Optical Method for the Detection of Dental Caries in Oral Cavity

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Abstract- Optical imaging in medical field is crucial for early detection of oral diseases, to carry out more effective minimally-invasive targeted-therapies and to restore diseased tissues functionally and aesthetically. Optical methods can be based on the properties of light scattering, absorption and fluorescence. In doing so, LEDs and classical light sources can be used. All of these methods have one basic principle in common; the optical spectrum of a tissue contains information about the biochemical composition and/or the structure of the tissue, which provide diagnostic information for tissue characterization. Among them, the most promising techniques to detect and classify different stages of caries are those based on the quantitative measurements of tooth auto fluorescence and diffuse reflectance. These techniques are non-destructive and allow detection of structural and elemental changes on the surface and inside of tissue. When tooth is irradiated with UV or blue light, several fluorophores in tissue produce a broad fluorescence distribution in the visible wavelength region. This fluorescence is referred to as the auto fluorescence, or endogenous fluorescence. Optical proprieties of caries affected tooth are different from sound tissue. Spectral imaging based on this concept may be advancement for the diagnosis of diseases.

Index Terms- LIF, NADH,DR, Dental caries, MATLAB

I. INTRODUCTION

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 varies with age, sex, socio economic status, race, geographical location, food habits and oral hygiene practices. 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.

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. By keeping this idea in mind diagnostic techniques based on optical imaging allow non-invasive and real-time characterization 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 light-induced fluorescence (LIF) and diffuse reflectance (DR) is enormous and yet, is not fully explored for early detection of dental caries invivo. The hypothesis of present work is that these optical techniques will help to discriminate different stages of caries with good sensitivity and specificity. This work mainly aims at testing the applicability of LIF and DR imaging techniques for detecting caries in its early stage.

II. FLUORESCENCE IMAGING

A. Concepts

Fluorescence imaging is a type of electromagnetic imaging which analyzes fluorescence from a sample. It involves using a beam of light, usually ultraviolet light, that excites the electrons in molecules of certain compounds and causes them to emit light; typically, but not necessarily, visible light.Tissue autofluorescence [2] originates from native tissues. Under UV and blue light irradiation, all biological tissues emit fluorescence from various endogenous fluorophores in tissue with a broad distribution in the visible wavelength region [5]. Diagnostic techniques based on fluorescence imaging have the potential to link the biochemical and morphologic properties of tissues to individual patient care. In particular, these techniques are fast, non-invasive and quantitative.

. Fluorophores that are speculated to play a major role of fluorescence in dental caries are the structural proteins like collagen, NADH and porphyrin[4] (bacteria content). Collagen forms the organic part of the dentin and any structural or pathologic association with caries processes, could be reflected in lower autofluorescence intensity. Porphyrinderivates i.e., porphyrins and metalloporphrins, are responsible for fluorescence emission from carious tooth in the red wavelength region. They typically have absorption maxima between 398 and 421nm and emission maxima between 530 and 633 nm. When excited with 407 nm[1] UV light, bacterial species such as Actinomycetsodontolytics, Bacteroidesintermedius,

Prevotellaintermedia,Corynebacterium species and Candida albicans emit fluorescence in between 620-635 nm.

B. Experiment Details

The major components used in the setup are power supply, LED driver circuit, LED module, lens, filter, USB Camera module and the display device.

LED module means the arrangement of four 405 nm LEDs(**HPLighting Corp.,** part# HPL-H44LU1C0, 120^0, 700mA) about 90° to each other around the camera. By arranging the LEDs in the same plane of detector it is easier to get uniform illumination at the tooth surface with the help of an LED driver circuit.

Long-pass filter (Passband = 490-850nm, 10mm in diameter) is fixed on the USB camera (5 MP USB2.0, FOV= 67°) provides necessary filtering to acquire fluorescence signals. The fluorescing images of the tooth are highly resolved and can cover an area of 12X12 mm with a field of view of 23.07°. The image acquisition interface and the pseudo coloring of the imagehave performed by using IMAQ & image processing tool boxes of MATLAB. Figure 1 explains the basic setup used for the fluorescence imaging of tooth caries.

