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Research Paper

Photoluminescence spectra of sound tooth and those of different carious stages

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ABSTRACT

In this study, nitrogen laser (N_2) was used to induce emission in human teeth to distinguish between dental caries and sound teeth. Three samples of dental caries and one sample of sound teeth was used to obtain fluorescence spectra illuminated with wavelengths of 337.8 nm, pulse energy 0.04 mJ and pulse time 100 ms. The absorbance of dental caries and sound teeth was determined using UV-Vis spectrophotometer. The result showed an emission of broad band that ranged from 363 to 627 nm, respectively. A significant decrease of the fluorescence signal intensity related to the carious stage in dental caries was observed, while it was higher in the sound tooth spectrum.

Key words: Dental caries, diagnostic, fluorescence, laser-matter interactions.

INTRODUCTION

Laser-induced fluorescence (LIF) is the optical emission from molecules excited to higher energy levels by absorption of photons. One of the most frequently used applications of LIF is measuring a biological preparation with a dye. A fluorescing dye which binds to specific structures inside a cell is chosen so that when the preparation is lit by a laser, an image of the structures can be made. Sometimes not even a dye is needed but already part of an organism, for example, photosynthesis (Kaminski, 2005).

Dental caries is a disease in which enamel and dentin are gradually eroded, due to the elimination of minerals by acid excreted from bacteria in tooth surface plaque. Dental caries is a chronic disease that occurs frequently. It is a disease that leads to the destruction of the tooth structure and eventually to infection of the dental pulp and even surrounding tissues. Factors contributing to the progression of the disease include diet (mainly fermentable carbohydrates), microbes, and the host (amount and constituents of the saliva and habits). The progression of dental caries lesions requires time. Fluoride protects the teeth from dental caries by influencing the tooth structure (Hernández-Monjarazz et al., 2018).

Dental caries is usually performed using a tool called explorer that catches as it moves across a tooth with a cavity. This method of detection has many limitations, including the instrumentation.

Tam and McComb (2001) reviewed the current knowledge concerning conventional and new diagnostic methods for occlusal caries. These methods have several limitations, particularly in their ability to diagnose early carious lesions. Part II examines new and emerging technologies that are being developed for the diagnosis of occlusal decay. Electrical conductance measurements and quantitative laser- or light-induced fluorescence represent significant improvements over conventional diagnostic methods, especially for *in vitro* applications and particularly with regard to sensitivity and reproducibility (Tam and McComb, 2001).

Costa et al. (2008) evaluated the use of a laser fluorescence device for detection of occlusal caries in permanent and found that the laser detection method produced high values of sensitivity (0.93) and specificity (0.75) and a moderate positive predictive value (0.63). The laser device showed the lowest value of likelihood ratio (3.68). Kappa coefficient showed good repeatability for all methods. Although the laser device had an acceptable performance, this equipment should be used as an adjunct method to visual inspection to avoid false positive results.

Anttonen (2007) used Laser fluorescence in detecting and monitoring the progression of occlusal dental caries lesions and for screening persons with unfavourable dieter habits. This study focused on the clinical use of laser fluorescence compared to visual inspection (VI) for

Figure 1: Dental caries.

detecting and monitoring the progress of caries lesions during a one-year follow-up period and for screening subjects with unfavorable dietary habits causing demineralization of teeth.

Yang and Dutra (2005) made attempt to emphasize the efficiency of laser-fluorescence (LF) and Fibre Optic Trans-Illumination (FOTI) as complementary methods for diagnosing the early caries lesion. It also demonstrated the interactive and didactic role of the Diagno dent pen.

Amaechi (2009) described the various technologies available to aid the dental practitioners in detecting dental caries at the earliest stage of its formation, assessing the activities of the detected carious lesion and quantitatively or qualitatively monitoring of the lesion over time. The need and the importance of these technologies were also discussed. The data discussed are primarily based on published scientific studies and reviews from case reports, clinical trials, and *in vitro* and *in vivo* studies.

Booshehry et al. (2011) evaluated different caries diagnostic methods, Clinical Visual Inspection, Fiber Optic Trans-illumination, Caries Indicter Dyes and Fluorescent Methods.

