Advanced Diagnostic Aids in Dental Caries – A Review

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Abstract

Dental caries is a common bacterial oral disease of teeth which affected 95% of population and still a major cause of tooth loss. Early Detection and Diagnosis of Dental Caries reduces irreversible loss of tooth structure, treatment cost and time. The traditional caries detection methods often fail to detect initial carious lesion. For this reason various new methods introduced which provide promising results in detection both early caries and also caries occurring on all surfaces of the tooth, which paves the way for a more preventive approach to caries management Aim of this review is to discuss about recent diagnostic methods for detection of dental caries.

Key words: Caries detection methods, Diagnosis, Radiography, Fluorescence, Transillumination, Sensitivity, Specificity

Introduction

According to shafer “Dental Caries defined as “the microbial disease of the calcified tissues of teeth characterized by demineralization of the inorganic portion and destruction of organic substance of the tooth”[1]

Early detection of carious lesions is an important process in order to detect the early stages of demineralization. World Health organization (WHO) report reveals that 98% adult people and (60-90)% of school children are suffering from dental caries.[2]

Need for accurate diagnosis before cavitation help of arrestment of the process by modifying diet, improving plaque control, and appropriate use of fluoride and improving dental health.[3]

Commonly used earlier diagnostic methods are Visual examination using mouth mirrors,

probes, and conventional radiography. Modern dentistry emphasizes more on prevention, and hence the original maxim of "extension for prevention" has been eschewed for a minimal intervention approach.

Detection and diagnosis at the initial (non-cavitated) and moderate (enamel cavitation) levels of caries is fundamental in achieving the promotion of oral health and prevention of oral disease. With advances in technology over the last 2 decades, alternative methods of detection have become available such as advancements in radiography and the development of fluorescence, transillumination and MID. These could potentially aid or replace the detection and diagnosis of caries at an early stage of decay. This would afford the patient the opportunity of a less invasive treatment with less destruction of tooth tissue and potentially result in a reduced cost of care to the patient and to healthcare services.

Qualitative versus quantitative methods

1. Conventional or traditional tools are qualitative in nature
2. They show a poor validity with low sensitivity and moderate specificity
3. This implies that caries diagnosis, as normally performed in daily clinical practice, is an inexact procedure that results in both over- and under-diagnosis. This has paved way to search for quantitative detection methods
4. Advanced diagnostic methods are all quantitative in nature They detect lesions at an earlier stage and are more reliable than the conventional methods.[4]

International Caries Detection and Assessment System (ICDAS)

International caries detection and assessment system (ICDAS) is an improved version of visual/tactile method of detecting caries. ICDAS is a two-digit identification system (X-Y). First the status of the surfaces is recorded as unrestored, sealed, restored or crowned. After that a second code is used (Y). This code evaluates the visual changes in the enamel to evaluate the visual changes in the enamel to extensive cavitation. The description is given in Table 1 and 2[5]

Table:1 Suggested restoration / sealant coding system of ICDAS II

0	Surface not restored or sealed
1	Sealant, partial
2	Sealant, full
3	Tooth colored restoration
4	Amalgam restoration
5	Stainless steel crown
6	Porcelain or gold or PFM crown or veneer
7	Lost or broken restoration
8	Temporary restoration
9	Used for the following condition:

	96: Tooth surface cannot be examined 97: Tooth missing because of caries 98: Tooth missing for reasons other than caries 99: Unerupted

Table 2: ICDAS scoring criteria

Score	Criteria
0	No or slight change in enamel translucency after 5 seconds air drying
1	First visual change in enamel (seen after prolonged air drying) or change in confines of pits and fissures
2	Distinct visual change in enamel
3	Localized enamel breakdown in opaque enamel (no signs of dentin involvement)
4	Underlying dark shadow from dentin
5	Distinct cavity with visible dentin
6	Extensive distinct cavity with visible dentin, involving more than half the surface

Diagnostic Tools for Caries

1) Visual method
2) Tactile method
3) Radiographs

   Conventional – IOPA, Bitewing

   Xeroradiography

   Digital

- Digital enhancement
- Subtraction radiography
- TACT

  Cone Beam Computed Tomography (CBCT)

  Optical Coherence Tomography (OCT)

4) Based on visible Light
- Optical caries monitor
- FOTI & DIFOTI
- QLF

5) Based on Laser Light
- Diagnodent
- DELF

6) Electrical current
- ECM

7) Ultrasound caries detector
8) Endoscope
9) Dyes

   Dyes penetration method

10) Midwest caries ID
11) Carie Scan

Digital Radiographic Methods

Digital radiography is a form of radiography that uses X-ray-sensitive plates to capture data and then immediately transferring it to a computer system without the use of an intermediate cassette.

