Original research article

Diagnostic aids in conservative dentistry: A systematic review

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Abstract

The commonly used clinical methods are inadequate for reliable diagnosis of caries lesions until demineralization is established. By the time a reliable diagnosis can be made, the damage is often irreversible, and restorative methods may be necessary to prevent further progress of the lesions. Early detection of the caries lesion would enable the dentist, by using effective prophylactic measures, to provide remineralization and conservation of the tooth substance rather than restoration of the dentition. Attempts to improve traditional methods or to develop new methods of detecting caries lesions have been numerous. This review article describes the traditional and the advanced diagnostic aids used in diagnosis of caries which may be helpful for a better treatment plan.
Keywords: Caries, Diagnosis, Remineralization, CBCT

Introduction

Operative dentistry is the art and science of the diagnosis, treatment, and prognosis of defects of teeth that do not require full coverage restorations for correction. Such treatment should result in the restoration of proper tooth form, function, and esthetics, while maintaining the physiologic integrity of the teeth in harmonious relationship with the adjacent hard and soft tissues, all of which should enhance the general health and welfare of the patient[1].

To diagnose carious lesions in patients, several factors must be considered. Some general factors are helpful in assessing a patient‘s risk for caries, including patient history information and general clinical examination results[2]. The ideal tool for diagnosis of the carious lesion should be non invasive, reliable, valid, sensitive, specific and provide a robust measurement of lesion size and activity and would be based on the biological process directly related to the carious process[3].

The ultimate goal of any caries detecting diagnostic tool is to improve both the sensitivity and specificity level. If the disease can be detected before cavitations occur, preventive therapy may avoid the need for any unnecessary operatory intervention. This would be stepping stone toward a more conservative and minimally invasive treatment approach.

Clinical diagnosis

Visual detection

It is the most commonly applied method. It uses combination of light and mirror.

Sensitivity of test: Visual detection is a traditional diagnostic method and it appears to have a very low sensitivity and high specificity in diagnosing caries.

The teeth should be clean, dry and well-illuminated during a visual examination to obtain maximum information.

In detecting occlusal caries it has a limited sensitivity. Black or brown discolorations and fissure morphology are not reliable for definitive diagnosis of occlusal caries. The opacities of the enamel may be more useful in determining caries with visual examination as long as they are not stained but the teeth should be clean, dry and well-illuminated. This optical phenomenon was explained by Black who stated that when a small white spot lesion is dried, air replaces the water in the porous tissue and because the refractive index of air (1.0) is further away from enamel (1.62) than water(1.33), the lesions becomes easier to see[4]. Visual caries detection is regarded as the method of first choice for assessing caries inpatients.

Tactile Sensation Method[4]

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Caries is diagnosed if tooth meets the ADA criteria of softened enamel that catches an explorer and resists its removal or allows the explorer to penetrate proximal surface under moderate to firm probing pressure.
How to do it: Black *et al*., 1924, gave the concept of passing the explorer into pits and noting whether or not there is softening and whether the instrument catches at any point. But using explorer in the intraoral examination may not improve diagnostic accuracy. Sticking probe may not be indicating caries but only be a sign of local anatomical features.

Benefits of visual-tactile diagnosis

- It is quick and easy to perform, does not need any expensive equipment, and can be completed without unnecessary radiation.
- Data shows that when non cavitated lesions are included in classification, the yield of visual- tactile caries examination is greater than that of radiographic examination because minor mineral loss es cannot be detected in radiographs.

Limitations of visual-tactile diagnosis

- This method requires subjective evaluation to be made by the practitioner.
- Lesions can go undetected because teeth are typically examined by the naked eye.
- Sometimes there is a need for supplemental analysis when faced with clinical signs that will leave a dentist uncertain, including dark occlusal or proximal shadows.

