

Optical Coherence Tomography Combined with the Confocal Microscopy Method and Fluorescence for Class V Cavities Investigations

M. Rominu, C. Sinescu, A.G. Podoleanu

Abstract—The purpose of this study is to present a non invasive method for the marginal adaptation evaluation in class V composite restorations. Standardized class V cavities, prepared in human extracted teeth, were filled with Premise (Kerr) composite. The specimens were thermo cycled. The interfaces were examined by Optical Coherence Tomography method (OCT) combined with the confocal microscopy and fluorescence. The optical configuration uses two single mode directional couplers with a superluminescent diode as the source at 1300 nm. The scanning procedure is similar to that used in any confocal microscope, where the fast scanning is en-face (line rate) and the depth scanning is much slower (at the frame rate). Gaps at the interfaces as well as inside the composite resin materials were identified. OCT has numerous advantages which justify its use in vivo as well as in vitro in comparison with conventional techniques.

Keywords—Class V Cavities, Marginal Adaptation, Optical Coherence Tomography Fluorescence, Confocal Microscopy

I. INTRODUCTION

No matter their chemical composition, tooth colored materials used for restoration of class V cavities are subjected to marginal leakage. This phenomenon has been widely investigated by a great number of authors.

For the evaluation of marginal adaptation in class V composite restorations, several methods have been developed (bacterial penetration, fluid transport, clarification, penetration of radioisotopes, electrochemical methods and gas chromatography). Dye penetration tests (microleakage tests) however, are to be the most widely used due to their ease of application and low costs. Their main disadvantage is that the samples are sectioned. The purpose of this study is to present an alternative non invasive/non destructive method instead of the dye penetration evaluation.

Along with the well known dye penetration technique, optical coherence tomography (OCT) was used for detection of voids and gaps at the interfaces which could have an impact on both

the marginal seal and microleakage. To our knowledge this method was never employed before in the study of the marginal seal between composite and tooth structure in class V cavities.

II. MATERIALS AND METHODS

A. Sample Preparation

202 human extracted teeth crack-free were randomly selected for this study. The teeth were stored in physiological saline solution prior to use. [2–Haller, 1993, 3–Li, 2002] A standardized class V cavity (mesio-distal width 3 mm, occluso-gingival width of 2 mm and a depth of 1,6 mm) was prepared on the buccal surface of each tooth using a regular grit fissure diamond bur (no. 835, ISO 806 314 108 524 018, Hager&Meisinger, Neuss, Germany). According to Uno et al, the cavities were prepared with 90 degrees cavo-surface angle. [7–Uno, 1997] The preparations were parallel to the cemento-enamel junction, with the occlusal half of them extending approximately 1 mm above the junction. The cavities were conditioned as follows: total acid etching, 15 seconds with 37,5% phosphoric acid Gel Etchant (Kerr), than application of OptiBond Solo Plus (Kerr) adhesive. All cavities were bulk filled with Premise (Kerr) composite. All materials were used according to manufacturer's instructions. The composite restorations were finished and polished [4–Lim, 1999], using a fine grit diamond bur (no. 858F, ISO 806 314 165 514 014, Hager&Meisinger, Neuss, Germany) and Kerr-Hawe polishing discs (Dentsply DeTrey, Konstanz, Germany). The specimens were then stored one week in distilled water (37°C) and thermocycled (1000 cycles) with a dwell time of 25 seconds in each bath (transit time 5 seconds) between 5-55 °C. The restored teeth were stored in distilled water (7 days). The occlusal and gingival interfaces were examined by the Optical Coherence Tomography method (OCT) combined with the confocal microscopy. [6–Podoleanu, 2004] The optical configuration (fig.1) uses two single mode directional couplers with a superluminescent diode as the source at 1300 nm. The scanning procedure is similar to that used in any confocal microscope, where the fast scanning is *en-face* (line rate) and the depth scanning is much slower (at the frame rate).

B. Optical Coherence Tomography

To obtain 3D information about the object, any imaging system is equipped with three scanning means, one to

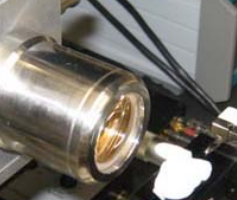
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The diagram illustrates the experimental setup for measuring the time delay of the optical Kerr effect. It features a laser source (SLD) connected to a series of couplers (50/50) and single mode fibers. The light path includes polarization controllers, a balanced detector, a high-pass filter, a rectifier, and an amplifier. The setup also incorporates a frame grabber, a PC, a display, a motion controller, and an axial stage. The optical components include FPR2, lenses, mirrors, and a sample mounted on a tube mount, with a scanner and XY mount for precise positioning.

