

OCT Application in Direct Dental Restorations Marginal Fit Evaluation

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To apply OCT analysis in secondary caries and marginal gap detection and evaluation for direct dental restorations is the aim of the paper. 15 extracted teeth with pre-existing direct dental restorations were analysed through OCT to evaluate marginal fit of restorations. The OCT system used was manufactured by Thorlabs (OCS1300SS), powered by a swept laser source with central 1310 nm wavelength, 100 nm spectral bandwidth and 12 mW average power. The occlusal area of the teeth was sampled pictured in 10 mm width, 10 mm distance and 3 mm depth. OCT was used also to evaluate in micrometers (μm) the maximum marginal gap between dental filling and tooth. OCT analysis of the marginal fit of direct dental restorations after A scan examination revealed that amalgam had the smallest marginal gap (width 210 μm , depth 90 μm), followed by glass ionomer (width 350 μm , depth 280 μm), and composite (width 520 μm , depth 300 μm). OCT analysis revealed that for marginal fit evaluation amalgam had best performance, followed by glass ionomer, and ultimately, by resin composite. OCT could be used as an alternative method to appreciate the marginal fit of direct dental restorations giving details that could help dentists to take best treatment decision, whether to repair or to replace the restorations.

Keywords: optical coherence tomography, marginal gap, direct dental restoration

Direct dental restorations could rebuild teeth morphology through many techniques and with different types of materials. Over time, on molars, dental amalgams, dental resin composites and also glass ionomer materials were recommended and used. Clinical performance of a direct dental restoration was evaluated through criteria that defined the esthetical properties, functional properties, biological properties [1, 2]. Major causes of direct dental restorations failure were secondary caries and restoration fracture [3, 4].

According to Schneider [5], it is important for dentist to have the possibility to assess the quality of bond at the margins of the cavity and the tooth-filling interface, as well as to detect secondary caries and compare different restorative materials in clinical trials or in vitro studies. OCT is considered a promising technique helping dentists to achieve these requirements. In 1998, scientific literature revealed for the first time reports of OCT use in dentistry to observe hard and soft oral tissues [6-8]. OCT was used in dentistry as an alternative non-invasive method of assessing the marginal integrity of direct dental restorations [9-11].

The adhesive failure evaluated as a space between tooth and restoration is a parameter through which the quality of restorations can be assessed [12]. According to Hickel [1, 2], and clinical criteria recommended by FDI, the marginal integrity of restorations could be appreciated using a 5 point score, depending on the size of the gap between tooth and restoration evaluated with tip of blunt explorers of different diameters. Evaluating the width of this gap allows the dentist to take the right therapeutic decision: restoration polishing for score 2 (50 μm width), restoration monitoring for score 3 (50-150 μm), restoration repair for score 4 (over 250 μm), restoration replacement for score 5, appreciating a loose filling. The existence of the secondary caries is hard to appreciate clinically. There are reports of marginal discoloration wrongly appreciated as secondary caries and

subsequently unnecessary restored [1, 2]. OCT used as a tool used to appreciate clinically secondary caries existence and also to measure the marginal gap between dental filling and tooth would be very useful [9-12].

The clinical performance of a restorative material is evaluated after at least 3 years [13-15]. Although clinical trials remain a gold standard for assessing the quality of dental fillings, these are difficult to achieve. Through ex vivo and in vitro studies, OCTs allow us to get very valuable information about defects of the marginal fit of restoration up to a 3 mm image depth [13]. The study on extracted teeth with old direct dental restorations aimed to highlight OCT application in secondary caries and marginal gap detection and evaluation.

Experimental part

Methods

15 extracted teeth with pre-existing direct dental restorations (glass ionomer cement, amalgam, resin-composite) were analysed through OCT to evaluate marginal fit of restorations. Teeth were extracted due to periodontal problems, diagnosed on radiography. Extracted teeth were washed under waterflash, then disinfected in 10% hydrogen peroxide for 10 min and then scaled and polished to remove periodontal tissue fragments and bacterial plaque. For the OCT analysis the teeth were fixed in a silicone mass.