Diagnostic aids

The diagnostic aids can be divided into-

1. Traditional diagnostic aids
2. Radiography
3. Temporary elective tooth selection and impression
4. Caries detector dies
5. Advanced diagnostic aids

Radiographs

Dental radiographs are a useful and necessary tool in the diagnosis and treatment of oral diseases such as caries, periodontal diseases, and oral pathologies. A radiograph is one of the most important tools in making a diagnosis[5]. Without radiograph, case selection, diagnosis, and treatment would be impossible as it helps in the examination of oral structure that would otherwise be unseen by the naked eye. Radiographs help to diagnose tooth-related problems like caries, fractures, root canal treatment or any previous restorations abnormal appearance of pulpal or peri radicular tissues, periodontal diseases, and the general bone pattern. Sometimes the normal anatomic landmarks like maxillary antrum, foramina, tori, inferior alveolar canal, etc. may be confused with endodontic pathologies which may result in wrong diagnosis and thus improper treatment. In operative dentistry, x-ray films have a significant impact as diagnostics In pulp tissues radiographs may help in identifying chronic pulpitis and in differential diagnosis with apical periodontitis[6].

Conventional radiography[7]

Conventionally, two types of techniques are usually employed. These include intra-oral periapical radiography and bite-wing radiography. Others like occlusal radiographs, and panoramic radiographs are important but rarely employed in the detection of caries. Panoramic views are employed for having a broader view of the oral cavity. Moreover, the panoramic technique utilizes intensifying screen, which may hamper the finer details; whereas, the occlusal technique does not determine the angulation of a tooth in that particular arch.

Types of radiographs

- Bitewing radiographs
- Occlusal radiograph
- Panoramic radiograph
- Periapical radiographs

Xeroradiography

Xeroradiography was invented by a physicist Chester F.Carlson, in 1937. Hebasedhis invention on the principle of photoconductivity, i.e., some materials which are nominal insulators become conductors when they are exposed to light or ionizing radiation. Using selenium as a photoconductor, he was able to reproduce a number of graphic articles, and with the aid of another physicist, Otto Kornei, successful images were made[8].
The main characteristics of the xeroradiographic technique are the ability to have both positive and negative prints together. When a positive current is applied to the film, negative particles are attracted, and

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when a negative current is applied, positive particles are attracted[8].
Xeroradiography is an electrostatic process that uses an amorphous selenium photoconductor material, vacuum deposited on an aluminum substrate to form a plate. the plate enclosed in a tight cassette may be linked to films used in halide-based intraoral technique[9].
Xeroradiography is a highly accurate electrostatic imaging technique that uses a modified xerographic copying process to record images produced by diagnostic X-rays. In this technique, a conventional single-phase dental X-ray unit is used as an X-ray source, but instead of a silver-halide film image, a uniformly charged selenium alloy plate housed in a light-proof cassette is used.

Advantages
- Elimination of accidental film exposure
- High resolution
- Simultaneous evaluation of multiple tissues
- Ease of reviewing
- Economic benefit
- Reduced exposure to radiation hazards
- Cephalometrics analysis
- Easier and rapid interpretation

Disadvantages
- Technical difficulties
- Fragile selenium coat
- Transient image retention
- Slower speed
- Technical limitations

Radiovisuography[9]
The RVG system is capable of rapidly displaying a digital radiographic image on a monitor which results in lower patient radiation.
The "Radio" component is the conventional X-ray generator with a timer, capable of very short exposure time, along with image receptors. The "Visio" portion converts the output signal from a CCD to a digital format and displays it on a monitor. The "Graphy" component consists of a data storage unit connected to a video printer.
The most significant advantages of digital imaging, therefore, are computer-aided image interpretation and image enhancement, in addition to the obvious options of standardized image archiving and image retrieval. The CCD is a solid-state detector composed of an array of X-ray or light-sensitive pixels on a pure silicon chip. A pixel or picture element consists of a small electron well into which the X-ray or light energy is deposited upon exposure.

Applications
- Dental Caries Detection
- intrabony defects
- Periapical pathologies detection
- Detection of root fractures
- Detection of root canal lengths
- Application In mentally retarded/developmentally disabled individuals
- Telemedicine
- The technique is simple to use, but the assessment of images may require a certain degree of familiarization as the image is different from a conventional radiograph.

