CARIES DIAGNOSIS EVOLUTION AND APPLICATIONS OF DIAGNOSTIC AIDS

Abstract

Dental caries has emerged as a global health concern and needs immediate attention. Early diagnosis plays a critical role in its successful management and has gained importance in restorative dentistry as it focuses on minimally invasive treatment alternatives.

Dental caries, if detected in early stages before cavitation or irreparable loss of tooth structure can result in an important change in choice of dental treatment or material. The conventional methods of caries detection are inconsistent as they are not specific and accurate. This has resulted in development of numerous new devices and procedures for identifying incipient carious lesions. The aim of the chapter is to create awareness amongst students and clinicians regarding contemporary caries detection methods which are less invasive and have better accuracy.

Authors

Dr. Varsha Uttarwar
Lecturer
Department of Conservative dentistry and endodontics
RD DCRC,
Nagpur , Maharashtra, India.

Dr. Mohit K Gunwal
Associate Professor
Department of Conservative dentistry and endodontics
RD DCRC,
Nagpur, Maharashtra, India.

Dr. Vidya Mokhade
Lecturer
Department of Conservative dentistry and endodontics
RD DCRC,
Nagpur, Maharashtra, India.

I. INTRODUCTION

Dental caries, a progressive bacterial deterioration of teeth, is a widespread ailment affecting 95% of the population and remains a significant contributor to tooth loss. Recent years have witnessed a huge surge in research efforts focussed on diagnostic techniques, particularly concerning the early detection of caries as it is a preventable disease.The evolution of new technologies for the early detection of dental caries can help in timely intervention and prevention of dental decay in the incipient stage which will further lead to health and economic benefits. The use of technology along with the clinical visual examination will help the dentist in precise diagnosis at a nascent stage. Thisin turn will provide the opportunity to reverse the process and aid in tracking the progression of these lesions thereby excluding the need for aggressive surgical interventions.

1. **Historical Perspective:** The Visual andTactile Examinationmethod of detecting caries with a dental mirror and probe is the oldest and most common techniqueof diagnosing dental caries. For a precise evaluation the teeth should be clean and dry and a proper light source needs to be used. This helps in detecting white opaque spots, stains, surface irregularities and early carious lesions. When inspected using proper illumination the carious tissues diffuse light making them look whiter and opaquer. The dentinal lesions appear as darkened areas under the enamel and as the caries progresses the overlying tooth structure breaks down and a cavity can be observed. The disadvantage is that the results are subjective and can be false depending on the clinician's judgement, efficiency, and experience. The results must be corroborated using other diagnostic tools for precision. In contrast, contemporary diagnostic aids offer minimally invasive approaches, quicker and more accurate outcomes, and a reduced rate of false negative findings.

   Diagnostic aids likeCBVT, electronic caries detector, fibre optic transillumination, LASERS (DIAGnodent) & ultrasonic caries detectors provide more accurate diagnosis.

2. **Caries Detecting Dyes**: The carious dentin has two layers of demineralized tissue. The first layer, the infected dentin is soft and contaminated with micro-organisms and has reached the irreversible stage of dental caries. The second layer, the affected dentin is hard, discoloured not contaminated with micro-organisms and has a capacity to regenerate. Clinically it is difficult to differentiate the two layers, caries detecting dyes were thought to be beneficial in these conditions. But studies have revealed that the decalcified organic tissues and not the micro-organisms take up the dye which can lead to excess cutting of the tooth structure. And the dye residue that remained on the walls of the cavity may weaken the shear bond strength between therestorations and the enamel.

3. **Radiographic Examination**: It is the most important tool in the detection, extension and visualization of dental caries, especially when the caries is not seen clinically. Studies have shown that bitewing radiography has been proven to be an efficient method in the detection of inter proximal caries. But radiographs also have some disadvantages,hence to be used as an adjunct with clinical and tactile visualization for confirming the presence of dental caries. The fact is that radiographs are 2 dimensional images of 3 dimensional objects sometimes leading to false diagnosis because of overlapping of the tooth tissues. The real cause of periapical pathology cannot be ascertained with a radiograph alone.

Cervical burn outs may appear as radiolucent areas which may be mistaken for caries. Despite the disadvantages, radiographs are the most used diagnostic tools and the development of new technologies has led to a more accurate diagnosis of dental caries.

