Chapter 1

Background, Intention and Description of the Problem
1.1 BACKGROUND AND INTENTION

Dental caries is an important Dental-Public-Health dilemma and it is the most widespread oral disease in the world. The prevalence of dental caries has been of great concern for long and is a principal subject of many epidemiological researches carried out in India and abroad. This disease not only causes damage to the tooth, but is also responsible for several morbid conditions of the oral cavity and other systems of the body (WHO 1981). The prevalence pattern of dental caries not only varies with age, sex, socio economic status, race, geographical location, food habits and oral hygiene practices but also within the oral cavity. All the teeth and all the surfaces are not equally susceptible to caries. Factors contributing to the progression of the disease include diet (mainly fermentable carbohydrates), microbes, and the host (amount and constituents of the saliva, habits). The progression of dental caries lesions needs time. Fluoride protects the teeth from dental caries by influencing the tooth structure.

Over the last decades, a remarkable decline in caries prevalence has been noticed in the world population, primarily due to the increase in scientific knowledge on the etiology, initiation, progression and prevention of the disease coupled with the wide scope of preventive measures and fluoride therapy (Elderton, 1983; Kidd et al, 1987; Newbrun, 1993; Ekstrand et al, 2001). However, it is still a major oral health concern in developing countries, affecting 60-90% of the school children and the vast majority of adults (World Oral Health Report, 2003). On the other hand, dental caries is highly prevalent in India, which is influenced by the lack of dental awareness among the public at large and is reported to be about 50-60% in India (Naseem, 2005). The dramatic improvements in the prevalence and incidence of dental caries and the changes in the epidemiology and pattern of disease over the past thirty years is well documented (Marthaler 1990, 2004). Most notably, the rate of progression through the teeth has slowed. This reduction in prevalence has not occurred uniformly for all dental surfaces. The utmost reduction was seen at smooth surfaces lesions, followed by proximal surfaces, so that occlusal surfaces are now the most probable sites for development of caries. Nevertheless, the disease has not been eradicated and although less widely distributed in the dentition and less acute in terms of lesion progression, caries persists in the general population.
In addition to the drastic changes in the disease manifestation itself, in recent years there has also been major progress in our understanding of the mechanisms underlying the development of clinical stages of the disease. In clinical dentistry, this new knowledge has led to an evident change in the interpretation of signs of possible hard tissue damage due to caries at individual tooth sites. Thus the initial effect of the disease on the enamel is clinically undetectable subsurface demineralization and net loss of tooth mineral as the result of a mineral imbalance between plaque fluid and tooth surface (Fejerskov, 1997). At this stage, the damage is reversible and the affected site can be remineralized. Factors that determine the balance of the reactions and thus the likelihood of mineral loss or gain and the rate at which it occurs, are composition and thickness of the biofilm covering tooth surfaces, the diet, the fluoride ion concentration, and the salivary secretion rate (Kidd & Fejerskov, 2004).

In clinical dental practice, the decrease in the rate of lesion progression has led to the modification of thresholds for restorative intervention and a change towards a less invasive approach to the management of the disease. Despite our improved understanding of the caries process and the availability of effective intervention, caries lesions still progress to the stage where tooth structure is compromised and invasive intervention and restoration are required. On the basis of these concepts of the disease process, lesion detection and early intervention, the goals of caries management are to inhibit the initiation of new lesions, to arrest the progression of established lesions and to enhance the natural process of lesion repair by remineralization (Featherstone, 2004).

For decades, dentists have relied on visual inspection, tactile examination with probe and X-rays to identify dental caries and early-stage cavitation sites. Among these, visual inspection is the favoured choice to diagnose dental caries because it is non-destructive as compared to mechanical methods such as probing, which can damage tooth structure and X-rays, which are ionizing and hazardous in nature. All of these methods have limitations affecting either their diagnostic ability or their practicality in a clinical setting. Once the caries cavity is detected by conventional techniques, tooth demineralization has usually progressed through approximately one-third to one-half of the enamel’s total thickness (Angmar-Mansson and ten Bosch, 1993; Schneiderman et al, 1997; Ashley et al, 1998; Hintze et al, 1998; Ross, 1999; Young, 2002). Because X-rays only show good contrast when considerable mineral loss has already taken place, this technique allows detection only of already well-advanced caries. At this stage, the treatment option is drilling and filling with restorative material. Thus there is an emerging need for sensitive, clinically relevant methods for early
detection and quantification of caries lesions. The development of new techniques could improve the accuracy of detection and especially could create the possibility of early caries detection and helps to apply suitable preventive measures or operative procedures.