Modified radiographic techniques
Digital enhancement[10]
A digital image is an image formed and represented by a spatially distributed set of discrete sensors and pixels. When viewed from a distance, the image appears continuous, but closer inspection reveals individual pixels. A digital image is an image that is recorded with non-film receptors.
There are two types of non-film receptors for recording digital images.
1. The digital image receptor (DIR) which collects the X-rays directly (Direct digital imaging)
2. Video camera for forming digital images of a radiograph (Indirect digital imaging)

Digital image receptor works on a charged couple device (CCD), which is electronically connected to a computer. CCD is a semiconductor made up of metal oxides such as silicon that is coated with x-ray sensitive phosphorous. The CCD is sensitive both to X-rays and visible light. The intraoral DIR is placed in the oral cavity instead of the X-ray film. The image area is limited by the size of the CCD present in the digital image receptor. Once the image is captured by the CCD, (like an image of silver halide crystals in

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an X-ray film) it can be stored in the computer memory for image processing and can be displayed for viewing.

Advantages
- The radiation dose is approximately 60-90% lower
- The image receptor is often larger
- Darkroom is not required. The image is immediately available.
- The image can be electronically transferred
- Magnification, contrast, and brightness can be adjusted
- There is no need for processing solutions to protect the environment and lowering costs.

Disadvantages
- The life expectancy of CCD is not fixed
- Patient's discomfort
- Temporary image retention
- Slower speed

Subtraction radiography

Digital Subtraction Radiography (DSR) is a method that can resolve deficiencies and increase diagnostic accuracy. Subtraction radiography is a computer-aided radiographic diagnosis tool that has a wide range of potential applications in clinical dentistry.

These include the detection and monitoring of early changes in mineralized tissues[11]. Subtraction image is performed to suppress background features and to reduce the background complexity, compress the dynamic range, and amplify small differences by superimposing the scenes obtained at different times[12]. It was used to compare standardized radiographs taken at sequential examination visits. All unchanged structures were subtracted and these areas were displayed in a neutral gray shade in the subtraction image; while regions that had changed were displayed in darker or lighter shades of gray[13].

Subtraction radiography has also been used in the evaluation of the progression, arrest, or regression of caries lesions. Subtraction radiography is also considered superior to conventional film radiography for detecting recurrent caries. It is also useful in detecting the progress of remineralization and de-mineralization patterns of dentinal caries.

Cone beam computed tomography (CBCT)

CBCT is a 3D radiographic tool that allows us to understand the maxillofacial complex and the spatial relationship of anatomic structures.

Computed tomography (CT), was invented by Hounsfield35 in 1973.

Cone beam computed tomography (CBCT) is a new application of CT that generates 3D data at a lower cost and absorbed doses than conventional ―fan beam CT found in the practice of the medical field[14].

Cone beam computed tomography (CBCT) is a relatively new method to visualize an individual tooth or dentition in relation to surrounding skeletal tissues and to create three-dimensional images of the area to be examined.

CBCT is a three-dimensional imaging method that offers the possibility to view an individual tooth or teeth in any view, rather than predetermined default views. Therefore, CBCT can be a powerful tool in endodontic diagnosis, treatment planning, and follow-up.

Uses of CBCT[15]
- Evaluation of root canal morphology
- Diagnosis of endodontic pathosis
- Assessment of pathosis of non endodontic organ
- Evaluation of root fracture
- Analysis of internal and external root resorption
- Diagnosis of invasive cranial resorption
- Endodontic surgical planning
- Identifying an untreated or missed canal
- Visualized extruded root canal materials that are affecting surrounding anatomical structures.

Advantages[16]
- Increased accuracy
- Higher resolution
- Reduced scan time
- Reduction in radiation dose
- Reduced cost for the patients
- CBCT eliminates the superimposition of surrounding structures producing additional clinically

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relevant information
- CBCT can give a three-dimensional image that is the size of the cavity, the size, and shape of the pulp canal, etc.

