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Review:

Deep Learning Concept for Early Dental Caries Detection

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Abstract:

Identifying dental caries in a dental operatory can be challenging for pediatric dentists at times because of the fluctuating features of the lesions based on their developmental stage. Thus, pediatric dentists can suggest specific and unique treatment methods. Noninvasive interventions, such as fluoride therapy and sugar control, can successfully reverse and treat early aberrations, sometimes referred to as white spots. Dental cavities, on the other hand, lead to tooth structure deterioration and require restorative treatments of varying levels of difficulty, depending on the extent and severity of the damage that leads to the extraction of the tooth itself. These necessitate new concepts for detecting dental caries in children. The prospective review's objective was to determine the necessity of applying deep learning and contemporary principles in the diagnosis of early childhood caries.

Keywords: Deep learning, early childhood caries, children, pediatric dentist

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Introduction:

Dental caries is the second most prevalent disease that significantly impacts the health of human populations, and its etiology is multifactorial and dynamic. [1,2] Frequent consumption of high-sugar foods and inadequate oral hygiene practices cause an imbalance in the demineralization and remineralization of dental hard tissues, leading to the development of carious lesions.[3] Carious lesions can significantly impact a person's quality of life and become the primary source of dental discomfort due to their inability to regress naturally and the ineffectiveness of short-term pharmacological interventions.[4-10]

Diagnosing dental caries in a clinical setting can be difficult for dentists since the lesions might have varied characteristics depending on their stage of development. Therefore, dentists can recommend distinct treatment techniques.11 Noninvasive methods like fluoride therapy and sugar regulation can effectively reverse and treat preliminary deviations, also known as white spots. [12] Cavities, on the other hand, cause tooth structure deterioration and necessitate restorative procedures of varying complexity, depending on the depth and severity of the damage. [13] To stop the disease early and use minimally invasive treatment methods, [14] it is important to know the different stages of carious lesions, especially the first ones. The goal is to keep healthy tooth structures as much as possible. [3,15]Additionally, early detection of carious lesions allows for more conservative and cost-effective treatments, avoiding the need for repetitive and complex procedures that may eventually result in tooth loss. [15]

Literature review:

In the dentist's office, visual inspection with artificial lighting and a blunt-tipped probe primarily detects carious lesions. [11] This procedure is reliable, noninvasive, cost-effective, and readily conducted. It allows for the early stages of carious lesions to be detected. [16] In addition, visual examination allows for assessing the activity, depth, and ability to retain carious lesions, unlike other diagnostic techniques. [13] Researchers have developed several detection methods to maintain the sensitivity and accuracy of this technology, thereby minimizing the impact of the clinician's expertise during the process. [17,18] The International Caries Detection and Assessment System (ICDAS), developed by Ismail, [19] is a widely utilized method for evaluating the health and decay of tooth surfaces. It can measure both healthy and carious surfaces, including early lesions, and provide a comprehensive assessment of the overall condition of the tooth. Research has demonstrated that ICDAS exhibits a diagnostic precision like histological analysis in detecting dental caries. [20,21] However, the precision of ICDAS is contingent upon the clinician's proficiency and prior training. [19]

The pediatric dentists can utilize various ancillary examinations such as radiography, computed tomographic scans, transillumination, and histological investigation to identify carious lesions.[22] Nevertheless, these approaches have significant constraints for their practical use, and they exhibit inconsistent efficacy in identifying carious lesions, particularly in the initial stages.[23] As a result, there has been an increasing demand for automated tools that use deep learning algorithms to assist clinicians in identifying dental caries at the earliest clinical stages.

Deep learning utilizes two primary models: Massive-Training Artificial Neural Networks (MTANNs) and Convolutional Neural Networks (CNNs). These models employ numerous layers of network structures to facilitate automated learning and self-learning through backpropagation.[24] The field of deep learning with image input has experienced rapid growth and has excellent potential to become a critical platform in medical image analysis. The medical industry widely uses classification as one of its most common applications.[25] The applications of deep learning in dentistry are noteworthy in various domains, including teeth-related disorders, dental plaque, and periodontium.[26]

There are now various methods for developing automated diagnostic tools for dental caries. These methods include conventional data-mining algorithms[27] for parameters obtained from annual oral examinations, as well as classification algorithms that involve two distinct steps: image segmentation and classification. [27,28] At the moment, the most common way is to use advanced deep learning models to build an object detector. These include Convolutional Neural Networks (CNN), Deep Neural Networks (DNN), Region-Based CNN (R-CNN), Fast R-CNN, Faster R-CNN, Mask R-CNN, You Only Look Once version 3 (YOLOv3), RetinaNet, and Single-Shot Multi-Box Detector (SSD). [26,28-31] Ding's research shows that the YOLOv3 algorithm can identify caries. [32] Kim used the RetinaNet model to build a home dental care system and documented that it enabled patients to handle their dental issues competently by delivering essential dental treatment information. [33] Estai conducted a study using the Faster R-CNN algorithm to automatically detect caries on bitewing radiographs. This study exhibited a favorable performance in identifying proximal surface caries on dental bitewings. [34] Moutselos et al. conducted a study that used DNN Mask R-CNN to accurately identify caries on occlusal surfaces, achieving an accuracy rate of 0.889. [30] A different research study utilized convolutional neural networks (CNN) to identify white spots in dental photographs, yielding an average accuracy ranging

from 0.81 to 0.84 (31). Other commercially available software programs can detect dental caries, including Logicon Caries Detector, designed explicitly for dental monitoring.[35]

Prior research primarily focused on laboratory settings, with minimal data available on the potential of AI in vivo.[29] Duong et al. have utilized photographs captured by mobile phones to create automated software for detecting caries on the occlusal surface of molars and premolars (36). Both the training and testing data consisted of desiccated dental specimens. In vivo, Casalegno et al. identified caries lesions on the back teeth' biting surfaces and adjacent surfaces. Nevertheless, they employed the near-infrared transillumination device, a tool rarely used in clinical practice, to capture the images.[37] In a study, Kuhnisch used deep learning to diagnose tooth decay using intraoral pictures. Professional cameras, specifically the Nikon D300, D7100, and D7200, equipped with a Nikon Micro 105 mm lens, captured the images.[38] Thanh MTG et al.[39] used four advanced deep learning models—Faster R-CNN, YOLOv3, RetinaNet, and SSD—to find both non-cavitated and cavitated caries in pictures taken with a standard smartphone. AI applications, particularly YOLOv3 and Faster RCNN, have shown promise in the real world for diagnosing cavitated caries. Nevertheless, the precision and responsiveness of four models in identifying early caries were not as high as anticipated for practical application. The literature recommends using Digital Single Lens Reflex (DSLR) cameras for dental photography.[40] The digital images captured with these cameras are then used to diagnose caries lesions and other dental illnesses.[41-43] However, the requirement for expert abilities and a unique flash setup make DSLR cameras less suitable for widespread use. Presently, smartphones are not solely portable gadgets with superior computational capacity and connectivity compared to modern mobile phones, but they also possess integrated cameras, enabling users to capture high-resolution photographs effortlessly.[44,45] Various researchers[46-62] focused on deep learning and using different tools; still, there is a need for further research to establish the deep learning concepts for the detection of oral diseases in children.

Conclusion:

Deep learning in early dental caries detection will undoubtedly be of assistance to pediatric dentists in providing appropriate treatment in a timely manner. However, additional research is required to establish this concept in pediatric dentistry. The development of software, which will include the incorporation of knowledge, will play a significant role in the application of deep learning concepts in the detection of early childhood caries.

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