1.2 OBJECTIVES OF THE STUDY

Detection of dental caries using optical techniques is receiving a lot of attention these days. Several, published data demonstrate the potential of optical spectroscopy to characterize caries lesions. Diagnostic techniques based on optical spectroscopy allow non-invasive and real-time characterisation of tissue. In particular, these techniques are fast, quantitative and can be easily automated. As well as, they also elucidate the chemical composition and morphology of the tissue which in turn help in monitoring metabolic parameters of the tissue and also distinguish sound from carious tooth. Among them, the potential of laser-induced fluorescence (LIF) and diffuse reflectance (DR) is enormous and yet, is not fully explored for early detection of dental caries in vivo. The hypothesis of present work is that these optical techniques will help to discriminate different stages of caries with good sensitivity and specificity. This thesis mainly aims at testing the applicability of LIF and DR spectroscopic techniques for detecting caries in its early stage. As part of this work, the applicability of LIF and DR spectroscopy in detecting early demineralization and remineralization is also tested.

In this current thesis, autofluorescence and diffuse reflectance spectra were obtained from sound and caries tooth belonging to different categories, with the intention of early detection of tooth caries. The major objectives of the study are:

1. Development of a compact, non-invasive, point monitoring laser-induced fluorescence reflectance spectroscopy (LIFRS) system for simultaneous measurement of laser-induced fluorescence and diffuse reflectance spectra from the same tooth samples, to detect dental caries or discriminate different stages of caries.

2. Standardization of measurement parameters and study protocol through in vitro studies

3. To test the applicability of the developed LIFRS system to detect dental erosion.

4. To test the ability of the device to detect early demineralization changes in tooth.

5. To study the effects of remineralization treatment on demineralized tooth.
6. Modification of the device based on the \textit{in vitro} results, for clinical studies at the Department of Conservative Dentistry and Endodontics of Government Dental College Thiruvananthapuram and to measure LIF and DR spectra in patient and correlate with visual-tactile and radiographic findings.

7. To check the diagnostic accuracy of LIFRS system with visual-tactile and radiographic examination, in terms of sensitivity, specificity and ROC analysis for detection of dental caries both \textit{in vitro} and \textit{in vivo} conditions.

1.3 SOME FACTS ABOUT DENTAL CARIES

Dental caries is a dynamic process, taking place in the microbial deposits (dental plaque on the tooth surfaces), which results in a disturbance of the equilibrium between tooth substance and the surrounding plaque fluid so that, over time, the end result is the loss of mineral from the tooth surface (Thylstrup and Fejerskov, 1994).

1.3.1 Carious process

The carious process affects the mineralized tissues of the teeth mainly enamel, dentin and cementum, which is caused by the action of microorganisms on fermentable carbohydrates in the diet. It can eventually lead to the demineralization of mineral portion of these tissues, followed by the disintegration of the organic material. At the crystal level, onset of carious process may be expected, but progression of a microscopic lesion to clinically detectable lesion is not a certainty because in its initial stage, the process can be arrested and a carious lesion may become inactive. Nevertheless, progression of the lesion into dentin can finally result

\begin{center}
\includegraphics[width=0.5\textwidth]{Fig_1_1.pdf}
\end{center}

\textbf{Fig. 1.1} Etiology of dental caries.
in bacterial invasion and death of the pulp and spread of infection into periapical tissues, producing pain.

1.3.2 Etiology of Caries

Dental caries is a multi-factorial disease. Many variations are seen in the incidence of caries due to the complex interplay of several factors. Basically, caries occurs when there is interaction of four principal factors; the host i.e., tooth, the microflora, the substrate and the time. For caries to occur all the four factors should be favourable- it means caries requires a susceptible tooth surface, cariogenic oral flora and a suitable substrate for a sufficient length of time (Fig. 1.1).

