Viability of imaging structures inside human dentin using dental transillumination

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ABSTRACT

Dental Transillumination (DT) is a technique for imaging internal structures of teeth by detecting infrared radiation transmitted throughout the specimens. It was successfully used to detect caries even considering dental enamel and dentin scatter infrared radiation strongly. Literature reports enamel's scattering coefficient is 10 to 30 times lower than dentin; this explain why DT is useful for imaging pathologies in dental enamel, but does not disable its using for imaging dental structures or pathologies inside the dentin. There was no conclusive data in the literature about the limitations of using DT to access biomedical information of dentin.

The goal in this study was to present an application of DT to imaging internal structures of dentin. Slices of tooth were confectioned varying the thickness of groups from 0.5 mm up to 2,5 mm. For imaging a FPA InGaAs camera Xeva 1.7-320 (900-1700 nm; Xenics, Inc., Belgium) and a 3W lamp-based broadband light source (Ocean Optics, Inc., USA) was used; bandpass optical filters at 1000±10 nm, 1100±10 nm, 1200±10 nm and 1300±50 nm spectral region were also applied to spectral selection. Images were captured for different camera exposure times and finally a computational processing was applied. The best results revealed the viability to imaging dentin tissue with thickness up to 2,5 mm without a filter (900-1700nm spectral range). After these results a pilot experiment of using DT to detect the pulp chamber of an incisive human tooth was made. New data showed the viability to imaging the pulp chamber of specimen.

Keyword list: Dental transilumination, spectral imaging, dental pulp chamber.

1. INTRODUCTION

In dental clinic routine one of the major relevance information that concerns the health of a dental element is the vitality of its pulp tissue. The dental pulp is the innermost tissue of the dental anatomy, involved by dentin and enamel and the outermost (coronary part) by the cement (root part). It consists of loose connective tissue, rich in nerve fibers and blood vessels. Among the types of cells present in the pulp odontoblasts, fibroblasts, mesenchymal cells and other lymphocytes are found by its composition. The pulp is considered a soft tissue which ensures the formation of dentin (dentinogenesis) throughout lifetime. Nutritional and sensory activities are some of pulps additional functions. Once the pulp of the tooth is diagnosed as non-vital, (which can be a consequence of infections, traumas or pathologies) clinical endodontic procedure suggests complete removal of degraded tissue as treatment , disinfection of dental remaining structures, and final dental repair in order to isolate the soft tissue from external[1-6] pathogens.

The clinical protocol to verify pulp vitality propound the sensitivity analysis and blood flow of pulp through well-defined clinical trials, which are associated with the history of local pain to determine pulp health. While the sensitivity informs

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the pulp´s ability to conduct nervous stimulation, blood flow (which is the main source of nutrition and oxygenation of fibroblasts) ensures its functional activity[1].The main techniques used to measure the pulp blood flow is Pulse Oximetry (PO) and Laser Doppler flowmetry (LDF).The LDF measures the velocity of the particles contained in the blood vessels through the scattering of red or infrared radiation and, thereby, indirectly indicates the existence of a blood flow in the pulp [2,3].The PO is a traditional technique which shows the percentage amount of saturated oxygen in the blood by measuring absorption of red and / or infrared radiation by hemoglobin (Hb) and oxyhemoglobin (HbO 2)[4-6]. Both techniques have dependence on the thickness of the enamel and dentin, besides that the presence of pigments, or crown restorations and the positioning of the probe on the tooth may increase the rate of false diagnoses[1-6].

In case of sensitivity, the most common tests to access the pulp nerve activity are the temperature and the electrical conduction trials. In temperature clinical testing the sample is submitted to thermal variations, sensitizing the tooth with high and low temperatures, inducing nervous stimulation to the patient. The sensitivity reported by the patient informs the clinician the type of nerve fiber that is active and provides the confirmation about the nerve activity[1-2]. In the electrical conducting tests the dental element is exposed to electrical stimulation induced by a probe and again the patient's response to the stimulus reflects the tooth nerve activity, since the electric stimulus aims to activate intact nerve fibers in the pulp[1-6]. In both cases the efficiency of the test result is compromised by the patient's subjective interpretation to the induced stimulation. Previous studies report significant increase of false diagnoses when young or anxious patients are tested and anticipate the sensitivity of nerve stimulation even without it having been induced, or when metallic materials in contact with the inner tissues (such as restorations and root pins) conduct the electrical stimulation to nerve fibers, or when traumatized teeth have some nerve rupture caused by injury, but blood flow remains intact. The false diagnose also can occur when the patient has a psychological disorder or is under alcohol effect, which modifies its limit of sensitivity to nerve stimulation[1-3, 6]. Some other limitations of susceptibility testing are the effect of drugs, age influence the reproducibility of the tests and the effect of tooth development[1].