Disadvantages
- Limited availability
- Significant capital investment
- Extensive knowledge of radiological interpretation.

Temporary elective tooth selection and impression

The temporary tooth separation technique has been proposed as an alternative diagnostic resource to overcome the difficulty of visually examining proximal surfaces.

Some studies compared the direct visual inspection after temporary tooth separation to conventional visual inspection and radiographic analysis and revealed higher accuracy values for direct visual inspection after temporary tooth separation[17].

It uses wedges and elastics. Helps in assessing whether radiographically detectable approximal enamel and dentin lesions are cavitated.

Combined with localized impression allows a more sensitive diagnosis of cavitation. Proximal surface impression evaluation can be an important resource for detecting the presence of cavitation when chromatic changes, and the small available visual gap in visualizing and probing raises difficulties in caries cavitation detection[17]. Elastomeric impression analysis after temporary separation of primary teeth is a useful cavitation diagnostic resource allowing its use in research and clinical practice when visual inspection is doubtful [18].

Caries detector dies[19]

Caries-detector dyes have proven to be useful in the identification and removal of carious dentin. Dyes are diagnostic aids for detecting caries in questionable areas, i.e., locating soft dentin that is presumably infected.

Fusayama [1972] introduced a technique – the use of basic fuschin red stain to aid in differentiating layers of carious dentin. In 1972, a technique using a basic fuchsin red stain was developed to aid in the differentiation of the two layers of carious dentin.

Because of potential carcinogenicity, the basic fuchsin stain was subsequently replaced by another dye and acid red solution. Since then, various protein dyes have been marketed as caries-detection agents. These products consist of a dye in a carrier fluid, which penetrates partially demineralized dentin, simply as a result of its increased porosity, giving it a red-to-pink coloration. So when carious dentin underlying enamel is exposed during a cavity preparation the dentist can apply the dye solution and use this to help his/her judgment as to when all the carious dentin has been removed.

In some cases, these dies to differentiate mineralized from demineralized dentin in both vital and nonvital teeth. Studies show that dye stains are about 85% effective in detecting all caries in a tooth.

Technique

The area to be tested is rinsed with water and then blotted dry as excess water dilutes the stain. The tooth is treated with a solution for 10 seconds. The tooth is rinsed with water and suctioned and then excess water is removed. After rinsing with water for 10 seconds, some tooth structure shows discoloration. Stained decay is removed with a spoon excavator and evaluated by tactile sensation. When removing stained caries, it is important to be conservative near the pulp.

Dyes for enamel caries
- Procion
- Calcein
- Zyglo ZL-22
- Brilliant blue42

Dyes for dentinal caries
- 1% acid red in propylene glycol
- 0.5% basic fuchsin in propylene glycol

Disadvantages
- Dye staining and bacterial penetration are independent phenomena, hence there is no actual quantification.
- They also stain food debris, enamel pellicle, and various other organic matter.
- These dyes can also stain DEJ.

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Advanced diagnostic aids

Quantitative light-induced fluorescence [20]

The quantitative light-induced fluorescence (QLF) method is based on the natural fluorescence of teeth. Currently, the method is predominantly used *in vitro* and in clinical studies for the early detection of carious lesions and for monitoring of de- and remineralization of white spots by quantifying the mineral loss and the size of smooth surface lesions.

It is an optical technique that uses the natural fluorescence of teeth to discriminate between caries and sound enamel based on the fact that the fluorescence radiance of carious spots viewed with QLF is lower than that of surrounding sound enamel.

QLF measures the percentage of change of fluorescence radiance of demineralized enamel, with respect to surrounding sound enamel, and relates directly to the amount of mineral lost during demineralization.

Applications of QLF are found in the testing of products designed to inhibit demineralization and promote remineralization of caries. QLF uses the natural fluorescence of the teeth, which is determined by the light absorption and scattering properties of teeth, to discriminate between caries and surrounding enamel.

