Evaluation of the integrity of dental sealants by optical coherence tomography

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ABSTRACT

Objectives. The purpose of the present research was to demonstrate images of failures into the structure of pit and fissure sealants using optical coherence tomography (OCT).

Methods. Five human third molars were selected and the sealant ALPHA SEAL LIGHT/DFL was applied according to the manufacturer instructions. For evaluation of the structure of pit and fissure sealants, twenty OCT images of each tooth were performed before and after application of sealant. A total of 200 images were evaluated. A home built spectral OCT system used was operating in spectral domain (SD-OCT), at 840 nm and a measured spatial resolution of 10 μm. The system is based on the Michelson interferometer set-up and is controlled by the software OCT 800 – Complex Square/LabView, that collects data and generates the image. The occlusal surfaces were scanned in a bucco-lingual direction and tomographic images parallel to long axis of tooth were obtained. After the achievement of the images by OCT, the crown of each tooth was sectioned in a occlusogingival direction (buccolingually). Images from each section were obtained and evaluated by an optical microscope. OCT and microscopic images were compared.

Results. Representative images showed that OCT image provides the insight into sealant material. It was possible to clearly identify the internal structure of sealant and the subjacent enamel. Sealant and enamel are very well distinguished, and failures at the interior and at surface are well detected.

Significance. OCT could generate images of the features of fissures, bubbles and failures in the adaptation of sealants, opening up possibilities in the future to monitoring sealant application and retention in short and long term.

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1. Introduction

It has been recognized for some studies the decrease of the prevalence and severity of dental caries [1–3], due mainly to fluoride presence in dentifrices and public water supply. However, these fluoride therapies benefit primarily smooth surfaces [4], while occlusal surfaces continue to be responsible for about 56–70% of caries in children 5–17 years of age [5]. Nowadays, the modern principles of dentistry emphasize preventive procedures as a way to control caries disease. Under the preventive methods available, fissure sealant has been used to prevent occlusal caries and is the best preventive method for these surfaces since it acts as a physical barrier.
that restrains the exchange of metabolic products between fissure microorganisms and the oral environment.

The key consideration to the success of the sealing procedures is adequate adhesion, adaptation and penetration of the material into the previously etched system of fissures. The penetration/adaptation in turn depends on the geometric configuration of fissures, the deposition of the material into the latter, and the physico-chemical characteristics of the sealer used [6]. It can be assumed that the sealant should penetrate reliably into the enamel, rendering this region beneath the sealant less prone to demineralization or caries attack in the event of sealant loss [7].

An important parameter in the evaluation of the clinical success of sealant materials is the marginal adaptation, mainly at the sealant margin. Etching procedures might increase adhesion to enamel of sealant materials, allowing better marginal adaptation [8]. The presence of a marginal gap can lead to marginal staining, which can be considered the first sign of sealant failure [9]. Marginal gap may also imply that there is no occlusal surface isolation against oral microorganisms and, consequently, risk for the development of dental caries is increased [10]. Traditional methods of evaluating the integrity of the dental sealants, such as visual and probing inspection, have been found to have far from optimal performance. These methods cannot identify gaps, adaptation or failures into the internal structure of sealants, which can cause des-adaptation, infiltration and loss of material [11].

The optical coherence tomography (OCT) is a well known technique for providing noninvasive, high spatial resolution (<10 μm) images of biologic microstructure [12]. The key elements of an OCT setup include a broadband light source, whose spectral width limits the axial spatial resolution; an interferometer, which generally employs a Michelson design containing in one of the arms the sample and in the other arm a delay line and an optical detector, whose signal output is electronically treated and fed to a computer for the image generation. Two domains can be exploited for implementation of an OCT system: the time domain or the spectral domain (SD-OCT). In the time domain, the optical delay line arm basically consists of either a movable arm or a Fourier domain delay line [13]. It has been shown more recently that spectral domain OCT (SD-OCT) has several advantages over the time domain OCT, including sensitivity [14] and fast acquisition data, and since the first report on imaging implementation using SD-OCT [15] its use has been widespread [13,16]. The SD-OCT can be implemented in two ways: either spectrally resolving the signal [16] or spectrally scanning the optical source [13].

OCT systems have been widely developed for ophthalmic applications [16] with several commercially available systems, and also for dermatological [17] and endoscopic [18] applications. Colston et al. [19] applied OCT to in vivo optical microscopy imaging of dental structure and Warren et al. [20] have performed OCT characterization of healthy teeth and caries lesions in vitro. More recently early caries diagnostics [21] and evaluation of enamel interface restoration have been described [22]. In 2006, Kauffman et al. [23] reported the first OCT image of dental pulps using rat’s teeth. Shemesh et al. described the first OCT to characterize the root canals wall and to diagnosis of vertical root fractures [24,25]. Our group has also recently described the application of OCT to characterize dental materials [26,27] and pulp-dentin complex [28].

Based on these considerations, the aim of the presented research was to demonstrate OCT images of failures into the structure of pit and fissure sealants and compare them with microscopic sections. In this study we will discuss these images and their relevance as a powerful tool to preventive dentistry, to evaluate and monitoring dental sealants, contributing to the treatment success.

2. Materials and methods

The experimental study was carried out in accordance with the ethical guidelines in research with human participants (approved by the Center of Health Sciences, Universidade Federal de Pernambuco, 2009).