Gopikrishna, Pradeep and Venkateshbabu[1] believe that a test of nerve action with objective response would minimize the amount of false diagnoses of pulp health; Ingle and Beveridge[7] believe that susceptibility testing can be considered objective, but other authors disagree with this opinion due to the subjectivity of the interpretation of the patient to feel the stimulus-induced[1-6, 8-9].According to that point of view, the sensitivity tests are easily applied in day-by-day clinical trials, but are not objective, while the blood flow tests are objective, but its instrumentation is not sufficient to the effective clinical use .

A modern technique for visualization of the internal structures of the dental elements is by near-infrared transillumination and dental transillumination (DT). In this technique, a source of near-infrared radiation (900nm-1700nm) radiates a dental element and the portion of radiation which is transmitted through the internal tissue is detected by a camera sensor composed of InGaAs which acquires the transillumination images[10-13].In this region of the spectrum there is a low scattering and low absorption of radiation by the dental tissue and the amount of radiation transmitted through the tooth is significant.The image formed also has a significant contrast. It is noteworthy that radiation with wavelengths around 1300 nm are less absorbed by enamel and are also poorly absorbed by water, which composes a relevant part of dental pulp [10-11, 14]. TD has been successfully used in observation of initial caries in extracted human teeth in vitro studies, acquiring images of the occlusal region of molars and incisors external faces (labial face). In these tests measurable and normalized contrast shows values between 0.2 and 0.6, according to the thickness of the element[11,13].

2. OBJECTIVE AND METHODS

2.1 Objective

This work aims to present the preliminary results of the DT initial experiments performed in different thickness of samples and in integer teeth.

2.2 Instruments and sampling

The experiment was divided in two different sets of assays, one to verify the DT effects in sliced samples and other to evaluate the results in integer teeth.

Samples were sliced lengthwise, considering parallel cuts to the mesial face of the tooth (with the IsoMet® 1000, Buehler, USA) and then passed through a sander (Aropol 2V,Arotec, Brasil, sandpaper with 180 mm) to adjust their depth. This procedure defined 5 groups of samples with thickness of 0.5, 1.0, 1.5, 2.0 e 2.5 mm.

The specimens were exposed to near-infrared (NIR) radiation (light source NIR HL-2000, Ocean Optics, USA) using optical filters to define the wavelengths bands of 1000 ± 10 nm, 1100 ± 10 nm, 1200 ± 10 nm, 1300 ± 50 nm and later, by removing the filter, were exposed to full NIR spectrum, as shown in the figure 1.

Figure 1 - Experimental arrangement: A) NIR source, B) Samples, C) Optical filters and D) FPA Camera.

For this first set of the experiment, the acquired images passed through computational processing, using the software Matlab (Matlab®, Mathworks, USA), in order to verify the intensity of transiluminated photons that reached the detector and to apply a colormapping processing on the DT image, thereby distinguish the different anatomies of the tooth.
The images were captured using a focal plane array (FPA) camera with InGaAs detector (XEVA 1.7 – 320 NIR, Xenics NV, Bélgica) using exposure times set in 1 ms, 5 ms and 20 ms for each sample for each band selection. This assembly marked the first set of the experiment.

For the second stage, samples of integer teeth were exposed to NIR in full spectra, and later were processed in the sander to compare the structures verified in the transillumination images with the anatomical structures photographed by a common camera.

3. RESULTS AND DISCUSSION

3.1 Sliced samples

When separated by filter bands, the images obtained were not sufficient to identify the different anatomical structures of the teeth, not providing sufficient contrast between the different structures.

Only when applied the whole NIR spectrum, the images were capable of define the tooth anatomical structures.