1.3.3 Clinical presentation of caries

The characteristics of carious lesions vary according to the surface on which they develop (Fig. 1.2).

1.3.3.1 Pit and fissure caries/occlusal caries

Pit and fissure caries “fans out” as it penetrates into enamel. The entry is over a small region but the occlusal enamel rods bend down and terminate on the dentin immediately below the developmental fault. This makes the carious lesion occupy a broad area of enamel after penetrating through a small opening on the pit or fissure. It is primary type and develops in the occlusal surface of molars and premolars. It appears brown or black and will feel slightly soft. In longitudinal sections of teeth, pit and fissure caries can be seen as a cone-shaped defect with its base towards the dentino-enamel junction (DEJ) and apex towards the pit. At the DEJ, the caries spreads laterally, rather than pulpally. So the carious lesion in dentin also appears cone-shaped with the base at the DEJ and apex towards the pulp.

1.3.3.2 Smooth surface caries

Caries starting on smooth surfaces has a broad area of origin and a conical extension towards the pulp. The path of origin is roughly parallel to the long axis of the
enamel rods in the region. It develops on the proximal surfaces of the teeth or on the gingival third of buccal and lingual surfaces. In longitudinal section, the caries process is seen as cone-shaped area, with its base towards the enamel surface and its apex towards the DEJ. At DEJ, it spreads laterally along the junction, rather than pulpally. The base of the cone in dentin is again at the DEJ and its apex is toward the dental pulp.

1.3.3.3 Root surface caries

The cementum covering root surfaces is relatively thin and provides little resistance to caries attack. Root surface caries begins directly on dentin. It is U-shaped in cross section and spreads more rapidly because dentin is less resistant to caries attack.

1.3.4 Histopathology of caries

1.3.4.1 Caries of enamel

Enamel is highly mineralized tissue and forms an effective barrier to bacterial attack. However, its organic substance and water content make enamel act like a molecular sieve allowing free movement of small molecules and blocking the passage of larger molecules and ions. Caries in enamel preferentially attacks the interprismatic areas and the more permeable Striae of Retzius, because these regions have more organic content, followed by prism cores. As caries progresses in enamel along these regions, it spreads laterally thereby undermining enamel.

The first sign of enamel caries is seen as white spot. It appears opaque on drying the tooth surface and translucent on wetting the surface. If the enamel lesion is allowed to develop, demineralization becomes more predominant, which in turn cause a break in the enamel surface, producing cavity. Once cavity is formed, bacteria gains entry into the surface and progress deeper into the tooth.

An early enamel lesion seen under polarized light reveals four distinct zones of mineralization. These zones include,

a) Surface Zone: This outermost zone is relatively unaffected by caries attack. It is well mineralized by replacement ions from plaque and saliva.

b) Body of the lesion: This is the major portion of enamel caries. It is poorly mineralized. Caries spreads along the Striae of Retzius and interprismatic areas
and then attacks the prism cores. Bacteria are present in this zone.

  c) **Dark zone:** This lies deeper to the body of the lesion and represents some remineralization.

  d) **Translucent zone:** This is the deepest zone which represents the advancing front of the enamel caries. This is translucent due to demineralization which creates a structureless appearance of the enamel.

These zones represent the dynamic series of events taking place in early enamel caries. The early enamel caries can be reversed and remineralized if plaque is removed.

### 1.3.4.2 Caries of dentin

Caries progression in dentin is different from that of enamel. Dentin has lesser mineral content and microscopic dentinal tubules provide a pathway for the spread of caries. Thus caries progresses more rapidly in dentin than in enamel. The DEJ is less resistant to caries attack and allows lateral spread of caries. Dentinal caries is V-shaped in cross-section with its base at the DEJ and apex towards the pulp. Changes seen as caries spread in dentin:

i) Weak organic acids demineralize the dentin.

ii) The organic content of dentin especially collagen undergoes degeneration and dissolution.

iii) Breakdown of the structural integrity and bacterial invasion.