The OCT system used was manufactured by Thorlabs (OCS1300SS), powered by a swept laser source with central 1310 nm wavelength, 100 nm spectral bandwidth and 12 mW average power. The device was used for 2D and 3D scanning of the teeth occlusal surfaces. The system's air resolution was 12 μm for axial and 15 μm for lateral resolution. The system allowed us to investigate a $10 \times 10 \times 3$ mm (length, width, depth) sample or $1024 \times 1024 \times 512$ pixels in about 30 s, using a charge-coupled device (CCD)-type detector [16-19].

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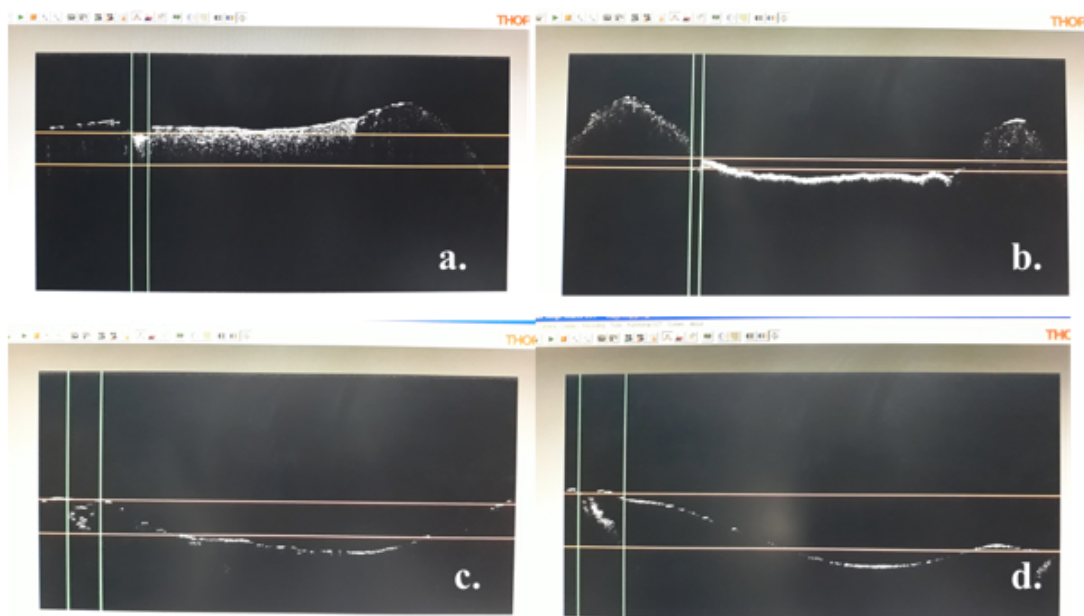


Fig. 1. OCT measurements of the marginal gap for glass ionomer filling (a), amalgam filling (b), composite fillings (c, d).

In order to evaluate marginal fit of direct dental restorations, we examined the occlusal area of the teeth. We sampled the area of interest pictured in 10 mm width, 10 mm distance and 3 mm depth. OCT was used also to evaluate in micrometers (mm) the maximum marginal gap between dental filling and tooth (fig. 1). All the molars had fillings appreciated as still functional by FDI criteria.

The study was approved by the Ethical Committee of the University of Medicine and Pharmacy of Craiova, Romania and the patients signed the informed consent.

Results and discussions

Sampled extracted teeth were molars, with glass ionomer occlusal filling (no = 5), amalgam occlusal restorations (no = 5), or composite restorations (no = 5).

Figure 2 depicted glass ionomer filling on a maxillary third molar (fig. 2a). OCT images of the restoration showed marginal leakage (fig. 2 b, c, d, e, f), marginal oblique lines signifying tooth cracks (fig. 2 d, e), incipient secondary caries pictured as a highly backscattering area at the left marginal aspect of the restoration (fig. 2 f). Also, OCT image showed the scratchy structure of the restoration, with surface ditches and cracks (fig. 2 b, c, e).

