IDENTIFICATION OF CARIOUS LESIONS IN ENAMEL USING OPTICAL COHERENCE TOMOGRAPHY

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ABSTRACT

The aim of this research was to asses wether OCT could be used for early detection of carious/ demineralised lesions in enamel. If application of Optical coherence tomography (OCT) could be used in early, chair-side detection of caries and therefore initiate the prompt treatment strategies required.

10 extracted teeth were selected with no visible carious lesion. All teeth were scanned using Xray Microtomography (XMT). Four teeth were found with areas of demineralisation which were not visible to the naked eye. The same lesions were then scanned using OCT. SAM software was used to analyse the depth of penetration. OCTview software was used for the OCT scans and ImageJ software was used to enhance the OCT images.

OCT was helpful in detecting carious lesions in enamel. Average depth of penetration in carious lesion: 10.49 +/-3.69 µm, sound enamel; 8.49 +/- 5.2 µm. Depth of light penetration was influenced by the degree of mineralisation. The two-tailed P value was less than 0.0001. By conventional criteria, this difference was considered to be extremely statistically significant.

Keywords: *Early caries detection, Optical Coherence Tomography (OCT), Enamel, XMT*

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INTRODUCTION

The fact that dental caries continue to be a health concern in spite of major advancements in the field of dentistry, calls for our attention as health care professionals.[1] Dental caries is a chronic microbial disease that results in localized damage of hard tooth structure.[2] The main etiologic agents are acid-producing bacteria, predominantly Streptococcus mutans (in caries initiation) and Lactobacilli species (in caries progression). Furthermore, due to the interaction of dietary, host and environmental factors that occurs over a period of time, dental caries is considered to be a multi-factorial disease.

Early detection of caries/demineralization is one of the most popular research fields.[3] Iatrogenic damages caused to the dental tissue by dentist are of great concerns.[4] The field of minimal invasive dentistry is gaining more popularity among the dentist and the patients.[5]

Optical Coherence Tomography (OCT) uses an optical heterodyne detection scheme which is based on the principle of Low Coherence Interferometry (LCI) to detect back reflected or back scattered light from the sample.[6] In general, from a sample a back reflected light combines with the reference arm's back scattered light at the fiber optic coupler before entering the photodiode detector.[7] When optical path of light from reference arms and sample are matched the interference of low coherent light occurs within the coherence length of optical source. As a result of this interference patterns which represents depth of back scattered intensity are registered as vertical spikes, while their heights are registered as intensity of reflected or back scattered light (Tommlins et.al. 2005).[8] These are the reflectivity profiles called "A-Scans". The combination of many one dimensional A-scans can combined to form two dimensional cross sectional images which are called "B-scans". They are formed by the lateral scanning optical beams across the sample. Similarly C-scans are produced by the transverse scanning of different depths of the sample.[9]

X-ray micro tomography which is also called Micro CT or commonly used XMT or µCT as an abbreviation is radiographic imaging technique which has the ability to produce Three Dimensional images at a resolution

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which is better than 1mm at a spatial resolution (Mizutani et.al.2012).[10] The preparation technique for the samples is minimal and for most of the materials this technique is non-destructive.[11] The benefit for this technique is that under different conditions many scans can be taken from same samples. For example, a tooth can be scanned under normal condition and then the effect of different material on the tooth surface can be monitored by taking another scan of the same tooth. Effect of mineralization and demineralization can be observed using this technique and the images produced are in extremely high resolution. The images produced can be seen in two dimensional high resolution or three dimensional ultrasonic imaging.[12]

Scattering Attenuation Microscopy (SAM) technique helps in detection of differentiating between several colors with human eye. False coloring can improve the contrast of the images but the over expression of signal intensity cannot define the true histopathological morphology. Microbubbles or Engineered microspheres are often used as exogenous contrast agents. A technique which is called spectroscopic OCT can be used; it has the ability the measure scattering of tissues or spectral absorption.[13]

Drishti is a multi-platform, open-source Volume Exploration and Presentation Tool. It is used for visualizing tomography data, electron-microscopy data and so forth. It aims to ease understanding of the data set and to assist with conveying that understanding to the research community or a lay person. The central idea about Drishti is that the scientists should be able to use it for exploring volumetric datasets as well as use it in presentations. It has been used number of purposes, such as volumetric visualisation of various computer tomography datasets.[14]

MATERIALS AND METHODS

The use of OCT as method for imaging tooth surface (Enamel) was investigated. `Drishti` software was used for 3-D observation of the scan. These scans were made using the software "OctView" and for enhancing different levels of mineralization we used ImageJ software.[15]

To detect carious lesion by X-Ray Microtomography 10 non carious extracted teeth were collected from the tooth bank that had been kept in a 20 % ethanol containing solution. Samples were cleaned, all the debris was removed by washing under normal water; and to remove the organic contaminants they were polished with pumice slurry. All samples were then placed in marked containers containing 20% ethanol in distilled water. A grain of thymol was added to keep the solution bacteria free.