II. RECENT ADVANCES IN DIAGNOSTIC PROCEDURES OF DENTAL CARIES

1. **Digital Imaging:** The advantage of digital imaging over traditional radiography is that the radiation dose is considerably lower almost 60-90% lesser. The image can be viewed instantly without any hassles of processing of the films.It can be saved, magnified, and adjusted as per the requirement. But like in conventional radiography the lesion should be decalcified up to 40% before being visible on the radiograph. The results for both, conventional and digital radiography in detection of proximal caries is comparable with no significant advantage.

2. **Fiber-optic transillumination (FOTI):** It is an extensively employed technique for diagnosing cariesand is anon-aggressive and cost-effective method. It is based on the concept of difference in light diffusion index of decayed and sound tooth structure. The normal enamel is composed of closely packed hydroxyapatite crystals,when this structure is deranged due to decalcification, the photons of light are dispersed resulting in an optical disarrangement. When we examine the carious tissues with fibre optic device, the demineralized lesions appear darker than the normal tooth structure.It is useful for detection of proximal and occlusal carious lesions.

3. **Digital imaging Fiber-optic transillumination (DIFOTI):** It is a digitalized rendition and a combination of FOTI and a digital camera. It uses infrared radiation of an invisible wavelength. It finds application in detecting incipient,advanced, and secondarycarious lesions as well as fractures, cracks, and fluorosis. However, it falls short in determining the depth of the caries penetration. Since it is digitalized, the images obtained can be saved and retrieved later whenever required.

4. **Quantitative light induced fluorescence (QLF):** It is a technology that has been in use for a significant period and is highly sensitive. It is based on the difference in diffusion of light in normal and carious tissues and the decline of auto fluorescence in the presence of demineralization. It has been observed that light scatters faster in carious tissues than in the normal tooth structure. Numerous studies have employed this approach for diagnosing both occlusal and smooth surface caries,monitoring demineralization and remineralization processesand for detecting marginal leakage around restorations. Thedevice however is unable to distinguish between caries, developmental anomalies and staining or calculus deposits 8. A novel device that operates on this principle is SOPROLIFE.

SOPROLIFE, a tool that employs light emitting diode fluorescence, serves the dual purpose of caries detection and a high magnification intra oral camera. This tool helps the clinician to distinctly identify affected and infected dentin. The infected dentin appears bright red in colour and the affected dentin appears orange coloured, helpingin removal of the carious lesion conservativelywhich aids in the prognosis.

5. **Laser- induced fluorescence:** It is highly sensitive as compared to the traditional methods of caries detection. It is used for the identification of demineralization and remineralization processes as well as occlusal caries lesions. The carbon dioxide laser is used in the detection of dental caries. It is based on the principle that the carious lesions have more organic compounds than the adjacent normal tooth tissues. The laser beam when applied on the affected area results in desiccation of the organic contents leaving a black sediment behind whereas the normal tooth tissue is unaffected. The most recent version of the diagnostic device DIAGNOdent (KaVo) is applicable for proximal surfaces too.

6. **Vista Proof:** It operates on the same principle as laser induced fluorescence but uses a distinct stimulation wavelength from Diagnodent. Additionally, it utilizes a video camera to capture fluorescence during the detection process.

7. **The Midwest caries I.D.:** It uses the principle that there is an alteration in the optical behaviour in the tooth suggestive of a change in the tooth structure and is not based on the bacterial content. It uses infrared light emitting diodes which transmit light to the affected area using a fibre optic probe. Another fibre optic probe captures light from the affected area which is measured by a photo detector. The signal levels are then compared with predetermined parameters. Studies have shown that this device is more efficient than the DIAGNOdent in detection of proximal caries. The device demonstrated a sensitivity of 80% and specificity of 98%.

8. **Canary System:** Utilizes a low powered laser to identify caries that might not be visible on X-rays or through traditional examination methods. This technology is capable of detecting decay, cracks, and defects by analysing and quantifying the breakdown of crystal structure. Remarkably it can identify lesions as tiny as 50 micrometres and can reach a depth of up to 5mm beneath the tooth's surface.19. The canary system employs transillumination technology, which renders the enamel somewhat transparent. In this process porous lesions tend to capture and absorb light, enabling the clinician to observe through the tooth, thereby revealing its internal structure and the presence of any carious lesions. A noteworthy aspect of this technology is its utilization of nonionizing radiation, making it well suited for use with children, pregnant women and individuals who prefer to avoid X-rays.