Pathological changes seen in carious dentin is divided into various zones. They are

a) **Zone 1, Normal dentin:** The deepest zone of carious dentin is normal with normal collagen, odontoblastic processes and intertubular dentin.

b) **Zone 2, Sub-transparent dentin:** Here the intertubular dentin is demineralized, odontoblast processes are damaged and fine crystals are seen in the lumen of the dentinal tubules. But no bacteria are present.

c) **Zone 3, Transparent dentin:** This is superficial to the subtransparent dentin. It is softer than normal dentin and exhibits mineral loss in intertubular dentin. No bacteria are present and collagen cross-linking is intact. So this layer is capable of remineralization.
d) Zone 4, **Turbid dentin:** Here dentinal tubules are widened and distorted due to bacterial invasion. There is considerable demineralization and collagen is irreversibly denatured.

e) Zone 5, **Infected dentin:** This is the outermost zone. It has decomposed dentin with destruction of dentinal tubules and collagen. A high concentration of bacteria is present. This zone has to be removed to avoid the spread of infection.

Since dentin and pulp are intimately related, once caries attack dentin the dentin-pulp complex produces a protective response by blocking the open dentinal tubules. This response depends on the severity of the caries attack.

**1.3.5 Diagnosis of dental caries**

![Fig.1.3. Diagnostic methods for dental caries.](image)

Early diagnosis of carious lesion is essential because the carious process can be modified by preventive measures so that the lesion does not advance. The search for an ideal caries diagnostic method continues as such technique must be accurate, sensitive, specific, reproducible and reliable. Traditional methods of caries detection include visual inspection, tactile examination with an explorer and radiographic examination. These traditional techniques are still used in contemporary dental
practices; nevertheless some practices have been altered due to paradigm shift or new diagnostic equipment (Fig. 1.3).

1.3.5.1 Visual examination

Visual inspection is best performed in a well lit, clean, dry field, with the aid of magnification. The first step in assessing the caries status of a patient is to visually inspect all tooth surfaces, including root surfaces (Baysan, 2007). Visual data of caries is a good indicator of the degree of caries penetration within tooth tissues. ‘Sharp eyes’, with or without the aid of x2-4 loupes, in combination with good illumination and drying with a three-in-one syringe, termed as detection triangle (Fig. 1.4), may offer more information than the use of a mirror and a sharp probe.

The procedure for initial visual inspection, with or without the help of loupes is as follows:

a) Clean the tooth surface
b) Place cotton rolls and saliva ejector
c) With the surface wet, examine the suspected white or brown spot lesions.
d) Dry the tooth using the three-in-one syringe.
e) Confirm the presence of any white or brown spot lesions.
f) If there is any obvious cavitation, then visual-tactile examination can be considered to determine if there is any exposed dentin (Ekstrand et al, 2001).

1.3.5.2 Visual-Tactile Techniques

At present, most caries tends to be detected using visual-tactile criteria, based on the presence or absence of cavitation and the surface texture of lesions. Usually curved explorers are used for examining occlusal pits and fissures while interproximal explorers
are used to detect proximal caries. The use of dental explorers may not improve the accuracy of diagnosis; indeed, it may increase the number of false positive diagnoses. Probing can also transfer infective microorganisms from one site to another and disrupt tooth surfaces prone to cavitation (Kidd et al., 1993). It has also been observed that excessive pressure with a sharp explorer tip can convert initial lesions into cavitation (Yassin, 1995). Therefore it is advised to use only blunt probes to remove debris and confirm frank cavitation.

1.3.5.3 Radiographic examination

The use of radiographs to scrutinize teeth and other oral structures for the presence of oral disease remains the ‘gold standard’ (Barnes, 2005). Conventional, intraoral periapical and bitewing radiographs are used to diagnose dental caries. Of the two, bitewing radiographs have more diagnostic value. Bitewing radiographs has been used for the detection of occlusal and proximal surface caries as well as caries adjacent to the margins of restorations (secondary caries) in posterior teeth in both adults and children (Fig. 1.5). Periapical radiographs are used for detecting early proximal surface caries in anterior teeth. Characteristics of acceptable radiographs are shown in Table 1.1.

