"Diagnostic Tools For Early Diagnosis Of White Spot Lesions"

Dr. Arisha Izhar[1],Dr. Panchali Batra[2],Dr. Sanjay Miglani[3]

[1]Research Associate (MDS Orthodontics), Faculty of Dentistry, Jamia Millia Islamia
[2]Professor (MDS, M.Orth), Faculty of Dentistry, Jamia Millia Islamia
[3]Professor (MDS, FISDR), Faculty of Dentistry, Jamia Millia Islamia
Email- [3] sanjaymig@yahoo.com, [2]panchali.batra@gmail.com, [1] arishaizhar@gmail.com

Abstract: Introduction: In the recent years there has been an increase in the development of the newer technological methods to diagnose early demineralized lesion or white spot lesion. The diagnosis of white spot lesion is not always simple and might be subjective to the practitioner.
Aim: This review aims to present an overview of the various qualitative and quantitative methods of detecting white spot lesion, including the novel technologies
Methodology: The most common method of qualitative assessment includes visual assessment and Photographic examination. Other qualitative methods are Fibre-Optic Trans illumination and digital fibre optic transillumination (FOTI and DiFOTI) and DiagnoCam. The quantitative techniques based on autofluorescence such as Quantitative light-induced fluorescence (QLF), Light Emitting Diode (LED) fluorescence and Laser fluorescence such as Diagnodent, electronductivity such as Electrical Caries Monitor (ECM) , Optical coherence tomography (OCT) and some emerging technologies are discussed along with their advantages and disadvantages.
Result: These technologies enables the practitioners to diagnose white spot lesion timely so that their progression to fully developed carious lesion can be prevented.
Conclusion: The quantitative methods with suitable levels of sensitivity and specificity should be the preferred method but should be correlated with the qualitative methods to obtain a valid diagnosis.

Keywords: White Spot Lesion, Diagnosis, Qualitative assessment, Quantitative methods, Fluorescence, caries

1. INTRODUCTION

White spot lesions (WSLs) are enamel surface and subsurface demineralization, that is devoid of cavitation.[1-3] These lesions are the first reversible clinical appearances to be observed that can progress to the formation of fully developed dental caries, if no preventive measures taken.[1, 2] The incidence rate of the initial demineralized lesions are high. The most developed countries has approximately 60-90% of school-aged children affected with the carious lesion and nearly 100% of the adult population is affected.[4] WSLs lesions are very unpleasing in nature, and might look unaesthetic and unappealing to patients and if not attended timely, can develop to a full carious lesion.[5] Dental caries is one of the most common causes for visit to dental clinics due to associated pain and discomfort. It impacts the quality of life, increases the risk of hospitalization, leads to absentia from school and offices and also adds to the economic burden of the nation.[6] Hence, preventive measures or early diagnosis are vital to cease the progress of these lesions. This would also help in addressing

the risk factors that can lead to the progression of the lesion, and guiding suitable actions to control those factors.
White spot lesions might develop if there is prolonged plaque accumulation leading to poor oral hygiene. Other risk factors include inappropriate diet, high DMFS, lack of adjunctive preventive measures during orthodontic treatment and overall timing of the treatment. A white spot over the surface of the tooth can either be intrinsic or extrinsic in origin[2]. Fluorosis, hypomineralization/hypomaturation and hypoplastic defects of enamel can lead to white spots which are intrinsic in origin and are noncarious. These developmental enamel anomalies are related to genetic aberrations and environmental variations, like various metabolic diseases and drug abuse, use of chemicals, radiation and trauma.[7] Hence considering the different origins of white spot lesions, their differential diagnosis becomes imperative as the treatment plan would depend on it.

The early enamel lesion (WSL) is detected as a white opaque spot when air dried and are hence called white spot lesions.[8] On cleaning and drying the teeth the demineralized white lesions seem rough, opaque, and porous whereas the noncarious ones seem smooth and shiny under adequate lighting.[9] The detection of white spot lesions in regular dental check-ups is challenging and often difficult; and the diagnosis is established on the clinician’s scientific and analytical sense and is often subjective. Because of the same reason, the quest of finding various novel technologies that are more specific and sensitive, are going on to assist the clinician diagnose white spot lesions as accurately as possible.