For the sliced teeth, the best images were obtained using 5ms exposition, as showed in figure 2.

As expected and verified in the figure 1 the thinner samples allowed the highest rate of transmitted NIR but by using the 5ms exposition was possible to define properly the anatomical structures of even the thicker samples with 2,5 mm.

Also according to the figure 2 the 1ms camera exposure time was not enough to show the samples internal structures, and the photons were captured with less efficiency then the ones submitted to 5 ms exposure in deeper thickness.

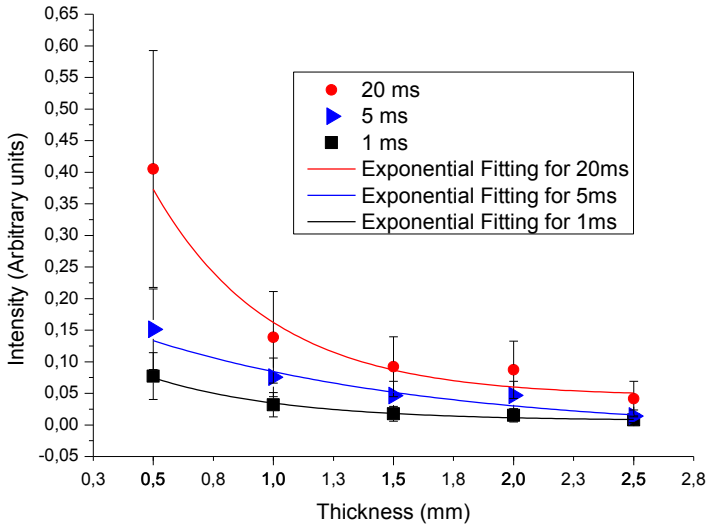

Figure 2 - NIR intensity due to the camera exposition

Figure 3 shows the possibility of distinguishing the different anatomical parts of the specimen by the differences of contrast observed on the image: in the arrow pointed as "1" is possible to verify the enamel structure, "2" shows the part composed by dentin and in the center of the piece, pointed by the 3rd arrow, is possible to identify the pulp chamber of the tooth, as it was circled by the thin green line.

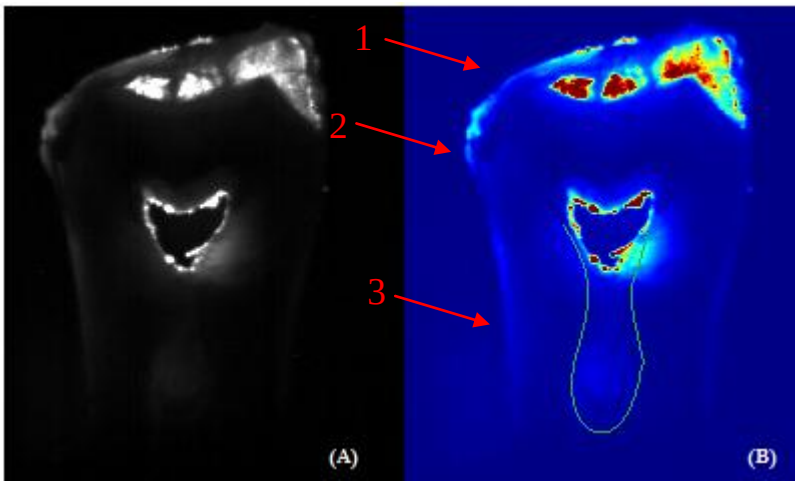

Figure 3 - Image obtained with 5 ms exposure and 2,5 mm thickness. A) original image B) processed image, with internal structures detached by green line; 1: Enamel; 2: Dentin; 3: Pulp.