There are two types:

Direct – The direct image receptor that collects X-ray directly, for example, RVG

Indirect – For example, video camera is used for forming digital images of a radiograph. (Fig.1)

Digital detectors

- Charged couple device (CCD)
- Complementary metal oxide semiconductor
- Photo Stimulable Phosphor plate (PSP)

Fig.1 Digital radiography

Digital image enhancement Resolution of unenhanced digital image is lower than radiographs. Range of gray shades is limited to 256, whereas in a radiographic film, over 1 million shades of gray appear.

Contrast can be digitally enhanced using a mathematical rule often decided by the algorithm/filter.They are not practically used because they are very time-consuming.

Digital subtraction radiography A digital bitewing radiograph is taken and later a second radiograph of exactly the same region is produced with identical exposure time, tube current, and voltage.

By subtracting gray values for each coordinate of the first radiograph from equivalent coordinate of second, a subtraction image is obtained. (Fig.2)

If no changes have occurred, the result of subtraction is zero. Nonzero result will be obtained in case of onset or progression of demineralization.

It is not yet routinely applied in clinical caries detection due to difficulty of image registration

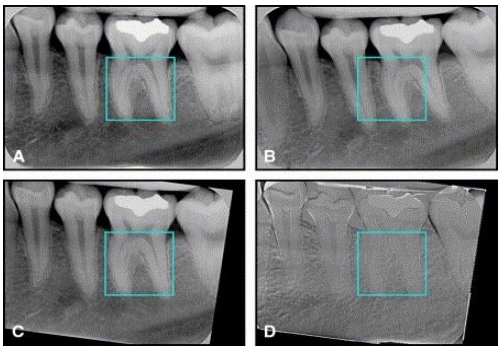

Fig.2 Digital subtraction radiography

Tuned-aperture computed tomography

This method constructs radiographic section through teeth. The slices can be viewed for the presence of radiolucency.

Mechanism of action

As exposure begins, the tube and film move in opposite directions simultaneously through a mechanical linkage.

With this synchronous movement, images of objects in the focal plane remain in fixed

positions on radiographic film and are clearly imaged.

On the other hand, images of objects located outside focal plane have continuously changing positions on the film. As a result, images of these objects are blurred beyond recognition by motion unsharpness. Slices can be brought together in a three-dimensional computer model called pseudo-hologram. TACT slices and pseudo-hologram can adequately detect small primary and secondary carious lesions.[6]

Cone Beam Computed Tomography

CBCT is a diagnostic imaging modality that provides accurate three dimensional (3D) representations of the osseous elements of the maxillofacial skeleton.

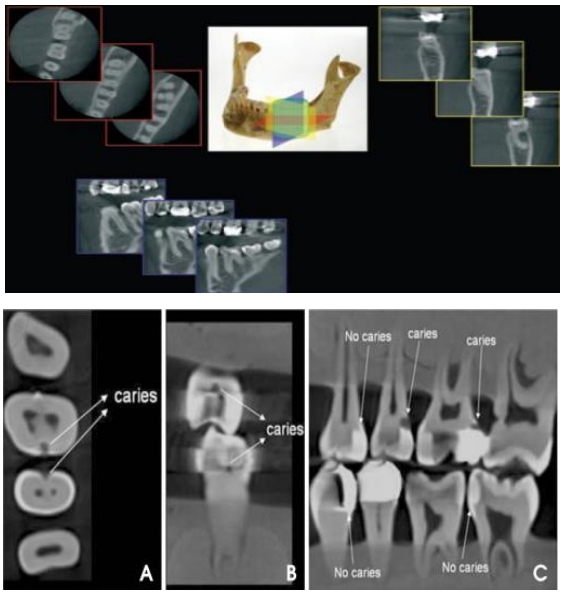

Fig 3: CBCT IMages

Advantages

- Improving the detection and depth assessment of caries in proximal and occlusal lesions
- Rapid scan time
- Image accuracy
- Reduction in radiation dose compare to CT
- Multiple imaging

Increace sensitivity & specificity.[7]

Optical Coherence Tomography (OCT)

OCT is an imaging technique that uses a beam of partially coherent light to create tomographic images.