Conventional examination to assess white spot lesions is predominantly done by visual, tactile examination with probing and photographic examination.[10] Although these methods are useful in detection, but they are not quantitative methods and need standardization. Because of these deficiencies, novel technologies like : QLF, DIAGNOdent, light-emitting diode, ECM, OCT and other newer methods have been developed to quantify the lesion and aid in better diagnosis and management. Since early diagnosis can prevent the progression of white spot lesion to a fully developed carious lesion, there timely diagnosis is very crucial. Though there are many articles published on the management of white spot lesion, very few articles focused solely on the diagnostic aspect of white spot lesions.[11-13] Hence this paper attempts to present an up to date overview of the various qualitative and quantitative methods of detecting white spot lesions.

2. QUALITATIVE ASSESSMENT METHODS

The most common method of assessing WSL qualitatively are Clinical visual assessment and photographs because these are easy to handle and manageable with ease of accessibility.

1. Clinical Visual Inspection

In order to have the correct visual assessment, there should be adequate lighting and the surface of the tooth should be clean and completely dry. On clinical examination these lesions demonstrate loss of enamel translucency because of transformed light properties with a chalky white presence, particularly when they are air dried or dehydrated. Different methods for visual assessment are Ekstrand assessment scale (1995), [14] the Nyvad system (1999), [15] the Dundee selectable Threshold Method for Caries Diagnosis (DSTM in 2000)[16] and the International Caries Detection and Assessment System (ICDAS in 2004).[17] The scores are given as follows (Table 1).

Table 1- Different systems for Clinical Visual examination

Ekstrand system	Nyvad system	DSTM system	ICDAS system
0- No/slight changes in enamel translucency after prolonged air drying (5 s)	0- Healthy tooth	G-Healthy tooth	0- Sound
1- Opacity/discoloration distinctly visible after air drying, hardly on wet surfaces	1-Active (Intact)	W-White spot lesion	1- First visual change in enamel
2- Opacity/discoloration distinctly visible without air drying	2-Active (surface discontinuity)	B-Brown spot lesion	2-Distinct visual change in enamel
3- Localized enamel breakdown in opaque or discolored enamel and/or greyish discoloration from the underlying dentine	3-Active (cavitated)	E-Enamel cavitation	3- Localized enamel breakdown
4-Cavitation in enamel exposing the dentine	4-Inactive (Intact)	D-Dentine lesion (Non cavitated)	4- Underlying dark shadow from dentine
	5-Inactive (surface discontinuity)	C-Dentine cavity	5-Distinct cavity with visible dentine
	6-Inactive (cavity)	P-pulp involvement	6- Extensive distinct cavity with visible dentine
	7,8,9- Presence or absence of caries which might be active or inactive in the filling or restorations.	A-Arrested dentinal decay F- Filled surfaces contiguous with the upper types of lesion	

2. **Photographic examination**

For the evaluation of WSL, various frontal and lateral digital photos are taken, registered and calibrated by practitioner and correlated according to the Gorelick index .[18] The scoring is done on the labial/ buccal surfaces of the incisors, cuspids and premolars and the index is given in Table 2.

However, the photographic methodology should be standardized and reproducible. The preferred specifications can be a DSLR Camera, a 100 mm macro lens with a dual point flash system. The aperture (f) should be smallest approx. 25 for intraoral images, and magnification of about 1:1. While taking the photograph the teeth should be in accurate axial position that is the occlusal plane should be parallel to the horizontal in photograph. The camera should always be in manual mode, autofocus is not reliable in oral cavity, shutter speed or the exposure time should be 1/200, ISO should be 100 and the magnification should be fixed.[19]

Table2: Gorelick Index Scoring

Score	Inference
1	no white spot formation
2	Thin rims of white spot formation
3	Thick bands of white spot formation
4	Cavitation due to white spot formation

3. Fibre-Optic Transillumination (FOTI, DiFOTI)

This concept of transillumination for diagnosis is based on the principle that different tissues vary in their refractive index when light is passed through them, based on their composition. Bendable thin fibers that are cylindrical in shape, made up of good quality glass or plastic are grouped together to form bundles of optical fiber. These fibers are covered by a material of low refractive index. However, due to the low refractive material on the outside and higher refractive material inside the core, the light gets reflected back into the core.[20]