The sampled tooth with amalgam restoration had a fracture of a cuspid as a result of extraction (fig. 3a). OCT images of amalgam filling showed a good marginal sealing, without marginal leakage (fig. 3b, c, d, e, f, g, h).

Figure 4 showed a composite filling on a mandibular first molar. The occlusal area of the tooth showed an occlusal resin composite filling with marginal leakage,

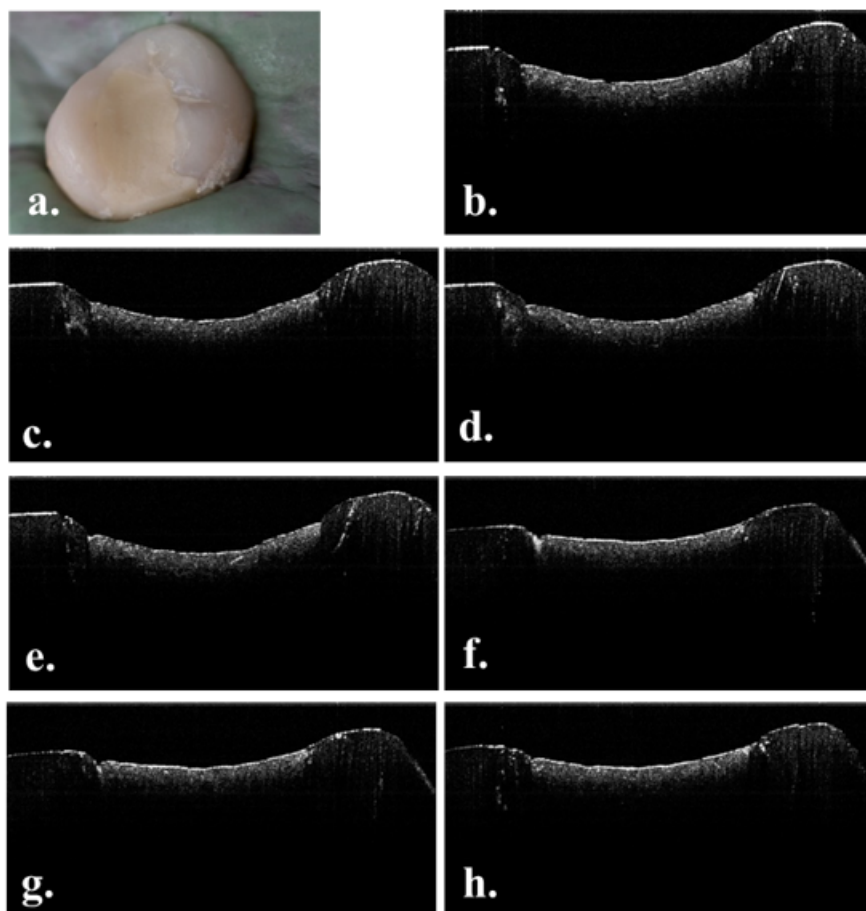


Fig. 2. Glass ionomer filling on a maxillary third molar (fig. a). OCT 2D images of occlusal area of the tooth (fig 2b, c, d, e, f, g, h).