The method of tooth transillumination with an appropriate intense light source is widely accepted by dental practitioners for caries detection in anterior teeth. For this purpose, transillumination is easy, fast, and inexpensive.

Principal of QLF

Fiber-optic transillumination (FOTI) uses the principle of light scattering to increase the contrast between normal and carious enamel. Light is applied to the side of the tooth and its transmission is observed from either the opposing side or occlusal in the case of molars and premolars.

Limitations of QLF

- For longitudinal measurements. QLF recordings should be performed under standardized conditions regarding the hydration status of the tooth.
- Lesions that are not limited to one surface but are situated mesiobuccally or distobuccally (eg, circular lesions) cannot be recorded, because the optical axis of the QLF device has to be oriented perpendicularly to the tooth surface.
- Although QLF was developed to detect carious lesions, it was observed that some QLF images showed areas on and/or within the tooth with red fluorescence of varying hues.

Fibre optic transillumination[21]

FOTI offers an alternative method of diagnosis that can be used to supplement the clinical examination. It is a simple, non-invasive, painless procedure that can be used repeatedly with no risk to the patient.

A narrow beam of bright white light is directed across areas of contact between approximal surfaces and the disruption of crystal structure, which occurs in demineralization, deflects the light beam and produces shadows.

When we examine the various tissues with a fiber optic device, we observe dark shadows along the dentinal tubules as it has a lower light transmission index compared with the sound tooth structure.105 FOTI devices are small, compact, and powered by batteries.

The technique of moving the light angulation to change the irradiance provides a more accurate portrayal of different tooth conditions.

FOTI works due to differences in normal enamel and dentin light transmission compared with caries, calculus, restorative materials, and external tooth discolorations.

Caries, which appear shadowed within the tooth, have a lower index of light transmission than sound tooth structure. Calculus shows up as a darkened area on the surface of the tooth. Translucent tooth-colored restorative materials can be easily distinguished from normal tooth structures using FOTI.

Applications[22]

- Its use as an adjunctive diagnostic aid for anterior and posterior interproximal caries and occlusal caries diagnosis
- detection of calculus
- evaluation of stained margins of composite resins
- evaluation of cusp fractures and cracked teeth
- as an exploration tool to illuminate endodontic access and root canal orifices within the pulp chamber of teeth during endodontic treatment
- as a tool for improved evaluation of soft-tissue lesions
- for evaluation of all-ceramic restorations to rule out any fractures before cementation
- for clinical evaluation of fracture and craze lines in all-ceramic restorations and natural teeth
- for evaluation of the depth of extrinsic staining to determine appropriate treatment Recommendations.

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Advantages

- No hazards of radiation.
- Simple and comfortable for the patients.
- Lesions, which cannot be diagnosed radiographically, can be diagnosed by this method.
- Not time-consuming.

Disadvantages

- Permanent records are difficult to maintain as can be kept in radiographs.
- It is subjected to intra and inter-observer variations.
- Difficult to locate the probe in certain areas.

Digital fiber optic transillumination [DIFOTI][23]

The method has been applied as an aid to the visual examination but yields qualitative information that is nonreproducible and needs subjective interpretation.

The major advantage of the method is that it is non-invasive and can therefore be as frequently used as needed.

The DIFOTI system was designed to overcome the limitations of FOTI by providing digital image capture. Such images can be stored in digitized form and compared with previously acquired images.

To date, the only clinical study on the diagnostic accuracy of DIFOTI concluded that the method could increase sensitivity when used in conjunction with digital or film radiography. Further studies are warranted to validate the method.

DIFOTI is a more recent development combining FOTI with a charge-coupled device digital intraoral camera. This instrument enables *in vivo* digital images to be captured with only very scan distortion when the light transmitted passes through the tooth and becomes a detectable signal read by a computer; it is then instantaneously displayed on a screen.