The FOTI are small and compact devices run on batteries with a fiber optic tip that should be oriented perpendicular to the facial surfaces illuminating the tooth surface.[21] Since the demineralized lesion has a low refractive index than the sound tooth structure, the illumination is less and it appears dark. A visible narrow white light illuminates tooth structure and reveals any color changes, texture and appearance of cracks, fractures, defects and existence of shadows or demineralization within the tooth structure. The shadows in the enamel gives a grey hue and shadows in the dentine gives the orange-brown or bluish hue. It is a safe procedure minimally invasive, pain free and does not have any harmful radiation. But, it is technique sensitive and expensive.

The diagnosis of the demineralization with FOTI might be subjected to intra and inter observer disparity. Hence to overcome this problem Digital imaging FOTI (DIFOTI) was developed in late 1990s. In DIFOTI the images are captured and stored by a CCD camera. Digitally processed images are developed and sent to the computer to assist in diagnosing the lesion.[22,23] DIFOTI has higher Sensitivity value that might give higher false positive results.[23] (Fig 1a,b)

Fig 1a- Fibre optic Transillumination (FOTI) device (reproduced with permission)[21]

Fig1b- Digital Fibre optic Transillumination device (reproduced with permission)[21]

4. Near-infrared digital imaging transillumination (NIDIT- DiagnoCam)

One more advancement of digital imaging transillumiantion is NIDIT device, also called as DIAGNOCam by KaVo developed in 2012. In this technique two near infrared (NIR) laser diodes are used at a wavelength of 780 nm causing luminescence of the tooth surface through the cervical or radicular region. This NIR light wavelength allows superior light spread into the tissues and hence gain deeper infiltration into dental hard tissues and get better picture quality than visible light.[24]

A proprietary software Kavo Integrated Desktop (KID) installed in a standard Computer/Laptop. The device is coupled with a head mounted retinal image display (RID) known as AiRScouter placed on right or left eye of the clinician which allows visualization of the image from the computer screen in front of clinician's eye (Figure 2).

According to a research done in vivo the efficiency of visual examination, radiography, laser fluorescence (LF) pen and NIDIT in diagnosing demineralized lesions was demonstrated. It showed that sensitivity value of visual examination was below par (0.16) and NIDIT sensitivity (0.99) measured the highest compared to the other methods.[25]

Fig 2- DiagnoCam set up (reproduced with permission) [24]

3. QUANTITATIVE METHODS

The detection of early lesions can be done prior than conventional methods with the help of quantitative methods. They are more dependable, consistent than the qualitative methods, can observe and quantify the progression of the disease. These methods are developed due to their increased need of detection lesions as early as possible and to have increased sensitivity towards the lesion. The following are the quantitative methods

1. Electrical Conductance measurement (Electrical Caries Monitor and Caries Meter L)

The sound enamel comprises high mineral content, which makes it a very good electrical insulator. Because of the mineral loss during the process of demineralization, there is formation of pores. These pores are then filled by saliva that provides a conductive passage for the electric current to pass. As these pores become larger, the conductance increases and hence they are proportional to each other. The technique uses an alternating current of consistent frequency that measures 'bulk resistance 'offered by teeth tissue.[26] Electrical conductance is affected by the following properties such as the contact region, depth of the dental tissues, presence of water in enamel, porous nature of tissues and ions present in oral fluids.[27] Two devices are:

1.1 Electronic caries monitor-ECM is a battery powered device incorporating a coaxial probe with airflow. Tooth resistance is recorded when a probe tip touches the tooth surface (Fig 3). The teeth are measured individually and are gently air dried after applying a conducting gel on their surface alongside the electrode of the device. The probe is adhered onto the tooth surface firmly and the measurement is done while activating coaxial flow. The instrument gives an audible sign after it reaches a stable reading and it is visible on the instrument display. The scores range from 0.70 till 13.20, indicative of increase in electrical conductivity.[21, 27] Three reading are made for molars and two readings for premolars according to each occlusal surface and maximum scoring is noted as the spot for tooth conductance.