3.2 Integer samples

The best integer teeth images were obtained for 20 ms exposure as shown in the figures 4 and 5:

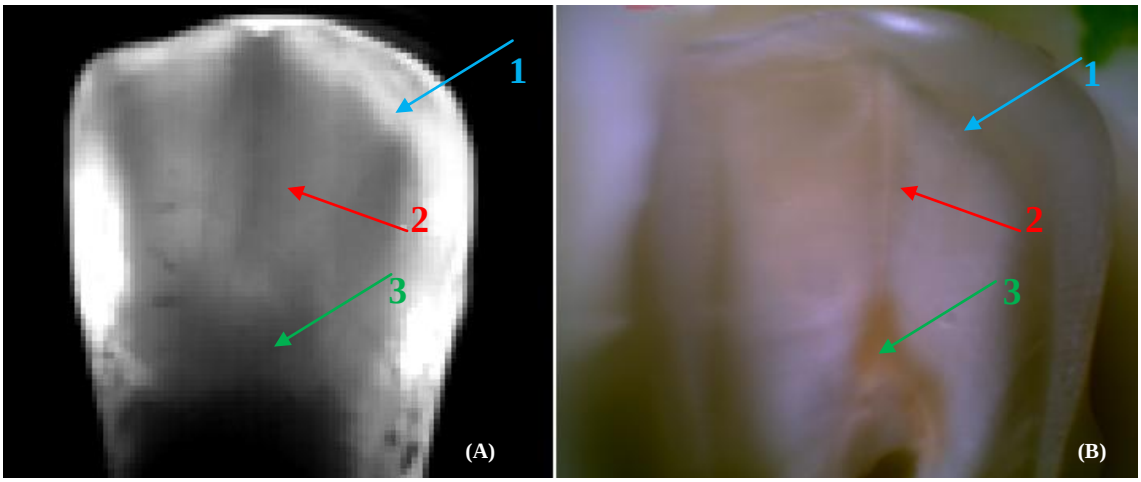

Figure 4 - Internal structures comparison of an incisive tooth. On the left (image A) is seen the DT image and on the right (image B) the common camera photo of the sliced tooth.

Analyzing the incisive tooth shown in the figure 4, on the "1" arrow is possible to verify the interface between enamel and dentin, on the "2" arrow is shown an characteristic tooth internal design, which helps to confirm the identity of the sample, and in the "3" arrow is possible to verify a region with less photons scattering, distinct as a darker region, identified by comparison as the pulp of the tooth.

Sample in figure 5 showed the same results obtained in figure 4.

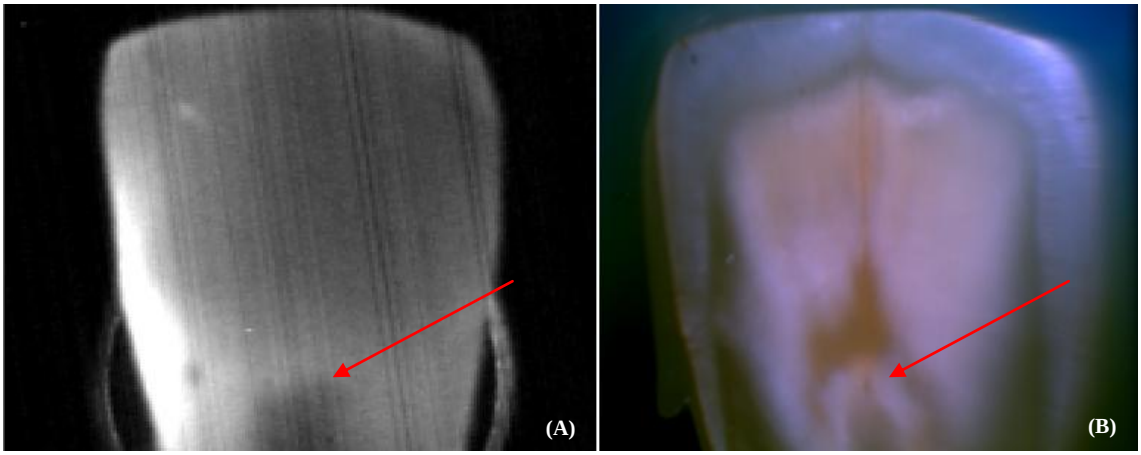

Figure 5 – Imaging of another incisive tooth where is possible to verify an pulp chamber.

Figure 5A highlights the darker area in the bottom center region of the sample and in the sliced tooth shown in the figure 5B this same region is anatomically characterized as the pulp chamber.

The methods employed to analyze the DT technique were very simple in this first experiment, only displaying the main hypothesis for a feasible detection system.