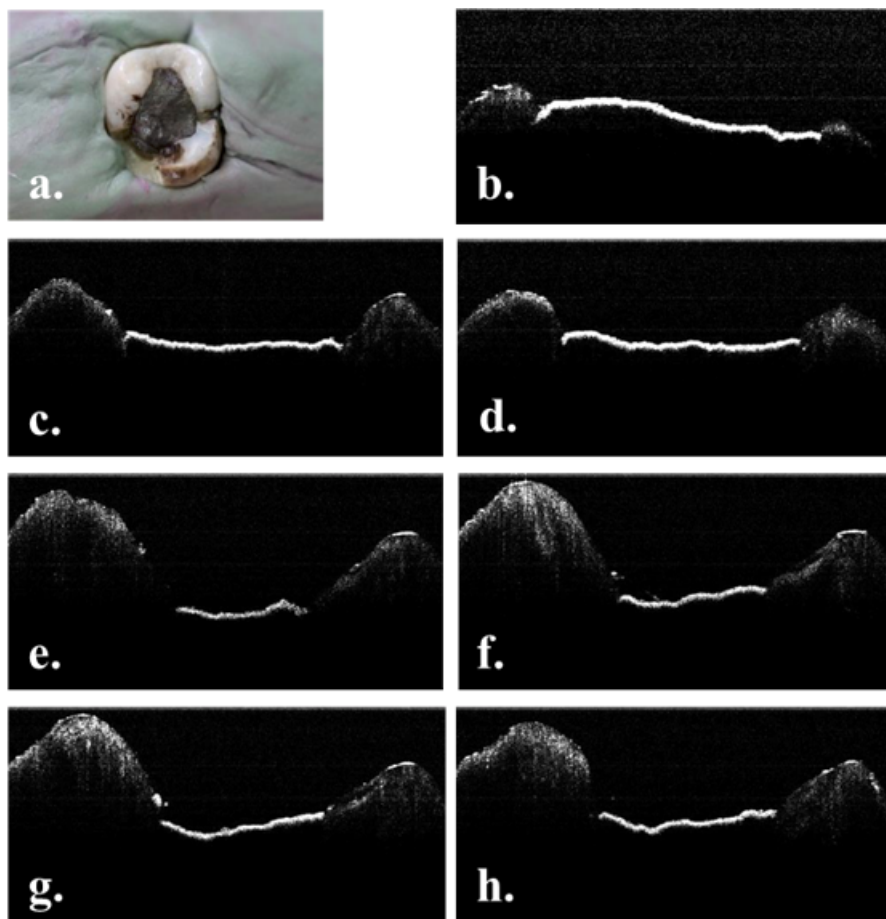


Fig. 3. Amalgam filling on a maxillary third molar (fig. 3; a). OCT 2D images of occlusal area of the tooth (fig. 3; b, c, d, e, f, g, h).