**Table 1.1 Characteristics of acceptable radiographs.**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Appearance</th>
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<tbody>
<tr>
<td>Image</td>
<td>All parts of teeth of interest must be shown close to natural size, with minimal overlap and minimal distortion</td>
</tr>
<tr>
<td>Area covered</td>
<td>Sufficient tissue surrounding tooth for diagnostic purposes</td>
</tr>
<tr>
<td>Density</td>
<td>Proper density for diagnosis</td>
</tr>
<tr>
<td>Contrast</td>
<td>Proper contrast for diagnosis</td>
</tr>
<tr>
<td>Definition and sharpness</td>
<td>Clear outline of objects, minimal penumbra</td>
</tr>
</tbody>
</table>

Adapted from White and Pharoah. Oral radiology principles and interpretation. 5th edition. St Louis, Mosby, 2004

Initial enamel caries in the occlusal surfaces are difficult to detect using bitewing radiographs due to its complicated three dimensional shapes. Also caries involving the buccal or lingual grooves of molars may mimic occlusal lesions due to superimposition. Once caries has progressed into dentin, it appears as radiolucent zone.

Bitewing radiographs are very important in diagnosing proximal caries. Early
proximal enamel caries appear as a small radiolucent notch below the contact area in enamel. Advanced proximal caries is seen as dark triangular area in the proximal enamel with its base towards the external tooth surface. Proximal caries may be scored according to its progress through enamel and dentin towards the pulp.

**Fig.1.5.** Bitewing radiographic image of different sized caries lesions in proximal and occlusal caries. (Adapted from Whaites, In Minimally Invasive Dentistry: The management of caries, Eds. Wilson NHF. Quintessence Publ. Co, Ltd, London, et al., 2007.

*Diagnostic yield*

Clinical examination only results typically in less than 50% of occlusal and proximal caries lesions present being detected. When clinical and appropriate radiographic diagnoses are combined, more than 90% of occlusal and proximal surface lesions may be detected, with cavitated lesions tending to be easier to diagnose correctly than non-cavitated lesions. Visual inspection and radiographs or bitewing x-rays, although effective in revealing advanced stages of caries (Kidd, 1994; Verdonschot et al, 1999) are unsuccessful in detecting early caries, especially in the complex anatomy of fissure areas (King and Shaw, 1979).

1.3.5.4 *Alternative caries detection methods*

In recent years, more than a few caries detection methods and devices have been developed. The advent of these detection techniques is welcomed as traditional caries detection methods do not allow for the detection of caries until they have progressed
through at least the thickness of enamel. Some of these new caries detection methods are so recent that they are not yet marketed to the dental profession and others have been found to be more practical for research purposes. These methods include:

1.3.5.4.1 Diagnostic method based on X-rays: Digital and subtraction radiography

Currently, digital radiographic methods offer a more superior means of detecting caries than conventional radiographs. Digital radiographic images are created by using the spatial distribution of pixels and the different shades of gray of each of the pixels. These radiographic devices interface with a computer to digitize the digital radiographic images into pixels that are then viewed on a computer. It offers several advantages over traditional dental radiography:

   i) Reduced radiation exposure to patient
   ii) Instant image visualization
   iii) Eliminates chemical processing and accompanying errors
   iv) Image enhancement, processing and magnification can be done

The most important advantage of digital imaging is that it can be used for subtraction purposes. Here images which are not of diagnostic value in a radiograph are reduced so that the changes in the radiograph can be precisely detected. Images taken over time are superimposed to check the differences between original and subsequent images.

1.3.5.4.2 Diagnostic systems based on electrical current: ECM/EIM

The theory behind the use of Electrical Conductance Measurement (ECM) is that sound tooth enamel is an insulator, due to its high inorganic content. On the other hand, carious or demineralized enamel has a measurable conductivity which increases with the degree of demineralization. On the basis of this difference, four coloured lights were used as indicator for caries.

   i) Green: no caries
   ii) Yellow: enamel caries
   iii) Orange: dentin caries
   iv) Red: pulpal involvement
Many researchers have used ECM for both *in vitro* (Verdonschot et al, 1993; Ashley et al, 1998) and *in vivo* studies (Rock and Kidd, 1988; Verdonschot et al, 1992a) and the reported sensitivities for diagnosing dentinal carious lesions of permanent molar and premolar ranged from 0.67 to 0.96, whereas the specificities ranged from 0.71 to 0.98. In addition, they are more accurate in diagnosing early occlusal caries than visual method, radiographs or fiber optic transillumination (FOTI). The major disadvantage of ECM method is the use of sharp metal explorers, which in turn cause traumatic defects in pits and fissures.