Fig 3- Electrical Caries Monitor (ECM) device (reproduced with permission) [21]

1.2 Caries Meter L- After the insertion of the conducting gel, the surface of the tooth is gently air-dried. Every tooth is dampened with slight amount of saline between each measurement to get correct contact between electrode and tooth. This device has a color coding to measure the extent of caries: green for no caries, caries in enamel appear yellow, caries in dentine appear orange, and caries reaching pulp appear red. Readings are made according to each occlusal surface.

A study done by Ashley concluded that ECM measurements were better in comparison to visual assessment, FOTI, conventional and digital bitewing radiographs in detecting posterior occlusal caries.[28] However, presence of stain is found to be a confounding factor along with diverse discrepancies on reproducibility, because of the inconsistent placement of the probe and its varying contact on the surface of tooth structure.

2. AC Impedence Spectroscopy (CarieScan Pro)

The device measures alternating currents at various frequencies that are directed to the tooth structure and a range of electrical impedance spots are generated. It is then compared to a map of reference teeth built up in the universities of Dundee and St. Andrews that gives the score of 0 to 100 along with the color code. Green color corresponds to 0-50, yellow 51-90 and red 91-100. It is a portable and compact detection device that is placed onto the surface of a tooth when it is appropriately dried and isolated.[29] Probe tip should be placed on the tooth structure and rests approximately for 5 seconds. The device has a tufted sensor brush that touches the surface being examined. Also, a metallic pin is positioned over the angle of patients 'mouth connecting to the device through a wire to make the circuit.[29, 30]

3. Fluorescence

The alteration of incident light after being reflected from a surface leads to variation in the wavelength and properties of light and that results in Fluorescence. The incident radiation in the blue and green zone of the spectrum releases yellow and orange fluorescence, radiation in red or near infrared zone releases red fluorescence and near ultraviolet light emits blue fluorescence.

3.1 Quantitative light-induced fluorescence (QLF)

The device is based on the property of autofluorescence. It is the inherent fluorescence of a material or the dental hard tissues.[31]There are two different QLF devices –the first device described by de Josselin de Jong et al in 1995 uses the light from argon ion laser, the second device described by Al-Khateeb et al in 1997 uses the light from a xenon lamp.[32]
It is based on the principle that there is different amounts of light scattering and absorption by sound and carious enamel leading to difference in their fluorescence. In a demineralized lesion, the quantity of light smattering is considerably more when compared to healthy enamel, however subsequent absorption of incident light is lesser in amount causing decrease in observed fluorescence (Fig 4). The blue band filter passes the incident light of 370 nm. The blue light through a fiberoptic cable reaches the hand piece of the device, illuminating the tooth surface resulting in autofluorescence and the image is captured onto the CCD camera. Mineral loss is quantified in relation to adjacent healthy tissue. The QLF software developed by de Josselin et al calculates the amount of mineral loss, a cover area is positioned surrounding the lesion in order to reconstruct the demineralized region enclosed by the healthy tooth structure.
Resulting fluorescence loss is measured by computing the change amongst the actual and the reconstructed area. Demineralized area (in mm^2), DF (mean change in fluorescence, in %), DQ (lesion area*DF). Parameters measured are fluorescence loss in percentageand maximum fluorescence loss in the lesion in percentage.[31, 33] A trial concluded that QLF detects and quantify any mineral loss and measures the size of lesions when Fluoride and non-F dentifrices were used.[34] Another study concluded that QLF-D detects red fluorescence depending upon the severity of the hypomineralization.[35]