9. **Fluorescence technology:** It can be linked to a computer and is based on the principle that there is a change in the temperature of 1degree C or less after the tooth absorbs infrared laser light. When the tooth surface is exposed to pulses of laser light it emits a luminescence along with release of heat. By modulating the frequency of the laser beam it helps in detection of decay with a combination of colour depiction and numerical readings. Thereby lesions as small as 50 micrometres can be detected up to 5mm beneath the surface making it highly precise and specific. Very few studies have been carried out regarding this method and more research is required for verifying the efficiency of this technique.

10. **Optical Coherence Tomography (OCT):** It is an imaging technology capable of non-invasivelyassessing and visualizing tissue microstructure in two dimensions. It uses infrared light instead of sound waves with no health hazards reported so far. OCT

generates high-resolution cross-sectional images of the oral structures. It determines not only the presence but also the depth of the carious lesions, and is used for detection of recurrent caries and marginal adaptation of restorations. And the advantage is that the patients are not exposed to X rays.

11. **Electrical Conductivity Measurements:** Enamel acts as a natural electrical insulator because of its high mineral content, but decalcification leads to formation of pores which are filled with fluids facilitating electrical conduction. The electrical conductivity is directly proportional to the decalcification process. The electronic tool uses a persistent frequency of 23 Hz of alternating current which records the tooth resistance. A study by Ashley concluded that this method is superior to other conventional techniques in detecting occlusal carious lesions which are non cavitated.

12. **Ultrasound devices:** In these devices sound waves are used for identifying the carious lesions. It is based on the principle that the travel time of ultrasound pulses varies and is different in normal and caries affected tooth tissues. The carious lesions produce significantly higher amplitudes. They are more precise in detecting interproximal caries compared to bitewing radiographs. But a disadvantage is that the caries can be detected only once the tooth has undergone certain degree of demineralization.

13. **Cone Beam Computed Tomography:** It is a relatively new utilization of computed tomography in which the radiation dose and costs are comparatively lower. In dentistry CBCT is widely used in the placement of implants, bone grafting, orthodontic treatment planning, diagnosing temporomandibular joint, identifying anatomic aberrations, analysing trauma patients and caries detection. It is possible to detect caries beneath the various types of ceramic restorations with the help of CBCT but teeth with metal or radiopaque restorationsshould not be considered for CBCT. Studies have shown that the number of false positive results can be increased with CBCT technique. The relevance of CBCT in detection of dental caries seems to be promising but more studies need to be carried out to ascertain the same.

The Logicon caries detector software is a computer aided design tool used specifically for the detection and diagnosis of dental caries.

III. FUTURE ADVANCES

1. **Artificial Intelligence-based models:** The AI based models are found to be superior and precise in the detection and diagnosis of dental caries. They are found to be highly effective economically and exhibit very few false negative errors as compared to trained clinicians. The results are excellent and dependable leading to accurate and early diagnosis of the carious lesions which in turn enhances intervention at incipient stage of the disease leading to a better prognosis. This aids in designingpreventive dental care, oral hygiene procedures and dietary plans for patients with high risk of dental caries. This is particularly useful in diagnostic dental camps held in schools and rural health centres. Although these models have delivered promising results more research needs to be carried out to evaluate their efficacy.

2. **Deep Convolutional Neural Networks (CNNs):** It is a rapidly developing field in health sciences showing promising results in diagnosing and evaluating the prognosis of a particular disease. In dentistry deep CNN deployed dental caries detectors are precise and accurate in identifying and locating the morphological changes which are related with the carious lesions.

IV. CONCLUSION

The field of dentistry is gradually moving towards a more conservative approach for treating dental caries. The recent advances in the available diagnostic methods accurately detect dental caries in the incipient stage, and therefore non conservative treatment can be commenced immediately to halt further progression of the carious lesion. The transition in treatment principle to "minimally invasive dentistry" where the carious process can be reversed is possible only because of the detection of caries in the early stages before cavitation of the lesion. The evolvement of latest technologies based on the optical properties of teeth such as fluorescence and transillumination could play a promising role in the detection of early carious lesions.A disease can be treated properly only if it is diagnosed accurately and that too at an early stage where it can be nipped in the bud stage emphasizing the need of proper diagnostic aids.