Other techniques would have to be applied to the samples, in order to verify the viability of this procedure. One of them would be to compare the DT with the principal method of anatomic evaluation, which is the X-Ray imaging, thereat being able to double-check the correlation between the internal structures of the tooth.

A second step for this study is to evaluate the pulp health, what could be done based on the contrast differences of those DT images of the healthy teeth in comparison to the damaged ones.

4. CONCLUSION

With this initial work the viability of the Dental Transilumination is proposed confirmed and through very simple methods, this study was able to testify the equivalence of the structures shown in the DT technique. The first evaluation of the sliced teeth was important once it provided information about how the light behaves according to the thickness of the medium, being possible to verify if this technique would be capable of be used in integer incisive teeth.

Regarding the integer teeth used, is understood that a more detailed approach has to be given to the molar and pre-molar specimens, since they present a deeper pathway for the ballistic photons that pass through the sample and reach the camera detector.

REFERENCES

[1] Gopikrishna, V., Pradeep, G., Aenkateshbabu, N. Assessment of pulp vitality: a review. International Journal of Paediatric Dentistry 2009; Vol. 19, p. 3-15.

[2] De Paula Eduardo, Flávia Tavares de Oliveira. Avaliação da fluxometria laser Doppler como teste da vitalidade pulpar. 2004. Dissertação de mestrado do Programa de Pós-Graduação em Ciências, área de concentração: Tecnologia Nuclear - Materiais, do Instituto de Pesquisa Energéticas e Nucleares.

[3] De Moraes, Mariana Petrone. Fluxometria laser Doppler da polpa dental após clareamento com laser de diodo. 2006. Dissertação de mestrado profissional do Programa de Pós-Graduação em Ciências, área de concentração: Laser em Odontologia, do Instituto de Pesquisa Energéticas e Nucleares.

[4] Jafarzadeh, H., Rosenberg, P. A. Pulse Oximetry: Review of a Potential Aid in Endodontic Diagnosis. Journal of Endodontics. 2009, Vol. 35, p. 329–333.

[5] Abrão, Carmen Viana. A oximetria de pulso como recurso auxiliar na determinação da vitalidade pulpar de dentes permanentemente traumatizados. 2006. Dissertação de mestrado do Programa de Pós-Graduação em Ciências Odontológicas, área de concentração: Endodontia, da Universidade de São Paulo.

[6] Kataoka, Simony Hidee Hamoy. A oximetria de pulso como recurso na determinação da vitalidade pulpar em pacientes submetidos à radioterapia para tumores malignos intraorais de orofaringe. 2010. Dissertação de mestrado do Programa de Pós-Graduação em Ciências Odontológicas, área de concentração: Endodontia, da Universidade de São Paulo.

[7] Ingle J. I., Beveridge J. E. Endodontics, 2nd edn. Philadelphia, PA: Lea & Febiger, 1976.

[8] Ehrmann E. H. Pulp testers and pulp testing with particular reference to the use of dry ice. Aust Dent J, 1977, Vol. 22, p. 272–279.

[9] Mumford J. M. Toothache and Orofacial Pain, 2nd edn. Edinburgh: Churchill Livingstone, 1976.

[10] Vo-dihn, T. Biomedical Photonics Handbook. Boca Raton: CRC Press, 2003.
[11] Jones, R. S., Huynh, G. D., Jones, G. C., Fried, D. Near-infrared transillumination at 1310-nm for the imaging of early dental decay. Optics Express, 2003, Vol. 11, No. 18, p. 2259-2265.
[12] Bühler, C. M., Ngaotheppitak, P., Fried, D. Imaging of occlusal dental caries (decay) with near-IR light at 1310-nm. Optics Express, 2005, Vol. 13, No. 2, p. 573-582.
[13] Karlsson, L., Maia, A. M. A., Kyotoku, B. B. C., Tranæus, S., Gomes, A. S. L., Margulis, W. Near-infrared transillumination of teeth: measurement of a system performance Journal of Biomedical Optics, 2010, Vol. 15, No. 3, p. 036001.
[14] Fried, D., Glena, R. E., Featherstone, J. D. B., Seka, W. Nature of light scattering in dental enamel and dentin at visible and near-infrared wavelengths. Applied Optics, 1995, Vol. 34, No. 7, p. 1278-1285.