Carious tissues have much lower electrical impedance or much better electrical conductivity than sound tooth. This principal of electrical impedance has been used to detect caries lesions at approximal surfaces of teeth (Huysmans et al, 1996; Longbottom et al, 1996). Even though the results from these *in vitro* studies were very promising, no follow up results have been reported since.

**1.3.5.4.3 Transillumination: FOTI and DIFOTI**

Transillumination has been used as diagnostic tool in dentistry for over 30 years (Stookey, 2003). Caries detection using transillumination with a bright fiber-optic light depends on the light scattering by the lesion. Increased opacity of the enamel is the visual sign of early caries. Optical scattering can be used to quantify the degree of demineralization in enamel and dentin. In sound tooth, scattering is more prominent than absorption. Nevertheless, when light transmits through damaged tooth, light absorption increases. Dark shadowing indicates the presence of caries. It is especially useful in detecting proximal caries, with the added advantage over radiographic techniques that the patient is not exposed to ionizing radiation. It does not detect small carious lesions; hence its use is limited.

The Digital imaging fiber-optic transillumination (DIFOTI) is a relatively new technique that has developed in an attempt to decrease the short coming of FOTI, by combing FOTI and a digital CCD camera. Illumination is delivered to the tooth surface by means of fibre-optic light source. The resultant change in light distribution is captured by the camera and is sent to the computer for analysis. It is non-invasive and can detect incipient and recurrent caries very early. But it does not measure the depth of the lesion and are not able to discriminate between deep fissure, stain and dental caries. Nevertheless, these techniques have lower sensitivities for caries detection when compared with radiologic images and poor reliability as compared to visual inspection and bitewing radiography (Hintze et al, 1998; Schneiderman et al, 1997).
1.3.5.4.4 Quantitative laser/light-induced fluorescence (QLF)-yellow/orange fluorescence

As the name of the method implies, QLF is based on fluorescent light. In QLF this light is not induced by X-rays or other ionizing radiation but by visible or near ultraviolet radiation. The fluorescence of tooth tissue has been known for a very long time. Three types of fluorescence have to be distinguished. The first is the blue fluorescence that is excited in the near ultraviolet. The second is the yellow and orange fluorescence excited in the blue and green. The third is the fluorescence in the far red and near infrared that has recently received much attention for quantitative non-image diagnosis of caries lesions. Initially the technique was developed using lasers and was demonstrated by Bjelkhan (1982). With concerns existing over the intra oral use of lasers, de Josselin de Jong (1995) developed a system using filtered visible light, QLF. The experimental method involves quantification of the light-induced fluorescence level of enamel. Sound, healthy enamel shows a higher fluorescence than demineralized enamel; demineralized areas appear relatively darker under light that excites the fluorescence.

The teeth are illuminated with a broad beam of blue-green light from an argon ion laser (488 nm) or blue light from a xenon arc lamp, equipped with a band pass filter with peak transmission at 370 nm. A yellow high pass filter (520nm) is placed in front of the CCD micro camera which captures the tooth image. Image of the tooth under examination is displayed on a PC screen (Fig. 1.6). The absolute decrease in fluorescence is determined by calculating the percentage loss between actual and reconstructed fluorescence and is expressed as F value.

The QLF has been tested in several in vitro and in vivo studies for smooth surface, occlusal and secondary caries (Al-Khateeb et al, 1997a; Emami et al, 1996; Pretty et al, 2002, 2003; Ferreira Zandona et al, 2000, Heinrich-Weltzein et al, 2005; Ando et al, 2000, Kuhnisch et al, 2006, Hall et al, 1997). It has shown that QLF is a sensitive, reproducible method for the quantification of enamel lesions on smooth surfaces. Nevertheless, its application seems to be restricted to a lesion depth of about 500μm.
Also, QLF cannot discriminate between active and inactive lesions and between caries, hypoplasia, stain and calculus.