C. Fluorescence and Confocal Microscopy



The OCT scanning at 18 or 8 degree (zoom) in air lead to stacks of 98 slices, with 33 microns between the slices. The

OCT/Confocal scanning lead to 3D reconstructions that allow localizing and evaluating the magnitude of the defects. After that the fluorescence agent (Fluoresceina) was applied on the teeth / resin interfaces and than another OCT scan was performed.

III. OCT RESULTS

Marginal adaptation at the interfaces and gaps inside the composite resin materials were identified by means of optical coherence tomography (fig. 2, 3). Exploration of the recent advances in OCT in terms of different excitation wavelengths and wider bandwidths can lead to state-of-the-art imaging systems in odontology.

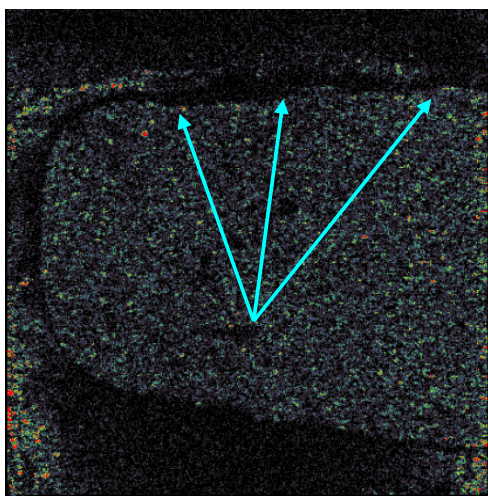


Fig.3. OCT investigation of sample 22, class V cavity filled with composite resin. In the upper part of the tooth resin interface a big gap can be spotted. Slice 43 from 98, 33 microns between slices, 8 degree scanning in air.

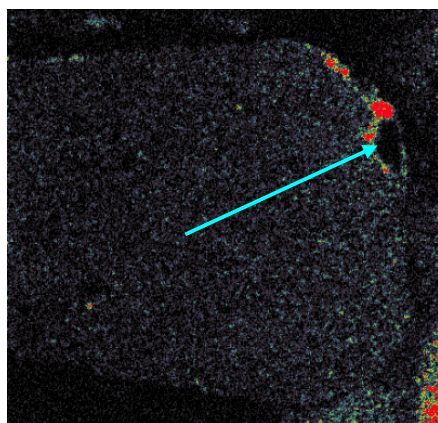


Fig. 4. OCT investigation of sample 46, class V cavity filled with composite resin. In the upper part of the tooth resin interface a big gap can be spotted. Slice 35 from 98, 33 microns between slices, 8 degree scanning in air.

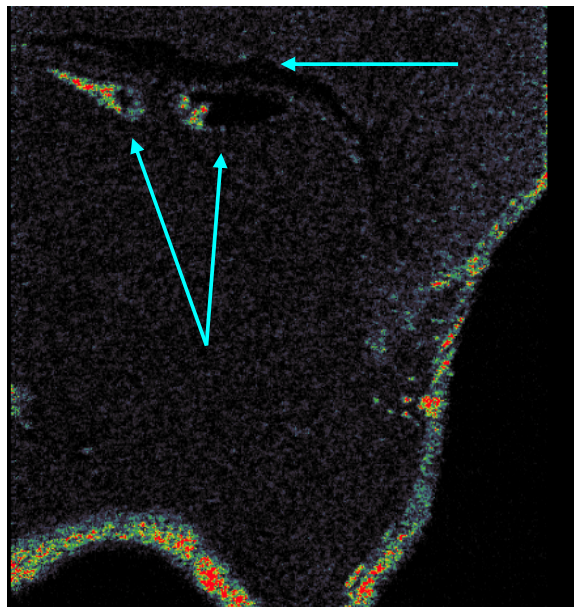


Fig.5. OCT investigation of sample 57, class V cavity filled with composite resin. In the upper part of the tooth resin interface a big gap can be spotted. Also two resin defects are located near the problematic interface. Slice 28 from 98, 33 microns between slices, 8 degree scanning in air.