REFERENCE

[1]   Ghodasra R, Brizuela M. Dental Caries Diagnostic Testing. [Updated 2023 Mar 19]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2023 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK574510/

[2]   Ntovas P, Loubrinis N, Maniatakos P, Rahiotis C. Evaluation of dental explorer and visual inspection for the detection of residual caries among Greek dentists. J Conserv Dent. 2018;21(3):311-318.

[3]   Datta, S., CHAKI, N. & Modak, B. A systematic review on the evolution of dental caries detection methods and its significance in data analysis perspective. Intelligent Data Analysis: From Data Gathering to Data Comprehension 2020:115–136.

[4]   Amaechi, B.T., Phillips, T.S., Perozo, B.I. et al. Evaluation of a novel caries detecting oral rinse. BDJ Open 2023; **9**:12.

[5]   Dayo AF, Amaechi BT, Noujeim M, Deahl ST, Gakunga P, Katkar R. Comparison of photothermal radiometry and modulated luminescence, intraoral radiography, and cone beam computed tomography for detection of natural caries under restorations. Oral Surg Oral Med Oral Pathol Oral Radiol. 2020;129(5):539-548.

[6]   Hülya Yılmaz, Sultan Keleş, Recent Methods for Diagnosis of Dental Caries in Dentistry, Meandros Med Dent J 2018;19:1-8

[7]   Zandona AF, Zero DT, Diagnostic tools for early caries detection. J Am Dent Assoc 2006; 137: 1675-1684

[8]   Sawle RF, Andlaw RJ 'Has occlusal caries become more difficult to diagnose? A study comparing clinically undetected lesions in molar teeth of 14-16 year old children in 1974 and 1982. Br Dent J 1988; 164(7): 209-211.

[9]   Sikri VK. Textbook of Operative Dentistry 2nd edition, Delhi CBS Publishers and Distributors Pvt. Ltd. 2010.

[10]   Demarco FF, Matos AB, Matson E, Powers JM. Dyes for caries detection influence sound dentin bond strength. J Oper Dent 1998;23(6):294-8.

[11]   9.Lain AP. Caries Detection and Diagnosis: Novel technologies. J Dent 2006; 34:727-739.

[12]   10. Preety IA Maupome G. A closer look at Diagnosis in Clinical Dental Practice: Part 5.Emerging Technologies for Caries Detection and Diagnosis. J Can Dent Assoc 2004; 70(8): 540.

[13]   11. Karlsson L. Caries Detection Methods Based on Changes in Optical Properties between Healthy and Carious Tissue. Int J Dent 2010; 20: 1-9.

[14]   12. Marinova Takorova M, Anastasova R, Panov VE. Comparative evaluation of the effectiveness of five methods for early diagnosis of occlusal caries lesions- in vitro study. J of IMAB 2014; 20(3): 533-536.

[15] Caliskan Yanikoglu F, Ozturk F, Hayran O, Analoui M, Stookey GK. Detection of natural white spot lesions by an ultrasonic system. Caries Res 2000;34: 225-32.

[16] Khanagar SB, Alfouzan K, Awawdeh M, Alkadi L, Albalawi F, Alfadley A. Application and Performance of Artificial Intelligence Technology in Detection, Diagnosis and Prediction of Dental Caries – A Systematic Review. Diagnostics 2022, 12, 1083.

[17] Bader J D, Shugars D A, Bonito A J. Systematic Reviews of Selected Dental Caries Diagnostic and Management Methods. J. Dent.Educ.2001;65:960-968.

[18] Sridhar N, Tandon S, Rao N. A Comparative Evaluation of Diagnodent with Visual and Radiography for Detection of Occlusal Caries: An in Vitro Study. Indian J. Dent. Res. 2009, 20, 326-331.

[19] Schneiderman A, Elbaum M, Shultz T, Keem S, Greenebaum M, Driller J. Assessment of Dental Caries with Digital Imaging Fiber- Optic Transillumination (DIFOTI): In Vitro Study. Caries Res.1997;31:103-110.

[20] Lee J, Kim D, Jeong S, Choi S. Detection and Diagnosis of Dental Caries Using a Deep Learning Based Convolutional Neural Network Algorithm. J. Dent.2018, 77, 106-111.

[21] Schwendicke F, Elhennawy K, Paris S, Friebertshauser P, Krois J. Deep Learning for Caries Lesion Detection in Near Infrared Light Transillumination Images: A Pilot Study. J. Dent. 2020;92:103260.