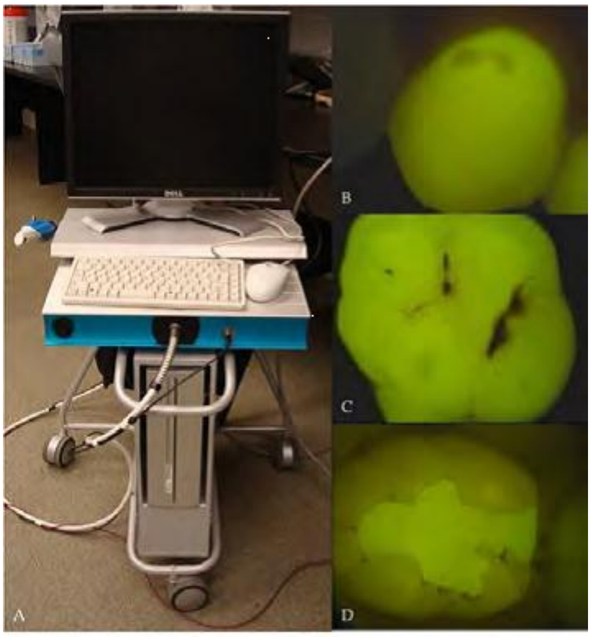

Fig 4A- Quantitative light-induced fluorescence device
Fig 4B, C, D- Fluorescent images of enamel caries (reproduced with permission) [21]

3.2 Laser fluorescence (DIAGNODENT)

It is a quantitative method based on the fluorescence caused by bacteria or their metabolites apart from light scattering. The light source emitted from the tip of this device is a red colored light of 655 nm wavelength causes excitation of the porphyrins and results in fluorescence of the tooth. Red light is absorbed in reduced amount and less reflected by tooth structure than shorter wavelength radiation. Apart from infra-red fluorescence, red light penetrates deep into tooth structure enabling easy detection of demineralized lesion.

Rodrigues et al in 2011 described two devices: DIAGNOdent device and DIAGNOdent pen.[36] Working principle of Diagnodent device and Diagnodent pen are similar and is based on characteristics of fluorescence, the light of a particular wavelength is absorbed by a fluorescent molecule and then the light is emitted at longer wavelengths. As the light source strikes tooth surface it is absorbed by the organic and inorganic elements along with the metabolites excreted by the bacteria. The bacterial metabolites are the porphyrins formed by numerous bacteria in the mouth.[37] The maximum fluorescence is observed in red spectral region that contains protoporphyrin and mesoporphyrin. However, the advanced dentinal lesion is more infected compared to early enamel lesion and hence this hampers the device performance in early lesions.[38] The device consist of laser diode, photo diode and a long pass filter.

The teeth are air died before placing the tip of the probe over the surface of tooth structure. Probe tip is adapted onto the individual tooth and measures the maximum reading on each surface. Angulation of the tip should be consistent. Fluorescence values is associated with an acoustic signal (Table.3) A systematic review suggests stain- and plaque-confounding factors as the major limiting factor as they might give false positives readings.[38] Another study compared Diagnodent, Cariescan Pro, visual examination and Diagnocam concluded that DIAGNOcam, DIAGNOdent Pen, and visual assessment methods might be efficient and helpful in identifying concealed caries.[30]

Table 3: Scoring of Diagnodent device

Readings	Inference
0-14	Absence of caries
15-20	Caries present in enamel
21-99	Caries present in dentine

3.3 Light Emitting Diode Fluorescence

LED fluorescence function based on the principle of difference in optical property. The demineralized tooth is less translucent than sound tooth. Hence there are difference in optical properties. There are two commercialized systems available now are Midwest Caries (MID) and Vista Proof (VP).

MID probe uses LED lights and captures the refraction and reflection of the LED with the help fibre optics which is then converted into signals. This is a small, battery operated device that has a portable handpiece with a probe. Probe tip should be held in such a manner that it is oriented parallel in relation to the long axis of the occlusal area. There is a built in microprocessor that detects variations in optical property (Fig 5). When a demineralized tooth is encountered there is an audible signal with a change in red color from green.[39] Audible signal is classified as (Table4).

Table 4: Scoring of Midwest caries device (LED Fluorescence)

Score	Inference
0	Green light without any signal indicative of healthy tooth
1	Red light with medium signal indicative of enamel caries
2	Red light with rapid signal indicative of dentinal caries

Fig 5- Midwest Caries (MID) device (reproduced with permission) [21]

Vista Proof is an intraoral camera consisting of 6 blue LEDs. The wavelength of these LED are 405 nm. The images are converted into electronic signal with the help of a software and images are analyzed. The red and green fluorescence is generated by the software and transformed into numbers and demonstrates those area of tooth structure with varying fluorescence of green to red color ranging in the wavelength of 510 nm and 680 nm correspondingly. The scores lies between 0 to 3 depending on the extent of the demineralization. Fluorescence ratio of demineralized lesion is calculated by ratio of maximum number of red and green lesion that is recorded (Fig 6).[40]