Use reflections of infrared light with considerable penetration into tissue without biological effect. (Fig 4)

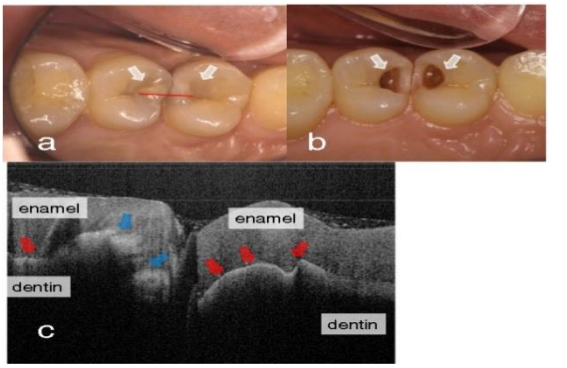

Fig 4: Optical Coherence Tomograph

Advantages:

- Detect caries at early stages of formation

- Depth of caries progression
- Non invasive
- Provides three dimensional map of light-reflecting interfaces in biological tissues such as micropores.[8]

Fibre optic transillumination (FOTI):

It is based upon the phenomenon of light scattering. Sound enamel is comprised of modified hydroxyapatite crystals that are densely packed, producing transparent structure.

Principle:

- It works because of the different index of light transmission for decay, sound tooth enamel and denin and healthy periodontium.
- Carious enamel has a lower index of light transmission than sound enamel, As the demineralization process disrupts the crystalline structure of enamel and dentin, more light is absorbed due to changes in the light scattering and absorption of light photons,an area of decay shows up as a more darkened shadow that follows the spread of decay along the path of dentinal tubules.

FOTI uses high intensity white light that is presented through a small aperture in the form of a dental handpiece. The tip is 0.5mm; light source is by a 150 watt halogen lamp set at maximum intensity.The probe is applied perpendicular to the buccal and lingual surfaces and its position and angulation varied to obtain maximum light scattering through the lesion. (Fig.5)

- The decrease of transmission is observed, traditionally as an ordinary rating scale.
- Shadow depth scale

  Score 0 = sound

  Score 1 = shadow in enamel

  Score 2 = shadow in dentine

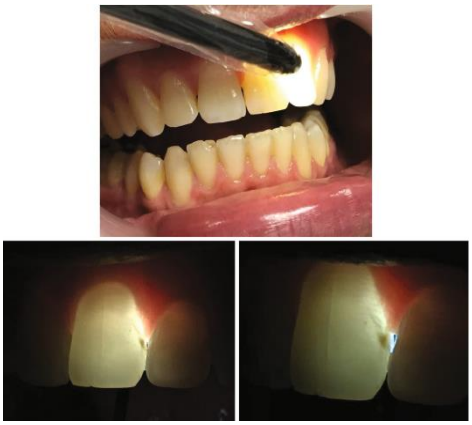

Fig 5: FOTI

Advantages

- It is simple, noninvasive, painless procedure that can be used repeatedly with no risk to the patient.
- It can be used for thedetection of caries on all surfaces; and is particularly useful at proximal lesions. lesions.

Limitations

- The system is subjective rather than objective.

- There is no continuous data outputted.
- It is not possible to record what is seen in the form of an image.[9,10]

Digital Imaging Fiber-Optic TransIllumination (DIFOTI):

Digital imaging fiber-optic transillumination (DIFOTI) was developed in an attempt to reduce the perceived shortcomings of FOTI, by combining FOTI with a digital CCD camera. (Fig. 6)

Fig 6: DIFOTI

Mechanism of action

It uses a safe white light with which images taken from all the tooth surfaces can be digitally captured using a digital CCD and sent to a computer for analysis. Receptor with photocells converts photon energy to electrical energy – transmitted to a video processor and converted into color value and displayed on video monitor.

When the teeth are transilluminated, areas of demineralized enamel or dentin scatter light and incipient caries appear darker in the resultant image. Images taken during different examinations can be compared for clinical changes between several images of the same tooth over time

DIFOTI system consists of two handpieces (one for occlusal surface and one for smooth surface and interproximal areas), a disposable mouthpiece, a foot pedal for selecting the image of interest and a computer system to capture and store the resulting image

Limitations

- Does not measure lesion depth
- Difficulty in discriminating deep fissures, stain and actual dentin lesions.
- Overdiagnos can occur due to lower specificity when compared with conventional radiographs.[11]

Quantitative light-induced fluorescence (QLF)

The use of fluorescence for the detection of caries first described by Benedic in 1929. Fluorescence results from change in the characteristics of light caused by a change in wavelength of incident light rays following reflection from the surface of material.

QLF is based on the principle of fluorescence. It enhances early detection of carious lesions, particularly progression or regression of white spots of smooth surface

lesions. It provides a fluorescent image of a tooth surface within yellow-green spectrum of visible light that quantifies mineral loss and size of the lesion (Fig 7).