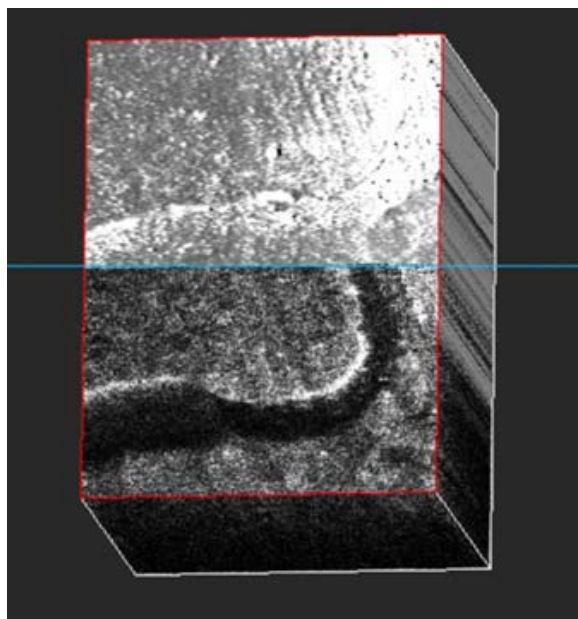


Fig. 6. Marginal gap of a class V cavity filled with the composite resin. 3D reconstruction of the OCT/ Confocal Investigation of sample 63. En-face scanning reveals the gap in depth. 1300 nm, slide 57 from 98, 18 degree in air. The upper image is the confocal projection on the investigated interface

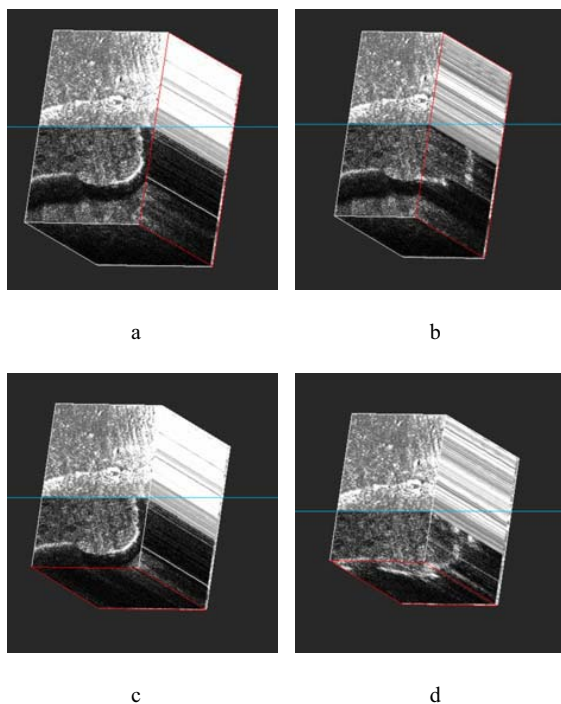


Fig.7. OCT/ Confocal Investigation of sample 63. Three dimensional reconstruction of the investigated interface allows to analyze the sections in depth using the B scanned slices obtained by C scan images recorded in en face imaging. Proximal introspection (**a** and **b**) and cervical introspection (**c** and **d**) towards the composite filling. The confocal image remains the same in all slices



Fig. 8. Applying the fluorescence agent on the tooth resin interface for sample 79.

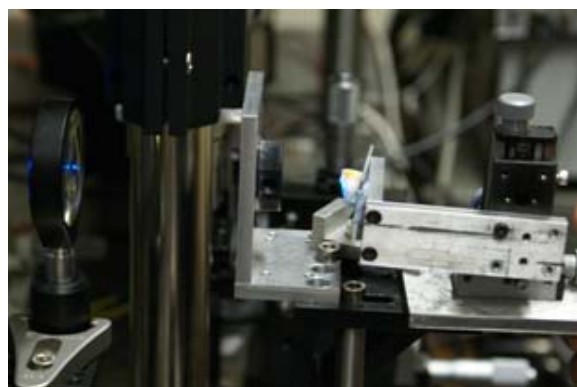


Fig. 9. OCT Fluorescence investigation in order to detect the micro leakage of the resin filling for sample 79.