1.3.5.4.5 **DIAGNOdent-infrared fluorescence**

The DIAGNOdent device (KaVo, Biberach, Germany) was introduced in 1998 by Hibst and Gall (1998) to help in the diagnosis of occlusal caries as an adjunct to visual inspection and radiographic examination (Fig. 1.7). It operates with light from a diode laser with a wavelength of 655 nm and 1 mW peak power, which is transported through a fibre bundle to the tip of a hand piece. The tip is placed in contact with tooth surface and laser light will penetrate the tooth. Both organic and inorganic molecules in the tooth absorb light. Fluorescence occurs within the infrared spectrum. The fluorescence as well as backscattered light is collected through the tip and passed in ascending fibres to a photodiode detector. The fluorescence light is measured and its intensity is an indication of the size and depth of the caries lesion. The fluorescence intensity is displayed as a number ranging from 0 to 99, with 0 indicating a minimum and 99 a maximum of fluorescence light.

In the presence of carious tooth substance, fluorescence increases. The cause of fluorescence is due to the presence of protoporphyrins and mesoporphyrins, by-products of bacteria (Hibst and Paulus, 1999, 2000). DIAGNOdent has been used widely for detecting occlusal and smooth surface caries (Aljehani et al, 2006, 2007; Antonnen et al, 2003; Bamzahim et al, 2004, 2005; Lussi et al, 2003, 2006). *In vitro* validity studies showed that the sensitivity of DIAGNOdent caries diagnoses ranged from 0.17 to 0.87, whereas specificity ranged from 0.72 to 0.98 (Lussi et al, 1999; Shi et al, 2000). Regarding the reliability of this method, good to excellent observer agreement were reported (Attrill and Ashley, 2001; Lussi et al, 2001). Majority of works indicate that DIAGNOdent is clearly more sensitive than traditional methods;
nevertheless, the increased likelihood of false positive diagnoses limits its usefulness as a principle diagnostic tool (Bader et al, 2004). It is therefore recommended that the DIAGNOdent readings should serve as guidelines and a treatment choice should never be based on its value alone.

1.3.5.4.6 Diagnostic based on ultrasound measurements

Ultrasonic imaging can be used to detect early caries on smooth surfaces (Ng et al, 1988). Here an ultrasonic probe is used to send and receive sound waves from the tooth surfaces. Sound enamel produces no echoes while, initial white spot produce weak surface echoes and cavitated areas produce echoes of higher amplitude. This method is inappropriate to apply in patients and also could not detect shallow caries lesions.

1.3.5.4.7 Optical coherence tomography (OCT)

Optical coherence Tomography (OCT) that uses low coherence interferometry, has found broad applications in the cross sectional imaging of biological structures, including dental hard and soft tissue. Polarization sensitive (PS) OCT systems that utilize polarized incident light (1310 nm) and measure the polarization information from the backscattered signal in two separate channels, have been used for imaging of birefringent tissues.

Due to the rod-like organization of hydroxyapatite crystals, dental enamel is usually birefringent, and initial measurement of tooth enamel with PS-OCT emphasized characterization of the tissue birefringence. PS-OCT images resolved enamel demineralization through an increasing backscattered intensity and changes in the enamel birefringence. If the incident illuminating light is linearly polarized, the light scattered from the demineralized lesion area will rapidly depolarize. Since carious enamel depolarizes incident polarized light, PS-OCT images both the surface and subsurface enamel by recording changes in the magnitude of scattering and depolarization without interference from the strong surface reflection. Several studies have demonstrated that remineralization has a significant effect on the mineral volume on the outer perimeter of the lesion, near the enamel surface. This suggests that PS-OCT could be valuable in imaging the remineralization of caries lesions. Demineralization in the enamel was resolvable to a depth of 2-3 mm into the tooth. Moreover, OCT is not well suited for imaging entire tooth surfaces or interproximal surfaces in between teeth due to time restraints and the enormous quantity of data that would be collected.
1.3.6 Prevention of dental caries

1.3.6.1 Oral hygiene

Plaque control is essential in caries prevention because caries does not occur in the absence of plaque. Personal hygiene care consists of proper brushing and flossing daily. The purpose of oral hygiene is to minimize any etiologic agents of disease in the mouth. The primary focus of brushing and flossing is to remove and prevent the formation of plaque. As the amount of bacterial plaque increases, the tooth is more vulnerable to dental caries. A toothbrush can be used to remove plaque on most surfaces of the teeth except for areas between teeth. When used correctly, dental floss removes plaque from areas, which could otherwise develop proximal caries.

