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In vivo evaluation of enamel dental restoration interface by optical coherence tomography

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Abstract. In this work, we report *in vivo* application of Optical Coherence Tomography (OCT) to assess dental restorations in humans. After approval by the Ethical Committee in Humans Research of the Universidade Federal de Pernambuco, thirty patients with resin composite restorations in anterior teeth were selected. The patients were clinically evaluated, and OCT was performed. Images were obtained using OCT operating in the spectral domain, with an 840 nm superluminescent diode light source (spectral width of 50 nm, fiber output power 25mW and a measured spatial resolution of 10 µm). The image acquisition time was less than one second. The results were analyzed with respect to the integrity and marginal adaptation of the restoration. Using appropriate software, the lesioned region can be exactly located and a new restoration procedure can be carried out. We have shown that OCT is more than adequate in clinical practice to assess dental restorations.

Sumario. En este trabajo, usamos la tomografía de coherencia óptica (OCT) *in vivo* en seres humanos para evaluar restauraciones dentales. Contando con la aprobación del Comité Ético de Investigación en Seres Humanos de la Universidad Federal de Pernambuco, treinta pacientes que tenían restauraciones dentales de resina compuesta fueron seleccionados. Los pacientes fueron evaluados clínicamente, e imágenes usando OCT fueron tomadas. Obtuvimos las imágenes utilizando la OCT que opera en el dominio espectral, con un laser de diodo superluminescente de 840 nm (con un acho espectral de 50 nm, una potencia de salida en la fibra de 25mW y una resolución espacial de 10 µm). El tiempo de adquisición de las imágenes fue menor de un segundo. Los resultados fueron analizados, observando la integridad y la adaptación en los bordes de la restauración. Usando el software apropriado, la región lesionada de la restauración puede ser localizada con exactitud y un nuevo procedimiento de restauración puede ser realizado. Demostramos que la OCT es más que suficiente en la práctica clínica para evaluar restauraciones dentales.

Keywords. optical coherence tomography, dental diagnostic, enamel-restoration interface, marginal microleakage.

1 Introduction

The improvement in the esthetic and physical properties of composite resins have established them as the material of choice for restoration of anterior teeth when used in conjunction with the acid-etch technique and dental bonding systems.[1]

Dental restoration interfaces can present failures, known as marginal microleakage. These failures are extremely difficult to diagnose and can develop into recurrent caries if left untreated. The most common tool used

for diagnostic imaging in dentistry, X-ray, is not able to visualize micrometric structures. A technique for evaluation of dental restorations in a non-invasive way is very desirable in clinical practice.

Dental restorations provide a barrier restricting oral fluids and bacteria from entering the tooth. An inadequate marginal seal can result in a further loss of tooth structure and dissemination of bacteria.[2] Optical Coherence Tomography (OCT) is a relatively new, but well established, imaging technique for diagnosis, that can produce two- or three-dimensional images of bio-tissues with a few µm spatial resolution. Using a low-coherence interferometric technique, OCT performs high resolution, non-invasive, cross-sectional tomographic imaging of tissue microstructures.[3, 4]

Our group has previously demonstrated the application of OCT for *in vitro* analysis of dental restoration of enamel.[5] Here, we present an *in vivo* study applying OCT to detect failures at the enamel-dental restoration interface in a clinical setting.

2 Material and methods

After approval by the Ethical Committee in Humans Research of the Universidade Federal de Pernambuco (registration number 241/08), thirty patients with resin composite restorations performed in anterior teeth during the period between 2000 and 2007 were selected for examination. The patients, both male and female, between the ages of 18 and 45, were clinically evaluated, and OCT was performed. The results were analyzed with respect to the integrity and marginal adaptation of the restoration.

The OCT setup uses a broadband light source (superluminescent diode, Broadband SLD Lightsource S840, SUPERLUM, Moscow, Russia) operating at 840 nm and with a spectral width of 50 nm, a fiber output power 25mW and a measured spatial resolution of 10 µm (Figure 1 and 2). The system is based on the Michelson interferometer set-up: in the reference arm, there is a mirror mounted on a piezoelectric base; in the sample arm, a mirror controlled by a Galvo motor is required for the scanning of light at the sample.

Light from the source is first split by a beam splitting mirror and travels down the reference and sample arms, respectively. The reflected and back-scattered light coming from both arms are then recombined at the beam splitter and collected by a spectrometer, consisting of a lens collimator system, 1200 l/mm grating and an optical detector (linear CCD cam, ATMEL, 2048 pixels, 12 bits, California, United States), connected to a computer. The system is controlled by the software OCT 800 – Complex Square, developed from LabView program language, that collects data and generates the image.