To this end, DIFOTI has been designed with a handpiece, a control panel, specific software, a personalized image-recording system, a pedal, as well as different projection possibilities according to the surface to be examined. Images captured by the camera are forwarded for computer analysis.

Optical caries monitor[24]

Optical caries monitor is a non-destructive method to quantify light scattering in bulk dental enamel and early carious lesions.

Light scattering by enamel has been shown to be caused mainly by the crystals in relation to their immediate environment.

The principle used is that in white spot carious lesions, scattering is stronger than in sound enamel surface. Light incident under 45° in a collimated beam enters the sample and scatters forwards, sidewards, and backward.

Light emerging from the illuminated spot is collected by the fiber optic head. When scattering is weak, collected flux is low whereas when scattering is strong (carious enamel), collected flux is high. Light is transported through a fiber bundle to the tip of the handpiece. The tip is placed against the tooth surface and reflected light is collected by different fibers of the same tip.

Infrared fluorescence [25]

In this technique, the tooth is exposed to light (irradiation) with a wavelength of between 700 and 15,000 nm. Barrier filters are used to observe any resulting fluorescence.

It has been established that the technique would be able to discriminate between sound and carious enamel and dentin.

Further studies are required to determine if the fluorescence signal from exposure to infrared irradiation is greater than that from other wavelengths. Additionally, there can be potentially damaging effects on the dental pulp due to heating effects from absorption of infrared irradiation, given the increased penetration and decreased scattering of the longer wavelength.

Magnetic resonance microimaging (MRM)

MRI, a well-established imaging technique in various areas of medicine, has become fundamental for the non-invasive diagnosis of soft tissue diseases since it has thegreat advantage of not using ionizing radiation, avoiding the biological damage related to other three-dimensional imaging techniques such as CT and CBCT.

Advantages

- No Ionizing Radiation: RF pulses used in MRI do not cause ionization and have no harmful effects of ionizing radiation. Hence can be used in childbearing ladies and children.
- Non-invasive: MRI is non-invasive.

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- Contrast resolution: It is the principal advantage of MRI, i.e. the ability of an image process to distinguish adjacent soft tissue from one another. It can manipulate the contrast between different tissues by altering the pattern of RF pulses.

Diagnodent laser diode fluorescence[26]

This is a commercial development of laser fluorescence and a variant of the QLF system.

DIAGNOdent was first introduced in 1998 to aid the diagnosis of occlusal caries in adjunct to visual and radiographic examination.

This system has a range of 0 to 99. The value 0 indicates the healthiest state of the tooth. It is an effective method for detecting initial lesions without cavitation. It‘s also useful for measuring different decalcification values on different surfaces of the tooth.

The fiber optic probe directed onto the occlusal surface of the tooth emits a light of wavelength 655nm. DIAGNOdent technology uses a simple laser diode to compare the reflection wavelength against a well-known healthy baseline to uncover decay.

At specific wavelengths that the device operates, healthy tooth structure exhibits little or no fluorescence, resulting in very low-scale readings on the display. Carious tooth structure exhibits fluorescence proportionate to the degree of caries, resulting in elevated scale readings on the display.[27]

Diagnodent pen[28]

DIAGNOdent pen is an advancement made in the DIAGNOdent technology.

DIAGNOdent pen is the perfect tool to detect fissures and smooth surface caries accurately.

Due to the limitation of diagnosis, the diagnosed pen was introduced. It permits the assessment of both occlusal and proximal surfaces.

The device works on the principle of the old version, but the design is different.

The tip is rotatable around the axis of its length, enabling the operator to assess mesial and distal surfaces from both sides i.e., buccal and lingual. The tip designed for proximal surfaces is made of sapphire fiber with a prismatic shape, and the light is directed laterally to the longitudinal axis of the tip.

This device could be used as an alternative to the radiographic method to aid the dentist in the decision-making process after visual inspection.

Laser Doppler flowmetry

Laser Doppler flowmetry (LDF) was introduced in dentistry in the late 1980s. This technique has been developed in many medical disciplines to assess blood flow in intact microvascular systems, such as the retina, renal cortex, and skin[29].