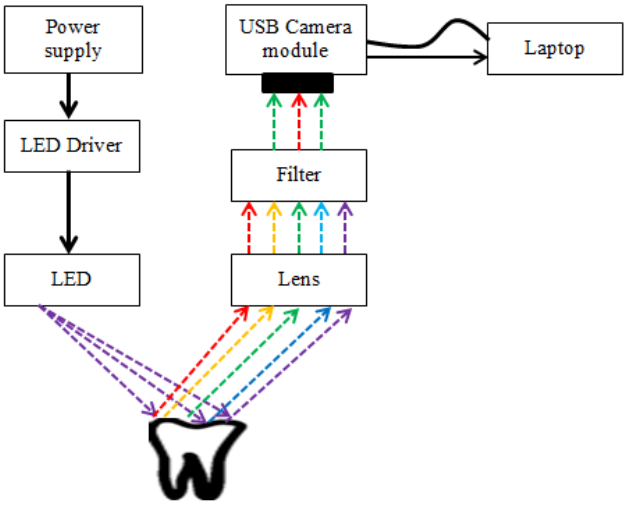

Figure 1. Setup for fluorescence imaging of tooth caries

C. Results and Discussion

The fluorescence images of tooth obtained in vivo are shown in the fig 2. The important section in this analysis is pseudo coloring or false coloring. False color refers to a group of color rendering methods used to display images in color which were recorded in the visual or non-visual parts of the electromagnetic spectrum. A false-colorimage is an image that depicts an object in colors that differ from those a photograph (a true-color image) would show.This colored image, when displayed, can make the identification of certain features easier for the observer.

Depending on the table or function used and the choice of data sources, pseudo coloring may increase the information contents of the original image. Here it is done by assigning pseudo color to the intensity of red channel and reallocating the pixel value in the image. The color coded image is shown in fig 2.

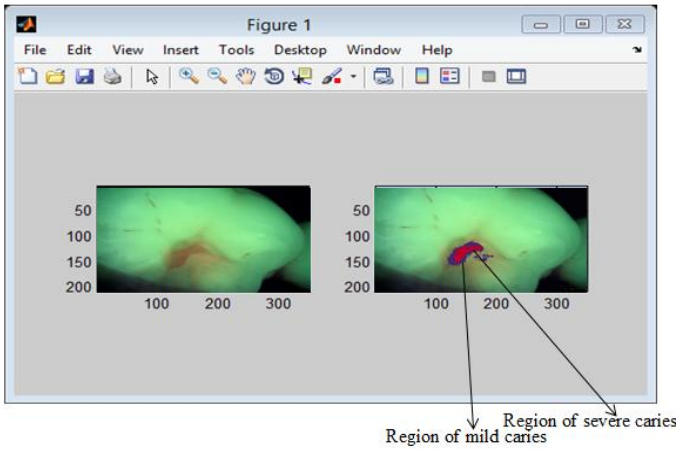

Figure 2. Fluorescence imaging of tooth with caries

Magenta: Region of severe caries
Blue: Region of mild caries
GREEN: Normal region of tooth.
Black: Noisy surrounding region

III. SPECTRAL IMAGING

A. Concepts

Spectral imaging which utilizing the use of diffuse reflectance extends the capabilities of biological and clinical studies to simultaneously study multiple features such as organelles and proteins qualitatively and quantitatively. Spectral imaging combines two well-known scientific methodologies, namely spectroscopy and imaging [1], to provide a new advantageous tool. The combination of these two is, however, not trivial, mainly because it requires creating a three-dimensional (3D) data set that contains many images of the same object, where each one of them is measured at a different wavelength. Here in this spectral imaging, it has been decided to use two different wavelengths and thereby two different images. The need to measure the spectrum at each point of the image requires combining dispersive optics with the more common imaging equipment, and introduces constrains as well.

The DR intensity of caries tooth is markedly lower than that of sound tooth. The DR spectrum shows a broad reflectance dip between 520, 540 and 580 nm, which might be due to hemoglobin absorption. The normalized spectrum shows a reduction in relative intensity with caries formation in the spectral window below 600 nm [6] whereas the trend reverses beyond 625 nm.

So that for DR imaging, we can consider any two regions of interest such as one relating to absorption and the other to point of maximum intensity i e, no absorption. Here the two LEDs that can use as the wavelength of interest are 520 nm and 625 nm. Under normal conditions, it may provide the image of usual teeth. But under caries affected situations, an additional reduction of intensity can be seen on the tooth surface.

B. Experiment Details

The major parts that have remarkable identities in spectral imaging section are oral camera (Hand piece) with its unique

structure, LEDs with its switching section and processing software (MATLAB).
The hand piece resembles an oversized pen is mainly designed to work as an oral camera. The main advantage of using oral camera is that it is a small camera that takes an X-ray of the outside of gum or tooth. Figure 3 represent the basic setup has been used for spectral imaging of tooth caries.