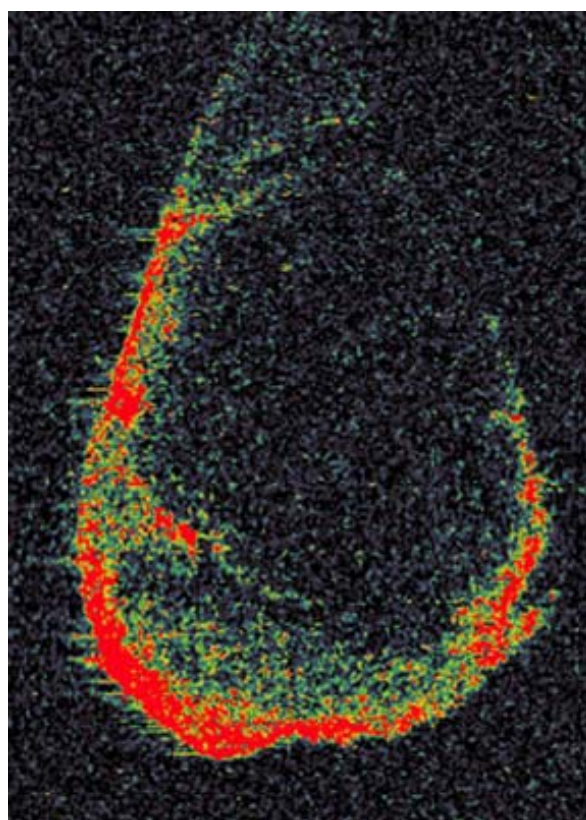


Fig. 10. OCT Fluorescence investigation with the micro leakage of the resin filling for sample 79.

IV. DISCUSSION

The test of microleakage at the tooth–restorative interface using various penetrating dyes has been widely used due to its ease of application . The results however, are subjected, partly or totally, to different influences of the methods that are applied. In addition, the comparison of results obtained by different authors is difficult and may even lead to doubtful interpretation [14].

The usage of organic dyes is the most used method for the

investigation of microleakage. The most commonly used dyes are methylene blue and basic fuchsin, with various concentrations and immersion times. Radioisotopes can also be used with different techniques, particle sizes and solution pH.

The interpretation of the results is based on previously established scores, probably due to their ease of examination. Another way of interpretation is to quantify the dye penetration measurements and to transform them into percentages.

The measurement of dye penetration in volume with a spectrophotometer method is another method of interpretation of micro leakage, but this technique requires a specific devices and professional training [14].

Other methods such as scanning electron microscopy (SEM) or dye staining gap tests have been used for evaluation of the marginal adaptation of the tooth colored restoratives. This quantitative method allows the assessment of the entire. The artifacts formed as a result of sectioning or dehydration can be minimized by utilizing replicas.

Another test using 1% red propylene glycol acid solution for 5 s to has been used to detect marginal gaps. The short time period of dye penetration allows only the capillary action thus preventing the diffusion into the adhesive layer.

The methods which evaluate microleakage by using sections may underestimate the extent of dye penetration. In order to overcome this major disadvantage, the clearing method was introduced, initially for the evaluation of root canal treatments. For the evaluation of leakage patterns around class V restorations, this method was used in combination with the silver staining method [15]. This method is unsuitable for detecting microleakage in enamel, but it can be used for cavities with margins below the cemento-enamel junction. Other authors compared the silver staining/clearing technique with a fluid filtration method, which was found to be more sensitive than the clearing method. The clearing protocol with India ink as a tracer was found to be a supplementary aid regarding the visualization of microleakage [15].

The OCT investigations point out many tooth resin filling interfaces with problems along with material defects inside the resin filling. Both those can lead to micro leakage and failure of the treatment of class V cavities. The OCT/Confocal Microscopy scanning allows to develop 3D images that are very useful in evaluating the location and magnitude of the defect. Finally the Fluorescence OCT point out the micro leakage for the samples investigated. Finally, as demonstrated in the literature, in vivo and real-time OCT images can be obtained, and therefore this method of assessment is potentially useful for clinical diagnostics.

V. CONCLUSION

OCT has numerous advantages which justify its use in the oral cavity in comparison with conventional dental imaging. OCT can achieve the best depth resolution of all known methods (in principle 1 micron if the source exhibits a sufficiently wide spectrum) and is safe.

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