Samples were placed in the XMT sample containing holders. Each sample was tightly packed in the cell/ sample holder to hold the sample firm when the stage is moving for the three-dimensional scans. All scans were done under standard resolution and the voltage was 70 kVp. XMT files produced were in "icq" file format which was converted to "Tomview" file using the 'icq2tom" software. Images were generated with Tom view and were observed for any pathologies or abnormalities. Samples were investigated in all three planes with Tomview.

The area of a sample was marked for any abnormality or pathology according to XMT results. The rest of the surface was covered with nail varnish to allow accurate scanning of that site by OCT exact scanning of the area with OCT. An exposed window was left for the working area. Then the samples were placed back again in the container with ethanol-based solution.

To detect same lesion with Optical Coherence Tomography

A stage was then created for the OCT scans for these samples. The OCT microscope is placed on a fixed table and the stage was firmly placed under the optical scope. A measuring gauge was fixed with the stage so that exact distance for the samples can be set under the optical scope for all the samples.

The direction and height from the base of the stage for tooth sample was noted for all scans. This step was taken to locate the sample at nearly exact position for rescanning after treating them with different solutions later in the project. The software that was used to scan the sample was "octView" (Fig1). The number of B-scans was set to 400, B-scan width was set to 250. Images were produced and analysed using ImageJ software (Fig2)

RESULTS

To detect and locate carious lesion by X-Ray Microtomography

The results of the scans revealed that out of six non carious teeth, two of the samples had areas of demineralization which were not visible from eye examination. In one of the sample a V-shaped lesion was found in enamel with its narrow side touching the dentine surface (fig 3). There was also a thin opaque line on the surface of the enamel which was continuous with the rest of the enamel surface. 3-D observation was confirmed using Drishti software around the area of lesion. In the second sample there was a linear shaped lesion on the distal side of the tooth which ended up with a deeper lesion on one side as marked in the figure # 23. On observation it was found that in sample a fracture line runs throughout the centre of the the enamel and dentin surface.

The Figure 5 and Figure 6 are representative image of an Optical Coherence Tomography two dimensional

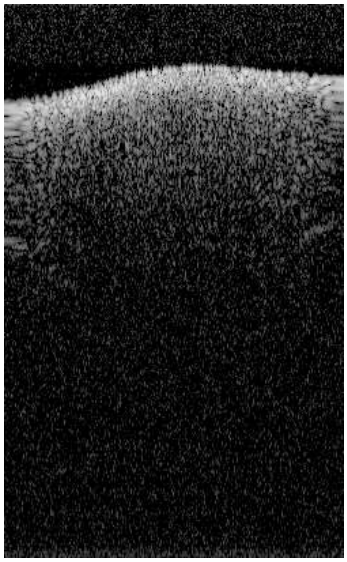

Fig 1: Mineralized Tooth obtained from ImageJ Software using OCT

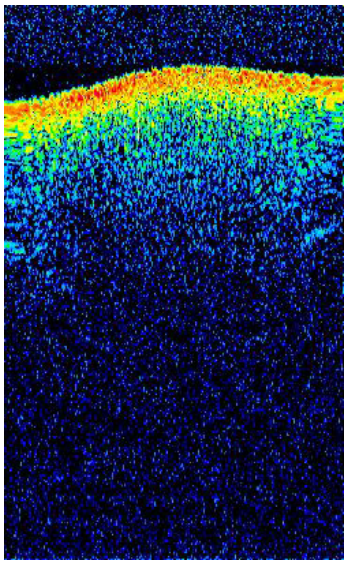

Fig 2: Same tooth enhanced with ImageJ software showing dense mineral zones

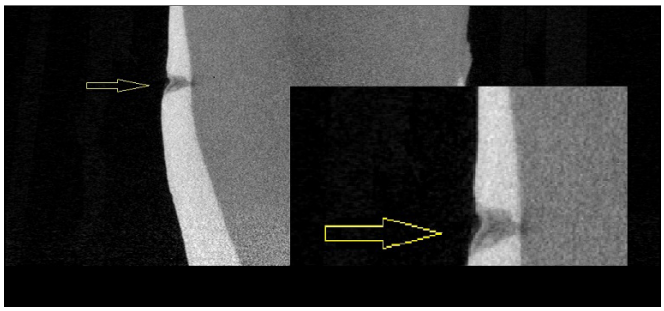

Fig 3: µCT showing a V-shaped lesion on the surface of enamel with its base touching the surface of the dentin.