Professional hygiene care consists of regular dental examinations and cleanings. Sometimes, complete plaque removal is difficult, and a dentist or dental hygienist may be needed. Along with oral hygiene, radiographs may be taken at dental visits to detect possible dental caries development in high-risk areas of the mouth.

1.3.6.2 Dietary modification

Dietary modification is recommended to patients with active caries and those who are at high risk for caries development. For dental health, the frequency of sugar intake is more important than the amount of sugar consumed. In the presence of sugar and other carbohydrates, bacteria in the mouth produce acids, which can demineralize enamel, dentin, and cementum. The more frequently teeth are exposed to this environment; the more likely dental caries are to occur. Therefore, minimizing snacking is recommended, since snacking creates a continual supply of nutrition for acid-creating bacteria in the mouth. Also, chewy and sticky foods tend to adhere to teeth longer, and consequently are best eaten as part of a meal. Brushing the teeth after meals is recommended. Mothers are also recommended to avoid sharing utensils and cups with their infants to prevent transferring bacteria from the mother’s mouth. It has been found that milk and certain kinds of cheese can help counter tooth decay if eaten soon after the consumption of foods potentially harmful to teeth. Also, chewing gum containing xylitol (wood sugar) is widely used to protect teeth. Xylitol’s effect on reducing plaque is probably due to bacteria’s inability to utilize it like other sugars. Chewing and stimulation of flavour receptors on the tongue are also known to increase the production and release of saliva, which contains natural buffers to prevent the lowering of pH in the mouth to the point where enamel may become demineralized.
1.3.6.3 Other preventive measures

The use of dental sealants is a good means of prevention. Sealants are thin plastic-like coating applied to the chewing surfaces of the molars. This coating prevents the accumulation of plaque in the deep grooves and thus prevents the formation of pit and fissure caries, the most common form of dental caries. Sealants are usually applied on the teeth of children, shortly after the molars erupt. Older people may also benefit from the use of tooth sealants, but usually their dental history and likelihood of caries formation are taken into consideration.

Fluoride therapy is often recommended to protect against dental caries. It has been demonstrated that water fluoridation and fluoride supplements decrease the incidence of dental caries. Fluoride helps prevent decay of a tooth by binding to the hydroxyapatite crystals in enamel. The incorporated fluoride makes enamel more resistant to demineralization and, thus, resistant to decay. Topical fluoride is also recommended to protect the surface of the teeth. This may include a fluoride toothpaste or mouthwash. Many dentists include application of topical fluoride solutions as part of routine visits.

1.4 CONCLUSIONS

Caries diagnosis in its early stage is often difficult. Accurate diagnosis is required in order to apply appropriate preventive measures or operative procedures. Recently, several techniques have been introduced to aid dentists in accomplishing this task. Exploration of the potential of new techniques in the biomedical field is always challenging. Conventional diagnostic methods to detect demineralization or dental caries have limitations affecting either their diagnostic ability or feasibility in a clinical setting. Therefore, there is a need to develop diagnostic methods that can accurately screen dental caries at an earlier stage.

Currently, radiographic examination is widely used as a diagnostic test adjunct to visual-tactile techniques. In view of the possible hazardous effects of ionizing radiation and the shortcomings in its performance in detecting small lesions, a search for alternatives to radiography has resulted in a number of advanced methods for the detection of caries lesions. The development of new methods could increase the accuracy of detection and in particular generate the likelihood of early caries detection. In this context, if applied effectively, optical spectroscopy has enormous potential to represent the main forward step towards advances in diagnostic applications. For the development of such optimized optical systems, there is a need
to understand the structure of tooth and its interaction with light. The next chapter
throws light on different aspects of optical spectroscopy and basic concepts of
interaction of light with dental hard tissue.