3 Results and discussion

Failures at the tooth-restoration interface can be associated with several reasons such as the use of incorrect restorative technique, the physical properties of the materials used and, especially, the contraction of the material generated during the polymerization of the restorative material. Operative Dentistry achieved some progress through the development of adhesive systems and improvement of composite resins, but failures are still observed at the tooth-restoration interface. The success of the restorative treatment depends of the integrity of this region and, for this reason, the tooth-restoration interface is the subject of much research and discussion in Dentistry.

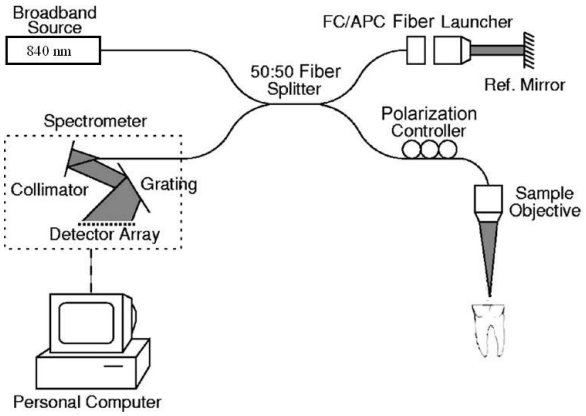
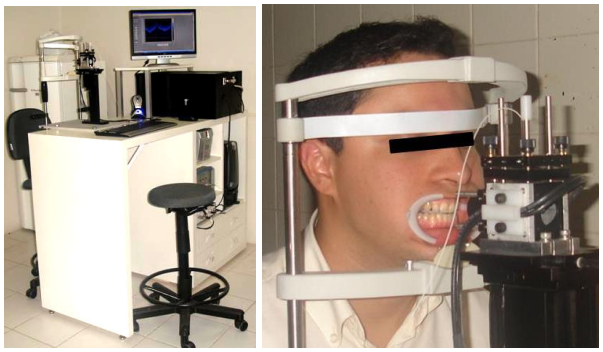


Figure 1: Schematic setup SD-OCT 840 nm.



Figures 2 and 3. Clinical Dental-OCT and patient position.

To perform the OCT examination, a lip retractor is used on the patient (Figure 3), and his face is positioned in an appropriate support (Figure 2), in front of the sample arm. The image acquisition time takes less than one second. Using appropriate software, the lesioned region can be exactly located and a new restoration procedure can be carried out.

Microleakage can progress and lead to secondary caries which are very difficult to diagnose.[6] Several techniques have been used for clinical diagnosis of caries and restoration faults in Dentistry. Multi-photon imag-

ing, infrared termography, infrared fluorescence, ultrasound, terahertz imaging and optical coherence tomography are a few techniques used for diagnosis.[7] The most common tools for detection of restorative failures are by tactile and/or visual inspection or by radiographic exams. However, according to their measurements, initial microleakages can be clinically imperceptible, and thus, secondary caries will progress.

An example of OCT image obtained directly in patients is shown in figure 4. Image 4a was obtained from a central superior incisor. The upper part shows the gingiva, and the lower part, the enamel. In figure 4a, the upper arrow shows the enamel-restoration interface, and the lower arrow, a fracture at the restoration surface.

Images 4b and 4c were obtained from central superior incisors. The upper arrow in figure 4b shows an adequate dental-restoration interface and the lower, a failure between resin increments. Finally, in figure 4c, two points of microleakage at the restoration can be observed.

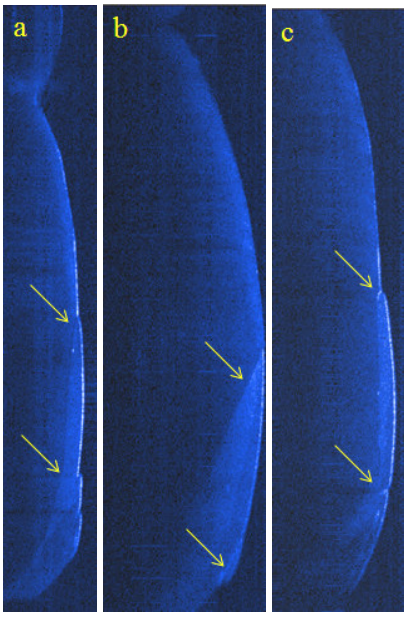


Figure 4. Images obtained from patients teeth, using OCT operating at 840 nm in the spectral-domain

4 Conclusions

We have shown that OCT is more than adequate in clinical practice to assess dental restorations for several reasons: it is a non-invasive, high resolution technique, able to do qualitative and quantitative analysis, free of ionizing radiation, and is near real time in terms of image acquisition. However, is necessary to develop an appropriate handpiece to make access to the posterior teeth in the oral cavity possible.

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