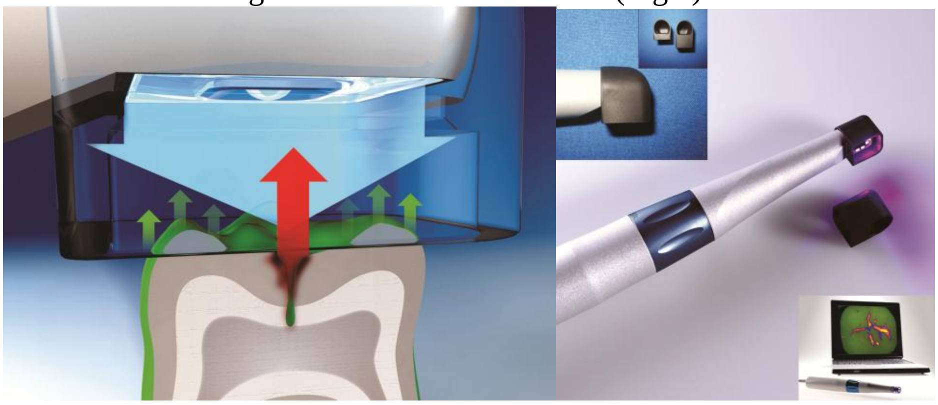

Fig 6A- Ultraviolet rays strikes the demineralized lesion that induces red fluorescence (reproduced with permission) [40]. Fig 6B- Vista Proof device (reproduced with permission) [40]

4. **Terahertz imaging (TPI)**

It is a non-ionizing, non-invasive, coherent optical imaging that uses a frequency range of 0.1 THz to 2.7. It is based on the phenomenon of variation in refractive index, loss and scattering of the THz signal. The incident THz pulse when reaches the surface of the tooth, some THz beam is reflected back and the rest is absorbed inside the tooth structure. Mineral loss causes a change in refractive index within the enamel and this change causes reflections which is accurately detected by the TPI system.[41] The lesions in the tooth structure relates to every peak in time-domain waveform. These peaks amplitude of every pixel when collectively recorded generates the image. When entire THz beam is recorded, an image of the tooth is generated. It gives 3D information about the structure and calculates the refractive index profile and lesion depth. The lesion thickness are calculated by inserting the optical delay between the two reflected peaks.[41]

$$\text{Depth} = \frac{\text{optical delay} * c * \cos\theta}{2n}$$

According to a previous study A TPI system investigated tooth samples ex vivo in 3D and compared with CBCT images and presented similar efficacy in identification and diagnosis of caries. Also, it is helpful in detecting early initial dental caries.[42] Although it is a new technical development, research systems for in vitro measurements are now commercially available.

5. Polarized Raman Spectroscopy

In order to overcome the problem of high false positives and negatives in detection of early lesion by different methods, Polarized Raman spectroscopy was introduced that provides biochemical characterization of hydroxyapatite in the tooth with high specificity and sensitivity. It provides detailed information about the biomolecular composition such as dentinal collagen and inorganic elements, crystallinity, orientation of mineral matrix of the tooth and also about the bacterial porphyrins in the demineralized lesion.[43] Polarized Raman spectroscopy uses near-infrared light source with the wavelength ranging in between 785 and 830 nm. This light source can efficiently distinguish the healthy and the carious tooth. In this method, parameters such as depolarization ratio and polarization anisotropy is calculated depending upon the intensity of Raman band near 959 cm.[43] With the progression of demineralization the caries develops and it causes increase in depolarization ratio whereas the polarization anisotropy decreases as the enamel structure is disoriented and distorted.

According to a study done by Sa et al in the year 2017 showed the effectiveness of micro-Raman spectroscopy and efficient monitoring of the change in the mineral composition of tooth enamel throughout the process of loss of mineral and then remineralization was elicited.[43] The method is undergoing many research at the current scenario.