Shakibaie et al. (2011) proposed the principle of the fluorescent phenomenon and thereafter explored the scientific background of fluorescent studies on the dental tissue. The laser-induced fluorescence can be used to detect and diagnose dental caries, calculus and bacterial biofilms in dental applications. Laser fluorescence was used to detect residual pulp tissue within the root canal, using a 308 nm wavelength ultraviolet laser, while Shakibaie et al. (2011) used 366, 405, and 440 nm wavelengths to distinguish the remaining pulp tissue and bacteria from normal hard tissue in root canals, respectively. Most work using fluorescence in dentistry employed visible light as the excitation source (Shakibaie et al., 2011).

Hsieh et al. (2013) described the applications of dental optical coherence tomography (OCT) in oral tissue images, caries, periodontal disease and oral cancer. The background of OCT, including basic theory, system set-up, light sources, spatial resolution and system provided. The comparisons between OCT and other clinical oral diagnostic methods are also discussed I the report of Hsieh et al. (2013).

In this work, laser-induced emission was used to determine the absorbance of dental caries and to distinguish between emission from dental caries and sound tooth.

MATERIALS AND METHODS

Samples

Dental caries and sound tooth were studied in this work. Immediately after extraction, the teeth were fixed in formalin, rinsed in distilled water and sampled independently by specialist-dentist. The conditions of the dental caries were in different tooth disorders, namely, superficial cavity, medium depth cavity and deep cavitation, while the control was the sound tooth (Figures 1 and 2).

No formalin spectrum signals from the samples were

Figure 2: Sound teeth.

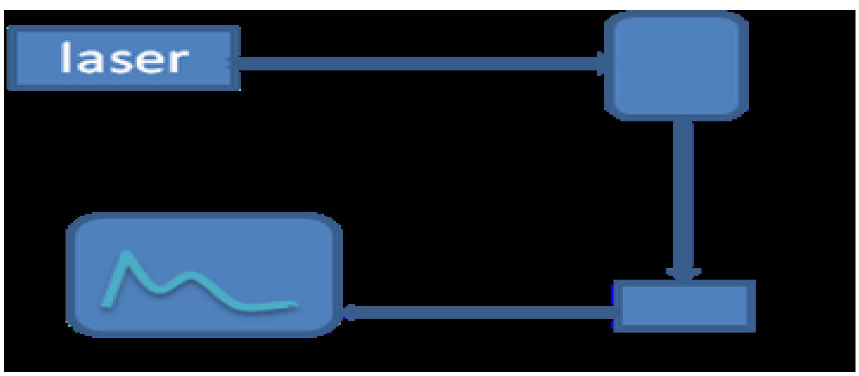

Figure 3: PL system.

recorded. The samples were kept in a proper environment. Each tooth from the samples were investigated using laser-induced fluorescence spectroscopy.

Detection system

The spectra were detected with a USB 2000+UV-VIS (PC2000, "Ocean Optics", Inc., Dunedin, FL, USA). A computer was utilized to control the system and to store and show data. The spectra were stored by the spectrometer specialized program (OOI Base, "Ocean Optics", Inc. Dunedin, FL, USA) and analyzed and graphically represented with another computer program (Origin 5.0, Microcal Software, Inc., Northampton, MA, USA) as shwon in Figure 3.

Photoluminescence (PL) system

Nitrogen laser was used as an excitation source to obtain the fluorescence spectra (337.8 nm, 14 J, 10-Hz repetition

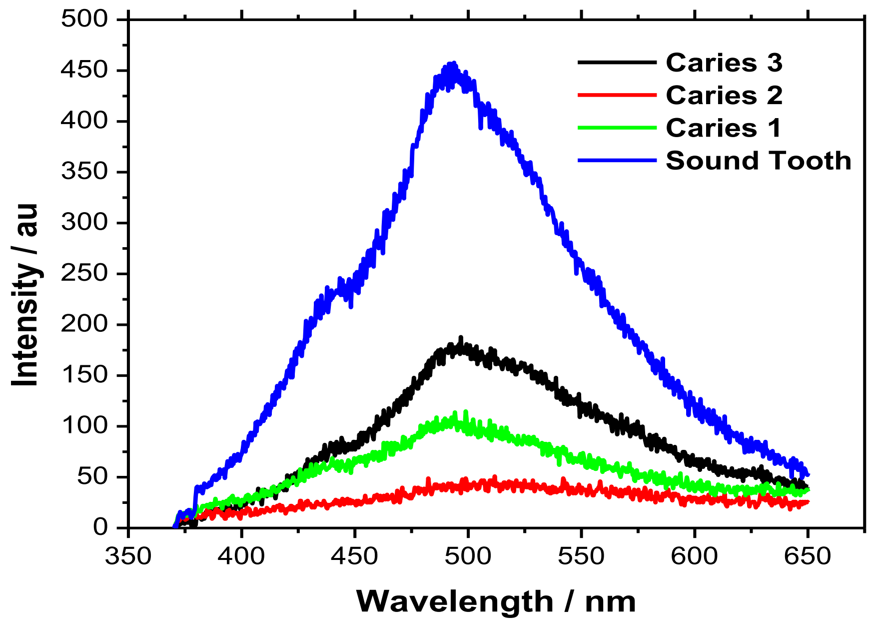

Figure 4: Spectra of dental caries and sound tooth (Excitation at 337.8 nm).