Five human third molars, acquired from teeth bank (Universidade Federal of Pernambuco) and free from apparent caries, macroscopic cracks, abrasions and staining on the occlusal surface (assessed by visual examination) were selected. Teeth were submitted to a prophylaxis using pumice and the material ALPHA SEAL LIGHT/DFL was applied according to the manufacturer’s instructions, as follows: the enamel surface was etched using 37% phosphoric acid (H3PO4) gel for 60 s, rinsed thoroughly for 10 s, and dried. The material was applied with a sharp explorer in order to avoid excessive spreading of sealant and light cured for 20 s using Radii-cal (Southern Dental Industries - SDI – Australia M.S. 10282499001). The specimens were stored for seven days at 37°C and 100% humidity.

For evaluation of the structure of pit and fissure sealants, 20 OCT images pre- and 20 OCT images post-sealant treatment were obtained. Thus, a total of 200 tomographic images were evaluated. A home built spectral optical coherence tomography system was used, whose diagram is shown in Fig. 1.

The OCT was operating in spectral domain (SD-OCT). The SD-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 25 mW and a measured spatial...
Fig. 2 – OCT images showing the comparison between the fissures before (A and B) and after (C and D) the application of the sealant. Small letters (a) and (b) indicate the tooth enamel and pit region, respectively. The arrow indicates the sealant–air interface. No defects can be observed in the sealant region.

Fig. 3 – OCT images after sealant application. The arrows indicate the presence of bubbles (A–C) in the sealant region and gap (D) in the sealant–tooth interface.
the sealant and subjacent tooth structure and a tomographic image parallel to long axis of teeth, was obtained. After the achievement of the images by OCT, the crown of each tooth was sectioned in an occlusogingival direction (buccolingually) with a water-cooled diamond saw. The slices obtained were evaluated by an optical microscope. A computer controlled optical microscope performed the microscopic image from each slice. The microscopic images and the correspondent OCT counterpart were compared. A calibrated examiner (A.K.S.B.) evaluated the microscopic and OCT images.

3. Results

Representative OCT images are shown in Figs. 2–4, which were obtained from the pit and fissure regions. It is possible to clearly identify the internal structure of sealant and the subjacent enamel. It can be seen that the OCT image provides the insight into sealant material about 1.50 mm deep at this wavelength. Sealant and enamel are very well distinguished, and failures at the interior and at surface are well detected.

Fig. 2 shows comparative images between the fissures before (A and B) and after (indicated by the arrows in Fig. 2C and D) the application of dental sealant. Feature of fissures are well delineated within the tooth image. Fig. 2A exhibits a shallow and wide fissure while Fig. 2B exhibits a deep and narrow fissure. After application of dental sealant, the superficial limit of the material is clearly delineated by a homogenous white line of high intensity. Even after the application of the protective material, the visualization of the subjacent region remains in a very clear way.

The result of Fig. 3A–D shows undesirable features after the sealant has been applied. Fig. 3A–C shows the presence of bubbles in the surface or internally in the sealant region, while Fig. 3D shows a gap between the sealant and the tooth structure (indicated by the arrow).

Fig. 4A and B, also for tooth after sealant incorporation, shows an incomplete penetration of the material. Fig. 4A shows the microscopic image of the sample, where a bubble located at tooth–sealant interface, at the interior region of the fissure, can be seen. This feature is also clearly observed in the OCT image of Fig. 4.

4. Discussion

Although the sealing of pits and fissures seems to be an efficient way for caries prevention, it is not clear that there is a consensus as to its indication, application techniques and control. Teeth with deep and retentive pits could also be candidates to receive a sealant protection [29]. When the occurrence of incipient caries is detected, or when there is strong suspicion, therapeutic sealant is indicated generally proceeding with an invasive or ameloplastie technique [30,31]. By employing the OCT technique, it is possible a greater control and visualization of the presence or absence of enamel cavities, thus avoiding the random use of the invasive technique [32].

The clinical diagnostic of incipient occlusal lesions is quite complex, leading to divergence among professionals as to the method to be used. Therefore, many times the use of the dental probe is substituted by visual examination [33]. However, the visual exam is not enough to confirm the depth of such pits, as is possible with OCT technology (Fig. 2A and B). The present research demonstrated that OCT has big advantage over these traditional methods and present good accuracy of images. As the OCT method is noninvasive and can generate video rate images, it has potentially great advantages for clinical use.

OCT technique can visualize and measure gaps, failures, bubbles (immediate or afterwards) as we have shown here (Figs. 3A–D and 4B). The presence of gaps lead to material loss at short term, therefore their identification may determine the useful material life [26]. Also, the technique is useful to monitor treatments, both for material evaluation as well as for demineralization progress or incipient lesion adjacent to the material [32].

Although not shown in this study, it has been demonstrated before [21] that at this wavelength, it is possible to penetrate the full healthy enamel (with typically 1.6 mm depth). Therefore, if a caries lesion is starting at the enamel–dentin interface, the OCT method can also detect it.

5. Conclusion

In conclusion, this research showed the use of OCT, a noninvasive and nondestructive technique, for analyzing the structure
of pit and fissure sealants and the subjacent enamel substrate. OCT could generate images of fissures, bubbles and failures in the adaptation of sealants. The use of OCT may aid in monitoring sealant application and retention in long term. Further in vivo studies are required to confirm the potential of the technique for clinical application.

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REFERENCES

[29] Campos MC, Ribeiro RA. Selantes de Fissuras e Fissuras: critérios para o uso, métodos e técnicas de aplicação e controle preferidos por odontopediatras de Minas Gerais. Arq Odontol 2005;41:001–104.