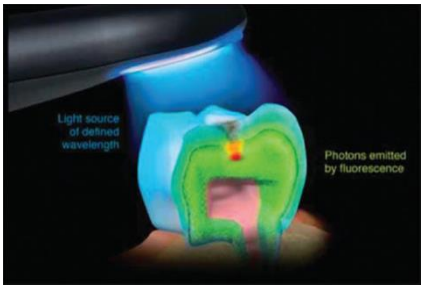

Fig 7: QLF images

It is a suitable method for quantitative assessment of early enamel lesions in visually inaccessible areas. Most important parameters produced by QLF are lesion area, depth, and volume.

Mechanism of action

System includes a measurement probe, control unit, and computer fitted with a frame grabber.

The control unit consists of an illumination device and electronics. Light source is a special arc lamp based on xenon technology. The light from this lamp is filtered by a blue-transmitting filter. A liquid light guide transports blue light to the teeth.

Recording of florescent image is done with a yellow transmitting filter positioned in front of the color CCD sensor. Image is then digitized by the frame grabber and is available for quantitative analysis.

Tooth is seen on a computer monitor as fluorescent green and dark areas indicate mineral loss or white spot lesions. Image can be saved and compared over time to track demineralization or remineralization.

At times, a red fluorescence appears that indicates leaking around restorations and sealants. It is emitted by porphyrins metabolized by bacteria in dental biofilm, calculus, or an infective carious lesion and usually indicates a high caries activity. Area of concern can be tracked over time to evaluate the success of remineralization.[12]

DIAGNOdent

DIAGNOdent was first introduced in 1998 to aid the diagnosis of occlusal caries in adjunct to visual and radiographicexamination. It generates pulsed 655 nm.[13] (Fig.8)

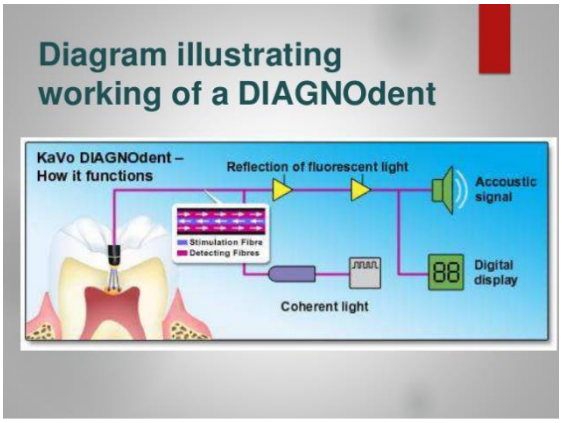

Fig. 8 DIAGNOdent

Mechanism of action

DIAGNOdent technology uses a simple laser diode to compare the reflection

wavelength against a well-known healthy baseline to uncover decay.

When device operates at specific wavelength the healthy tooth structure exhibits little or no fluorescence, resultingdisplay seena very low scale readings . Carious tooth structure exhibits fluorescence proportionate to the degree of caries, resulting in elevated scale readings on the display.[14]

The unit has a fiber-optic cable that transmits light source to a handpiece that contains a fiber-optic eye in the tip. First, the laser diode is aimed at the healthy enamel tooth structure to obtain a benchmark reading. After calibration, it is moved to inspect all the surfaces of the teeth, shining the laser at 2.5 mm into all suspected areas. As the laser pulses into grooves, fissures, and cracks, it reflects fluorescent light with particular wavelength. This is because light is absorbed by the organic and inorganic components of the tooth which induce infrared fluorescence. This fluorescence is collected at the top of handpiece and transmitted back to the DIAGNOdent unit. Light is measured by receptors, converted into an acoustic signal, and evaluated electronically to reveal values between 0 and 99.[15]

DIAGNOdent pen

DIAGNOdent pen is an advancement made in the DIAGNOdent technology. DIAGNOdent pen 2190 is the perfect tool to detect fissure and smooth surface caries accurately.[16](Fig.9)

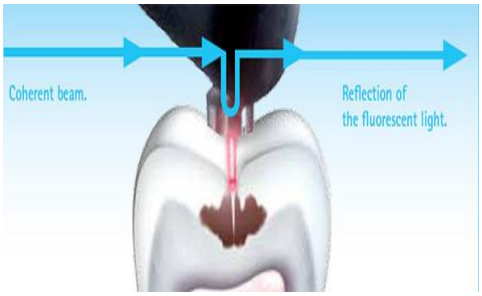

Fig 9: DIAGNOdent pen

Advantages

- 90% success rate in diagnosing pit and fissure caries
- Higher sensitivity (0.92) than electronic caries monitor
- High reproducibility and reliability
- Easy and quick to use and readily transportable
- Non-invasive and painless
- Does not suffer from operative bias, safe, and no X-ray exposure.