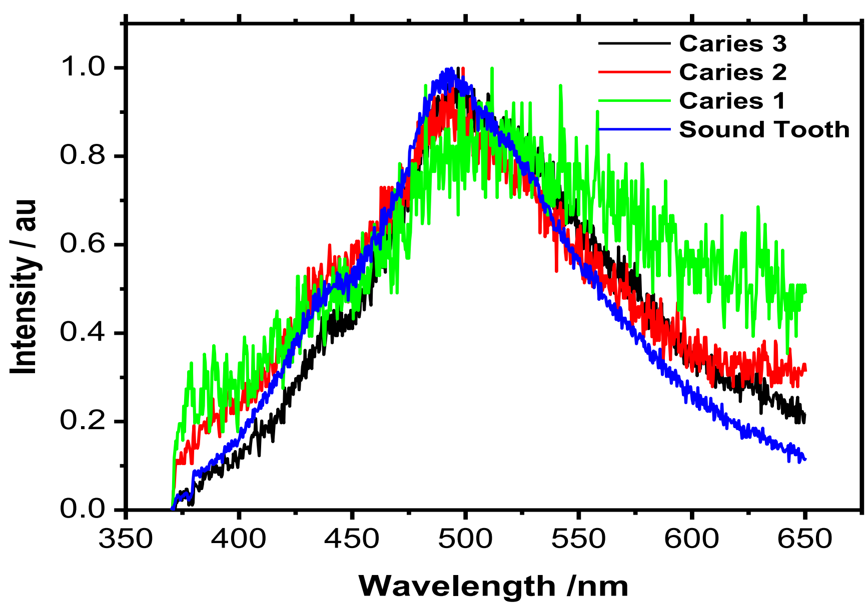

Figure 5: Comparison between spectra of a sound tooth and of different carious stages.

rate). Four fluorescence spectra were detected, three from the dental caries from an intact area of the tooth and one from the sound tooth. The spectrum of the sound tooth surface was used as a reference of the spectral changes in the dental caries. Schematically Figure 3 shows the Photoluminescence experimental set-up.

Photoluminescence (PL) properties were determined using nitrogen (N_2) laser with a wavelength of 337.8 nm, power 0.04 mW, and repetition rate 100 ms as shown in Figure 3.

RESULTS AND DISCUSSION

Figure 4 shows the fluorescence spectra for the dental caries affected by different stages of caries, namely, superficial cavity, medium-depth cavity and deep cavitation, using nitrogen laser as an excitation source. Normalization was done to compare the spectral shape changes in Figure 5; the spectra were normalized with respect to the maximum intensity peak. The sound tooth spectrum consisted of a broadband (485 to 495 nm maximum) of fluorescence with one secondary maximum at 440 nm, while that of the carious tooth exhibited the same maxima at 490 and 440 nm, respectively.

This intensity peak decreased further for all carious areas depending on the stage, with deep cavitation displaying the weakest fluorescence. The secondary peak of the carious areas at 440 nm also reduced for all carious areas depending on the carious stage. No direct relationship was observed between the changes of the fluorescence spectra shape and the caries condition.

In this experimental study, significant differences were observed between the fluorescence spectra of sound tooth and those of different carious stages. These differences can be attributed to differences in fluorophore content, but absorption and scattering of excitation and fluorescent light by the carious substance must also be taken into account.

The ability of laser-induced fluorescence spectroscopy was assessed to distinguish between initial caries and sound tooth and to classify the different stages of caries. The present study demonstrated the potential of the LIF technique to distinguish sound tooth from initial caries.

Conclusions

PE (photoemission) spectra of dental caries and the sound tooth was obtained and investigated with all samples producing abroad band in the visible region. The obtained results indicate different PE spectra from all samples. Comparing the PL spectra from the sound tooth with dental caries, it was observed that the intensity decreased in the caries tooth which indicates that the intensity depends on the amount of decay.

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