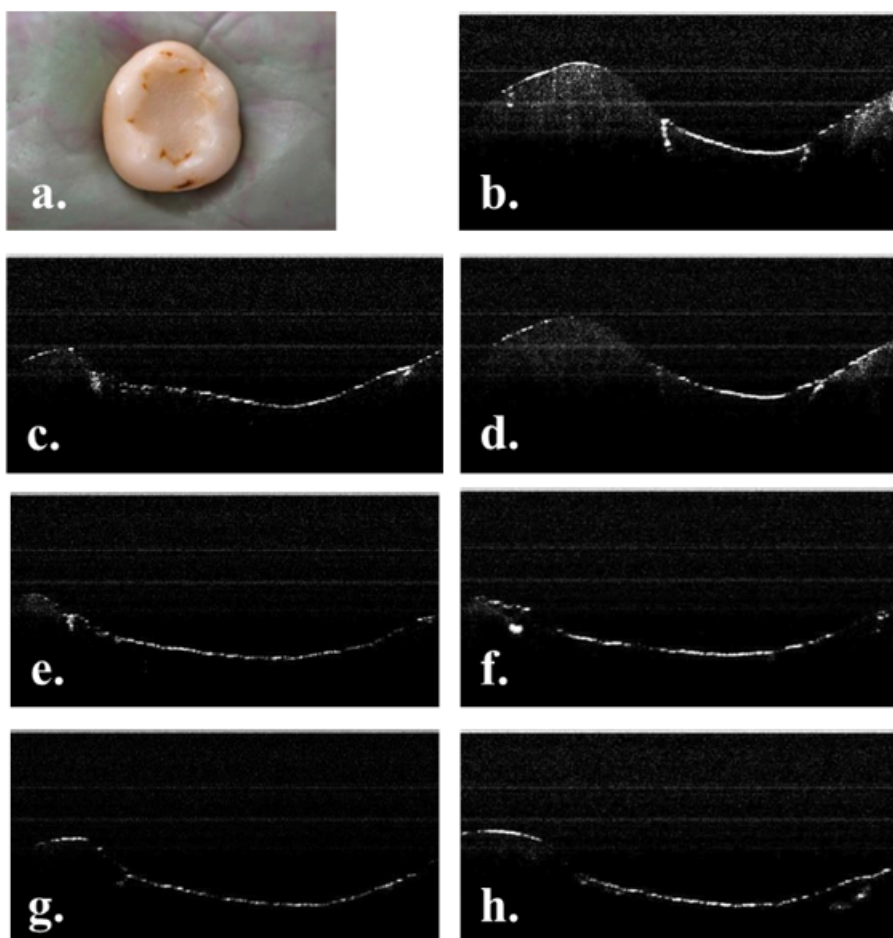


Fig. 4. Composite filling on a mandibular first molar (fig. 4; a). OCT 2D images of occlusal aspect of the tooth (fig. 4; b, c, d, e, f, g, h).

highlighted by the marginal stains (fig. 4a). The filling could be evaluated as still functional. OCT images showed a marginal leakage (fig. 4b, c, d, e), and marginal secondary caries as highly backscattering area (fig. 4f, g, h).

Composite filling on a maxillary second molar was presented in figure 5a. The occlusal area of the tooth showed an occlusal resin composite filling with marginal leakage, highlighted by the marginal stains (fig. 5a). OCT

images showed a marginal leakage (fig. 5 b, c, d, e), marginal secondary caries as a backscattering area (fig. 5 d, e), and composite fracture (fig. 5 f, g, h) visible as a ditch in the middle area of the restoration (fig. 5 a).

In figure 6 OCT 2D aspects of marginal gap are represented for sample extracted teeth with different filling materials. In case of glass ionomer filling, marginal gap had a width of maximum 350 μm , but presented aspects of backscattering light as in secondary caries (fig. 6a). For amalgam filling, maximum marginal gap was about 210 μm , and no sign of secondary caries was observed (fig. 6b). Two different molars with resin composite fillings were presented, and in both cases marginal gap was higher than 250 μm , equivalent with FDI score 3 (fig. 6c, d). Both OCT images of marginal area showed a backscattering area of light deeper than for amalgam and glass ionomer, and similar with secondary caries. OCT measurements of the depth of the area resulted in values of 280 μm for glass ionomer, 90 μm for amalgam, and 300 μm for composite.

Several glass ionomer cements with a high powder liquid ratio (like Fuji IX GC, Ketac Molar 3M Espe) were specifically used for dental atraumatic restorative treatment (ART) technique recommended by World Health Organization (WHO) in developing countries [20]. The cements were indicated on deciduous teeth, and in permanent molars only in small Class I cavities or for long-term temporaries [21, 22]. Irie et al [22] showed that immediate polishing of glass-ionomer fillings determined a larger marginal gap (80-100 μm) than delayed polishing after 24 h (9-21 μm).

Silver amalgam restorations were used for more the 150 years to restore tooth morphology on molars with the advantage of longevity and also a good marginal fit [23]. They were indicated in large tooth destruction and also when the cavity had a under gingival margin. The major defect was the colour for which other types of materials, like resin composites were searched and tried. Amalgam restorations have the advantage of a good marginal sealing