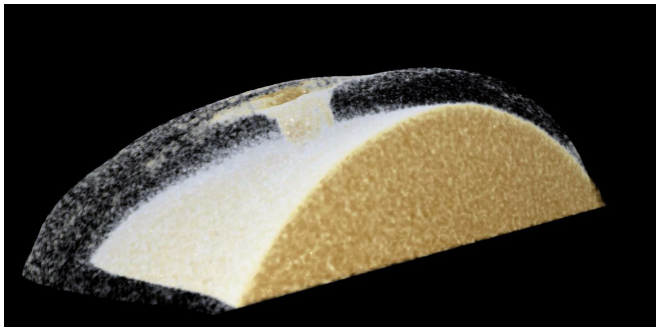

Fig 4: Remineralization around the lesion. Enamel removed using the software Drishti for 3-D observation.

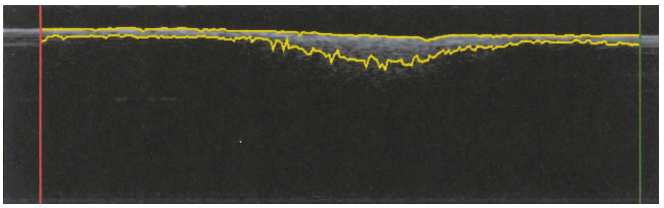

Fig 5: SAM software showing back scattering attenuation

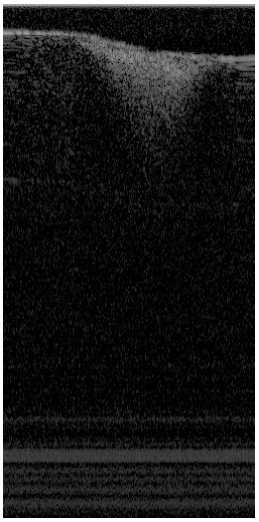

Fig 6: Oct image showing the V-shaped lesion

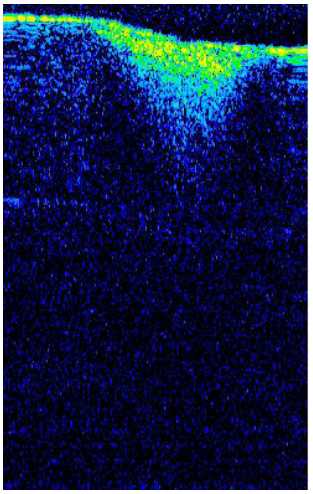

Fig 7: Image enhanced using with Image J showing mineral zones

(2-D) depth B-scan taken across the region of demineralization surrounded by sound enamel. There is significant subsurface light back scattering of light at the lesion site when compared to the back scattering of the surrounding enamel. Light has penetrated deep in the area of demineralization and is reflected back when it hits the sound enamel. The manual light-scale confirms the deeper penetration of light in the demineralized site.

When the average mean of penetration depth was noted and was compared with surrounding sound enamel depth of penetration, it was observed that the average depth of the light penetration at lesion site was 10.49+/-3.69 µm and the average depth of light penetration in the surrounding sound enamel was 8.49 +/- 5.2 µm. The two-tailed P value is less than 0.0001. By conventional criteria, this difference is considered to be extremely statistically significant.

DISCUSSION

Early detection of caries/demineralization is one of the most popular research fields. Iatrogenic damages caused to the dental tissue by dentist are of great concerns. The field of minimal invasive dentistry is gaining more popularity among the dentist and the patients.

The results of the XMT scans revealed areas of demineralization which were not visible with the eye. When these scans were compared with the results of OCT, it was found that OCT can detect changes in degree of mineralization of tooth. In the figure 3, it is observed that there is thin opaque line on the surface of caries which could suggest that there is possible remineralization occurring on the surface. When lesion was compared with the image created with ImageJ. Around the lesions there is a dark zone surrounding it, when image was observed with Drishti software using 3-D technology, it was found that there is remineralizing around the lesion site, only explanation of the dark zone was that area of remineralization was giving a different back and light was not able to pass below it.

OCT can be used under conditions similar to oral cavity for the determination of changes in the enamel surface. In one of the studies early erosion on bovine enamel was recently done.[16] Samples can be immersed in different demineralization solutions with different pH and real time observation of process of demineralization can be seen. A portable optical probe can be designed for the dental clinical use, for easy scanning inside the oral cavity.

CONCLUSION

OCT can detect carious lesions that are invisible to the eye, assess mineral density of enamel. Development of the technique to allow chairs-side diagnosis will permit early intervention to maintain oral and preserve whole body health.

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