6. Optical Coherence Tomography (OCT)

It is a high-resolution, non-invasive, nonradiative imaging method. Fujimoto in 1991 reported this technique for the very first time.[44] The modus operundi is like B-scan ultrasound technique, but the OCT uses infrared light as a source whereas ultrasound imaging uses sound waves. It is an interferometric technique which uses near infrared light sources of wavelength ranging between 850 to 1310 nm. When a tissue is illuminated by the striking of light on its surface, there is back-scattering of light on the basis of optical differences in the properties of the tooth structure causing the formation of images.[44] It consist of Michelson interferometer which splits light into two arms. These two light arms, one is reflected from the tooth and the other from the reference arm when combined provides a pattern. This pattern gives rise to depth also called as reflectivity profile, collectively termed as A-scan. The reflectivity of enamel decreases with increasing demineralization.

The combination of these A-scans longitudinally produces a 2D image called as B scan is achieved whereas transverse images are C scans at fixed depth. The former is quantitative assessment whereas the latter two are qualitative. According to Amaechi et al the degree of reflectivity (R) of the tissue is calculated by the area under the depth versus reflectivity curve. The reflectivity loss (R%) is the amount of demineralization or the mineral loss in a lesion is calculated as follows:

%Reflectivity loss (%dBmm) = [(Rsound – Rdemineralized)/ Rsound] * 100

Studies have demonstrated that OCT can detect early incipient carious lesion as early as 24 hour in its development.[44] However, this imaging technique can cause false positive cases and is subjected to inter- and intra-examiner variability.

6.1 Polarization-sensitive OCT (PSOCT)

A variant of OCT that has been developed in 1992. The technique uses polarized incident light and a pair of detectors that calculates the backscattered light in two dimensional axes.

Birefringence detected offers additional distinction between healthy and carious tooth. Caries can alter the property of birefringence shown by hydroxyapatite crystals. PS-OCT decreases the unwanted reflections from the tooth surface and constructs an axial polarization image that enables high resolution of lesion and the surface layer of tooth structure, hence detecting the incipient lesion.[44,45]

6.2 Swept source optical coherence tomography (SS OCT)

Another modification of OCT which uses wavelength tuned laser. This device emits Near-infrared light. SS-OCT constructs high resolution images of approximately 10–15 µm. In this technique the laser continuously sweeps over the wavelength. It detects the WSLs and the early carious lesion as bright lesion along with enhanced backscattered emission. SS-OCT constructs an image with enhanced brightness corresponding to the demineralized lesion. When compared to the chalky white lesion in cross-sectional images, these SSOCT images corresponds well.[45]

7. Multiphoton Imaging

This technique is based on the autofluorescence property of dentin that contains collagen. The light source is Infrared with a wavelength of 850 nm. When compared to a traditional fluorescence method (QLF) that emits only one blue photon to cause fluorescence whereas in multiphoton imaging two infrared photons are absorbed simultaneously. A fiber-coupled miniature spectrometer incorporated in the arrangement to provide spectroscopic investigation. A global histogram is constructed with the help of photons from the autofluorescence which is used to assess the carious lesion. The images are recorded using custom built multiphoton microscope. The illuminescence caused by fluorescence was distinguished from backscattered excitations of the laser rays. The autofluorescence image is captured near junction of dentin and enamel (DEJ) both of them show intense autofluorescence with multiple photon excitation. In order to calculate the loss of mineral due to demineralization and caries, the 3D imaging is done with the help of micro-computed tomography (micro-CT) in the system which quantifies the demineralization and mineral loss in the tooth structure, in the form of loss of fluorescence in the lesion.[46]

8. Infrared Thermography

It is a noncontact, noninvasive, nonionizing method of temperature changes measurement. The changes in thermal energy is measured after the loss of water by evaporation in carious lesion. Comparison is made to assess the difference between the emission of thermal energy of a healthy tooth and emission of thermal energy by demineralized tooth. The images that are produced by the emission of electromagnetic radiation are digitally stored and analyzed. Kaneko et al (1999) described the technique and calculated mineral loss by calculating area under the time-temperature curve.[47]

