the DD comparison, since there were too few studies available for the other comparisons (i.e., less than 4). All research included in the

quantitative synthesis used either histological investigation or surgical intervention as the reference standard. The surfaces examined were occlusal, and the dentition seen was permanent.

The visual inspection is the most used diagnostic technique for detecting caries, primarily because it is cost-effective. Although the ranges presented in this research may seem broad, the majority of studies indicate moderate to high sensitivity and specificity levels. In relation to the use of visual techniques for examining the occlusal surfaces of permanent teeth, the research conducted by Heinrich Weltzien et al. [2002] stands out as a noteworthy exception with a Se value of just 0.25. Additionally, the second-lowest Se value recorded was 0.54. Based on their research, ocular inspection was unable to accurately detect all occlusal caries, leaving a significant number unreported. Black and white imaging, used in addition to eye inspection, is one of the most ancient techniques for identifying tooth decay. The majority of the studies included in the analysis showed a poor sensitivity in detecting early-stage tooth decay, as well as in most cases of tooth decay on the biting surfaces without visible cavities. On the other hand, there were high Sp values observed for all surface types and dentitions, suggesting that this well-established technology has the ability to efficiently and accurately categorize non-carious surfaces.

The DD, or Double Device, has been extensively researched and analyzed in the current scientific literature. The original DD is only applicable to occlusal surfaces. The individual investigations exhibited Se and Sp values that varied from moderate to high for both permanent and primary teeth. The original DD has been replaced by the DD Pen, which is a smaller and improved iteration. The latter may be used for identifying approximal carious lesions, unlike its predecessor. Regarding selenium (Se), many research [Diniz et al., 2012, Cınar et al., 2013, Kucukyilmaz et al., 2015, Kockanat and Unal, 2017] indicate a slight improvement in the detection of occlusal caries compared to the original DD. However, the Sp values seemed to be comparable or somewhat lower than the same values produced with the original DD that is currently being used. The sensitivity values for permanent teeth and the specificity values for primary teeth were rather high for proximal lesions. Nevertheless, the sensitivity values for primary teeth and the specificity values for permanent teeth exhibited variations across different investigations.

The VistaProof fluorescence camera demonstrates a substantial level of sensitivity on both the buccal and occlusal surfaces. The wide range of selenium (Se) levels seen for occlusal lesions, together with the scarcity of research evaluating the effectiveness of Vis-taProof in real-world clinical situations, prevent any more definitive conclusions or conjectures about the use of this instrument. The CariesScan Pro gadget presents a comparable scenario, which adds additional ambiguity when making clinical practice decisions relying on the current information. The SoproLife fluorescent camera shows promise in accurately detecting occlusal carious lesions in both permanent and primary dentition. Additionally, it does not significantly fall behind in terms of Sp. Additional evaluation of this instrument would be beneficial. The QLF system was evaluated in just two of the research included in this review, despite being a diagnostic device

that has been extensively investigated in the scientific literature, particularly in an in vitro environment. So far, the focus of research on the QLF system has mostly been on its technical characteristics rather than its diagnostic accuracy in a clinical environment. This is likely a primary factor contributing to the under-representation of the QLF system in this study. Further, well planned clinical studies are important to ascertain the efficacy of QLF and provide pertinent clinical data.

10. Summary

Despite the emergence and comprehensive study of several diagnostic procedures in recent years, it is difficult to make definitive judgments about their usefulness. The findings of this systematic review and meta-analysis demonstrate a significant disparity in the sensitivity (Se) and specificity (Sp) values observed, which may be attributed to the diversity in the experimental conditions of each individual study.

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