The laser Doppler measures the flow of blood cells inside a tissue without causing the slightest deterioration of this tissue. Blood cells moving within the volume, illuminated by the beam, will cause the light to change frequency.

Laser Doppler Flowmetry (LDF) was first developed to assess blood flow in tissue systems[30].

The technique utilizes a beam of infrared light produced by a laser that is directed into the tissue.

As light enters the tissue, it is scattered and absorbed by moving red blood cells and stationary tissue elements. Photons that interact with moving red blood cells are scattered and frequency-shifted according to the Doppler principle This change in infrequency is called a Doppler shift. Part of the light within the tissue is scattered back to the probe and returned from there via an optical fiber to a photodetector in the instrument where it is converted into electrical signals[31].

The efficacy of LDF has been extensively studied in dental traumatology and maxillofacial surgery for the diagnosis of pulp vitality but the results observed are contradictory.

Pulp Oximetry

The pulse oximeter is a noninvasive oxygen saturation monitoring device widely used in medical practice for recording blood oxygen saturation levels during the administration of intravenous anesthesia through the use of finger, foot, or ear probes[32].

It was invented by Takuo Aoyagi, a biomedical engineer working for the Shimadzu Corporation in Kyoto, Japan, in the early 1970s.

Pulse oximetry is a completely objective test, requiring no subjective response from the patient, that directly measures blood oxygen saturation levels. The pulse oximeter sensor consists of two light-emitting diodes, one to transmit red light (640 nm) and the other to transmit infrared light (940 nm) and a photodetector on the opposite side of the vascular bed. The light-emitting diode transmits red infrared light through a vascular bed such as the finger or ear.

Tuned aperture computed tomography

The method is based on optical aperture theory, which extends and completely generalizes the better-known laminographic process termed tomosynthesis[33].

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It does so by eliminating most of the constraints underlying tomosynthetic image acquisition, projection geometry, and data management. The image produced with the technique is the three-dimensional image of the original object[34].
Detection of demineralization and vertical root fractures is possible with this method. Tuned aperture computed tomography works on the basis of tomosynthesis[35].
A series of 8-10 radiographic images are exposed at different injection geometries using a programmable imaging unit, with specialized software to reconstruct a three-dimensional data set that may be viewed slice by slice.

Lasers[36]
Laser is the acronym of the words 'Light Amplification by Stimulated Emission of Radiation'. Lasers have come shown a long way since Albert Einstein described the theory of stimulated emission in 1917. Lasers in dentistry are used as a treatment tool or as an adjunct tool.
By using the laser in the field of dentistry, the main goal is to overcome the disadvantages, which are currently being experienced in conventional dental treatment procedures.
Lasers are intense beams produced by stimulated emission of radiation from a light source. This diagnostic technique in which a Diagnodent, a 655 nm diode laser, aids in the detection of incipient caries is called laser-induced fluorescence.
When the laser irradiates the tooth, the light is absorbed by organic and inorganic substances present in the dental tissues, as well as by metabolites such as bacterial porphyrins. These porphyrins showed some fluorescence after excitation by red light. Since bacteria are present in the carious lesions, carious tissue exhibits more fluorescence as compared to the healthy tissue which distinguishes between the carious and sound tooth structure.
It can detect occlusal, and interproximal carious lesions or identify occult lesions beneath fissure sealants. Although the procedure is considered to be safe, further studies are required to explore the beneficial effects of this innovative technology[37].

Carbon dioxide lasers[38]
The reason for the application of a carbon dioxide laser as a diagnostic tool is that the subsurface of the carious lesion has more organic compounds than the adjacent sound tissues.
When a carbon dioxide laser is applied to an incipient lesion, the organic contents evaporate leaving a black carbonized residue behind whereas the inorganic substance of sound enamel containing the minimum amount of water is less affected by the laser beam.
Radiation of wavelength 10.6 μm - the most commonly used for CO_2 lasers, is strongly absorbed by water to the extent that it can be vaporized instantaneously. The fact that most biological tissues contain large quantities of water makes them vulnerable to destruction by irradiation from a laser beam of such a wavelength. The water in tissue is vaporized leaving a residue of carbon-based material.