Thermophotonic lock-in (TPLI) method uses a continuous low power intensity light source. The modulated light strikes the tooth surface and produces a thermal field inside the tooth structure causing generation and emission of infrared. The thermal wave field leads to emission which is captured with the help of Infrared Camera.[47] A study suggests that both TPLI and OCT contains adequate sensitivity for diagnosing fully formed initial caries lesion. It is based on light absorption instead of light scattering mechanism, and hence it shows increased specificity for detection resulting in reduced number of false positive results. It

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causes early distinction of initial lesion from sound enamel region. However, it is still at research stage and not commercialized due to cost and size of IR cameras. The major shortcoming is prohibiting the production of depth-resolved images.[48]

9. Frequency-domain infrared photothermal radiometry and modulated luminescence (PTR/LUM)

A recent technology, called the Canary System™ introduced in 2011 (Quantum Dental Technologies Inc., Toronto, Canada).This device is a small powered laser that is equipped with an intra-oral camera. The technique is based on modulated thermal IR detecting luminescence differences and also it can assess the temperature variation to quantify mineral changes. The images are taken and recorded in their software.[49]

Canary System TM divides the facial surface of photograph of an incisor tooth into 9 equal segments. Higher numbers on segments of the tooth, correspond to the presence of WSLs visually (Fig 7). The method of recording WSL is performed by holding the tip of the scanner on the desired tooth surface to be scanned. The system provides a number ranging from 0 to 100 on the digital display (Table 5). According to a study the Canary System TM has a sensitivity of up to 97%.[49]

Table 5: Scoring of Canary system

Score	Inference
0-20	Healthy tooth
21-70	Demineralization and Caries
71-100	Advanced Caries

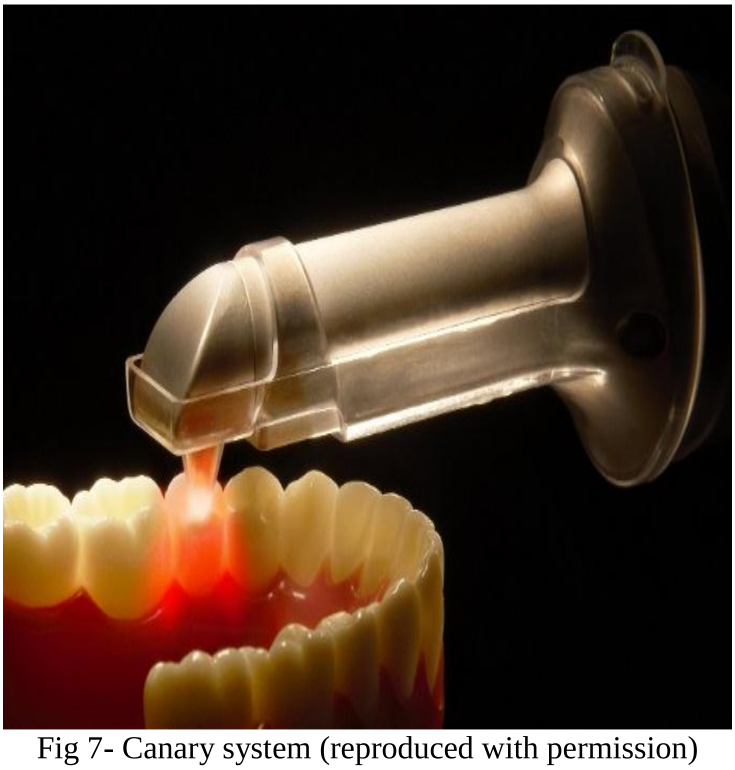

Fig 7- Canary system (reproduced with permission)

4. CONCLUSION

The progression of white spot lesion is initiated when the equilibrium between demineralization and remineralization is hampered. Although there are numerous methods that are accessible to the practitioner; however, but it is very important and essential to use quantitative methods of appropriate sensitivity and specificity in combination with qualitative methods to achieve an effective diagnosis. The presence of plaque is one of the major cause of development of WSL. The emphasis currently should be given to newer technologies that do not require professional intervention, such as smart toothbrushes that has plaque detecting sensors and glows blue when plaque is detected and turns white when cleared. These toothbrushes are synchronized with the smartphones via Bluetooth connection. Detailed study should be done on the efficacy of these toothbrushes.

Conflict of Interest: NIL

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