Limitations

- False results with the presence of plaque and debris
- Cannot distinguish between hypomineralized and carious structure

- Readings do not relate to the amount of dentinal decay and cannot be used for recurrent caries.

Ultrasound Caries Detector

It was introduced for detecting early carious lesions on smooth surfaces.

An ultrasonic probe is used which sends and receives longitudinal waves to and from the surface of the tooth. (Fig.10)

Initial white spot lesions produce no or weak surface echoes, whereas sites with visible cavitation produce echoes with substantially higher amplitude.

It is also more sensitive than visual-tactile method

Fig 10: Ultrasound Caries Detector

Advantages

- Small and handy systems
- Accurate diagnosis
- No pain to the patien

Disadvantages

- Area of diagnosis is confined to the dimension of the probe
- Technique sensitivity
- Status of lesion is not known such as arrested or active.[17]

Endoscopy

Endoscopy includes:

1) Endoscopically viewed filtered fluorescence

2) White light fluorescence

3) Videoscope.

Endoscopically viewed filtered fluorescence

This technique utilizes the fluorescence of enamel that occurs when it is illuminated with blue light in wavelength range 499–500nm.

When the tooth is viewed from a specific gelatine green filter number 58, attached to the eyepiece, white spot lesions appear darker than sound enamel.

White light fluorescence

A white light source is connected to the endoscope by a fiberoptic cable and teeth are viewed without a filter.

Limitations like weight of fiber-optic cable tends to destabilize the machine and the increased distance between eyepiece and light source decreases illumination

Videoscope

The integration of the camera and endoscope is called a videoscope.

This is designed in such a way that the image of the surface of enamel can be viewed directly over a television screen. The

videotapes are viewed by expert independent examiners who had also examined the teeth visually and by conventional methods.[18,19](Fig.11)

Fig 11: Videoscope

Intraoral Televisio Camera (IOTV)

Based on the same idea as endoscopes, using a small visualization device to provide a better view of the oral cavity.

The intraoral wand camera project magnified digital images from a patient's mouth(Fig.12)

Fig 12: Intraoral Televisio Camera

Advantages

- Increased vision
- Improved posture and patient positioning
- Increased magnification
- Helps in diagnosis.[20]

MIDWEST CARIES ID™ (MID)

MID is a small, battery-operated technology that emits a soft LED light for detecting and quantifying caries.

A specific fiber optic signature captures the resulting reflection and refraction of the light in the tooth and is converted to electrical signals that run through a computer-based algorithm for analyzing the presence of caries.[21](Fig.13)

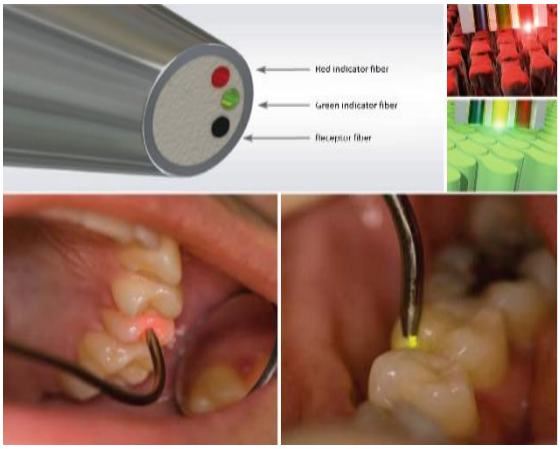

Fig13: MIDWEST CARIES ID™ (MID)

CARIESCAN

This device is based on alternating current impedance spectroscopy and involves the passing of an insensitive level of electrical current through the tooth to identify the presence and location of the decay.[22] (Fig.14)

It is the first dental diagnostic tool to use an impedance spectroscopy to quantify dental

caries early enough to enhance preventative treatment

Fig 14: CARIESCAN

Conclusion

The shift in treatment philosophy from “extension for prevention” to “minimally invasive dentistry” has afforded the dentist the opportunity to diagnosis and manage caries at an early stage. An ideal caries detection method should capture the whole continuum of caries process, from the earliest to the cavitation stage. It should be precise, accurate, easy to apply, and useful for all surfaces of teeth, as well as for caries adjacent to restorations. A Combination of these newer techniques with the conventional methods would help us to give more reliable and accurate results.

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Conflicts of interest

There are no conflicts of interest.

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