Optical coherence tomography
OCT is a new diagnostic imaging technology that was first introduced in 1991. OCT is an attractive non-invasive imaging technique for obtaining high-resolution images. OCT is a non-touch imaging technique for obtaining high-resolution images.
OCT combines the principles of an ultrasound with the imaging performance of a microscope, although ultrasound produces images from back-scattered sound echoes. OCT uses infrared light waves that reflect off the internal microstructure within the biological tissues.
OCT is based on low-coherence interferometry (LCI) and achieves micron-scale cross-sectional images.

Infrared thermography[39]
Thermal radiation energy travels in the form of waves. The changes in thermal energy can be measured when fluid is lost from a lesion by evaporation.
The thermal energy emitted from sound tissues is compared to that of the various structures.
This technique has been described by Kaneko in 1999 and has been proposed as a method of determining lesion activity rather than its presence or absence.
It is a method of determining lesion activity rather than a method of determining the presence or absence of a lesion.
Led technique- midwest caries ID[40]
The Midwest Caries I.D detects differences in optical behavior inside the tooth related to changes in the tooth structure and it is therefore not sensitive.
It uses infrared and red light emitting diode LEDs and a fiber optic to distribute light to the observed area present at the probe tip.
A second fiber optic collects light from the observed area to a photodetector that measures returned collected light. This photodetector then transmits the signal to a microprocessor that compares signal levels with defined parameters.

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When the result is positive, the processor deactivates the third green LED and pulses at a higher intensity than the red light. When the detection is negative,i.e., healthy tooth area, the green LED is dominant resulting in green illumination when healthy structure is detected and red illumination when caries are detected. A buzzer also beeps with different frequencies to indicate the intensity of demineralization detected.

Ultrasonic Imaging[41]

The use of ultrasound in caries detection was first suggested over 30 years ago, although developments in this field have been slow. The principle behind the technique is that sound waves can pass through gases, liquid sand solids, and the boundaries between them. Images of tissues can be acquired by collecting the reflected sound waves.

Mechanism of action

For sound waves to reach the tooth, they have to travel through a coupling medium or agent which has acoustic impedance. Various acoustic coupling agents have been used such as mercury, aluminum rods, water, and glycerin. An ultrasonic probe is used which sends and receives longitudinal waves to and from the surface of the tooth. Initial white spot lesions produce no or weak surface echoes, whereas sites with visible cavitation produce echoes with substantially higher amplitude.

Advantages

- It is a dynamic and readily available technique.
- It is particularly useful in the examination of superficial structures.
- It is widely available and relatively inexpensive.
- It is a non-invasive technique.
- Images are rapidly acquired.
- Images are simple to store and retrieve.
- It can be performed without heavy sedation.
- It has no known cumulative biological effects.
- Its ability to detect non-calcified pathological entities such as sialoliths.

Disadvantages

- The technique is very operator- and equipment dependent. It has to be performed by experienced investigators.
- Clinically only the bone surfaces and not the whole cortex or spongiosa can be visualized in intact due to ultrasound frequencies.
- Images when archived may be difficult to orientate and interpret unlike CT and MR scans, which have been acquired in standard reproducible scans.
- The difficulty of picturing the TMJ using ultrasounds depends on the limited accessibility of the deep structures, especially the disc, due to the absorption of the sound waves by the lateral portion of the head of the condyle and the zygomaticus process of the temporal bone.
- Ultrasound images are affected by inherent noise accompanying the signal returned to the transducer which makes interpretation of the static images, and sometimes the dynamic ones as well and a non-moving object will vary in appearance because of this noise.
- Ultrasonography waves do not visualize bone or pass through air, which acts as an absolute barrier during both emission and reflection.

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