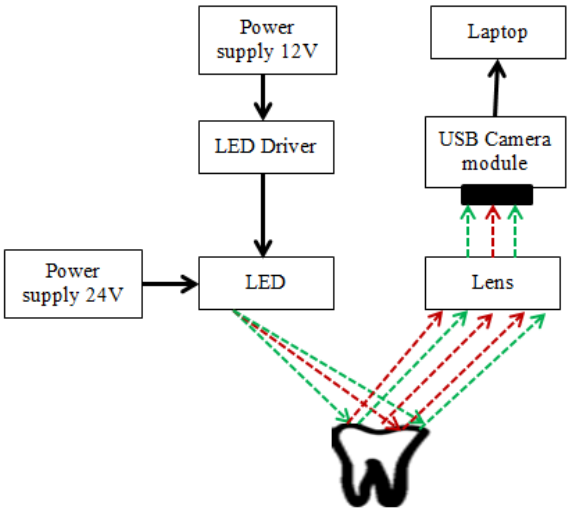

Figure 3. The basic setup for spectral imaging of tooth

The two LEDs arranged alternatively in the same plane for the illumination purposes are of 520nm (VLMTG1300−GS08, Viewing angle: 130°) and 625 nm (SML-D12U8W, Viewing angle: 160°). Both of them have very ultra-small foot print of 1.6 mm x 0.8 mm x 0.8 mm (L x W x H).
This can be accomplished by the spectral imaging process. Driving section and a switching section in the LED switching setup illuminates the two different sets of LEDs sequentially with fixed delay duration in between them. So that it can provide two different images within this particular fixed delay.Dividing the two images of different wavelengths (520 nm & 625 nm), one ratio image (625/520) can be obtained. It may carry the information about any abnormality in the tooth structure.

C. *Results and Discussion*

Image acquisition and processing of the image is done by using MATLAB. Figure 4 represents the images obtained by illuminating the tooth surface with red (625nm) and green (520 nm) visible light.

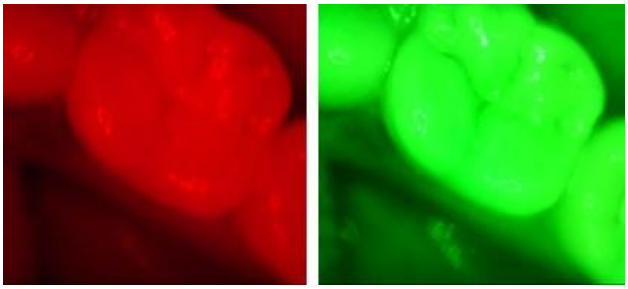

Figure 4. Images obtained by illuminating the teeth with red and green LEDs

Color mapping has done to make the acquired image more interactive and informative and it is done by converting the ratio image into gray scale and then assigns the pseudocolours by analyzing the intensity levels of entire pixels sequentially. So that it is easier to understand the image ie, the pixels with red color is the indication of high ratio intensity (Development of caries) and the pale blue colored pixels is the indication of low ratio intensity (Normal region).

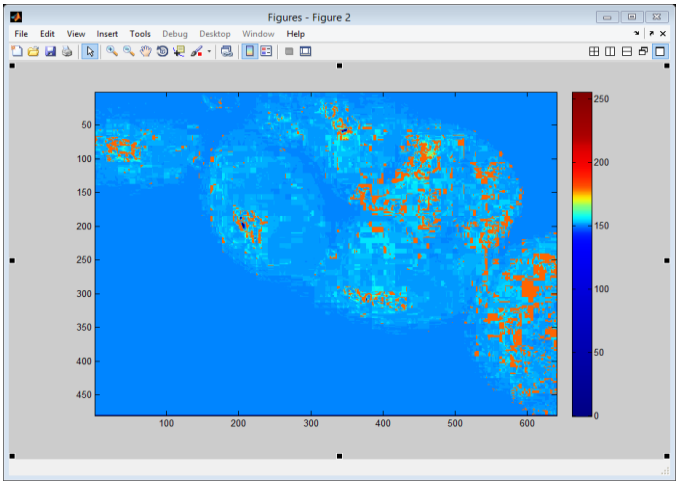

Figure 5. Pseudo colored image of the teeth

The pseudo color images has shown in the figure 5 is obtained must be standardized by performing sufficient number of patient trials and the results must be correlated with X-ray diagnostic procedures. With valid data, pseudo color map can be performed to distinguish the depth of demineralization. It means the depth of disease could be mapped with different color ranges.

IV. CONCLUSION

Many products are found to be safe and effective in bench testing, *in vitro* testing or animal studies, but fail to demonstrate the same effect in humans. These investigational products must be proven safe and effective in a clinical study in humans before use in the general population. So thatClinical trials are fundamental to the development of innovative, investigational products. The applicability of these two methods can be proven only after detailed patient trials.

This setup can be developed as a compact system by combining both fluorescence and Spectral imaging (diffused reflectance imaging) modalities. For this we can align the illumination sources of each modality in interchangeable heads. Hence the multimodal diagnostic approach can effectively monitor the caries lesions noninvasively. New designs can be launched include options of wired and wireless connectivity for convenience of the medical practitioners. This will be ushering for more dental practitioners to use this technology.

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