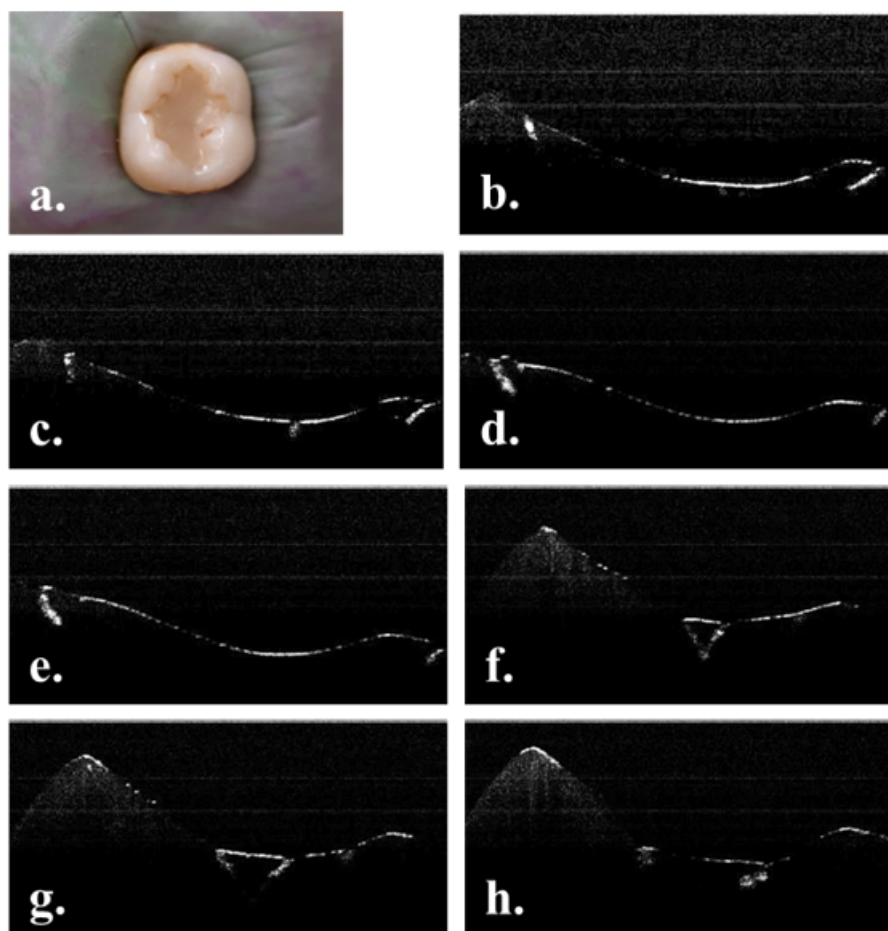


Fig. 5. Composite filling on a maxillary second molar (fig. 5; a). OCT 2 D images of the occlusal aspect of the tooth (fig. 5; b, c, d, e, f, g, h).

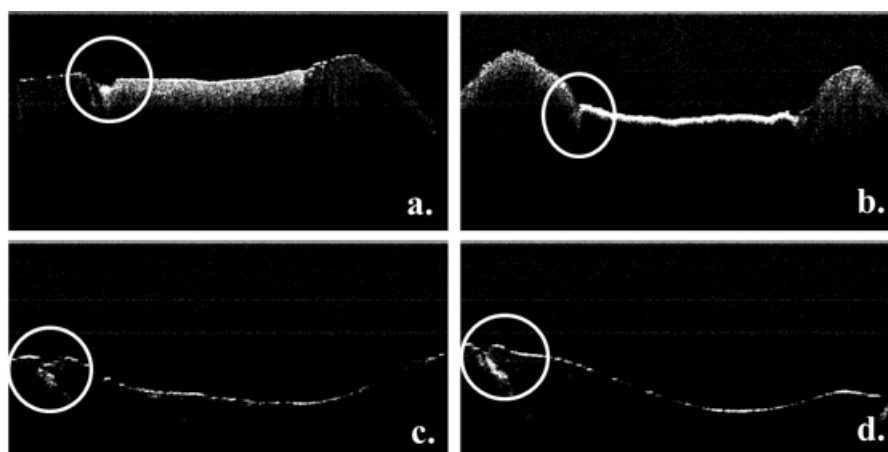


Fig. 6. Aspects of marginal gap on different types of filling on molars. a. Glass ionomer filling on molar (marginal gap of 350 μm); b. Amalgam filling on molar (marginal gap of 210 μm); c. Composite filling on first mandibular molar (marginal gap of 700 μm); d. Composite filling on first mandibular molar (marginal gap of 700 μm).

over time as a result of the formation of corrosion products [24]. This fact is highlighted by the OCT imaging of the amalgam restoration, pictured in figure 3, where cannot be observed marginal leakage. Although amalgam has a brighter image of the restoration, the marginal fit of the restoration could be observed on the OCT 2D image.

In a randomized clinical trial, longevity of amalgam and composite direct posterior restorations were compared on a span of 7 years [25]. The survival rate of amalgam restorations was 94.4%, higher than survival rate for composites, 85.5%. The major cause of failure for both types of direct dental restorations was secondary caries, with a risk quantified as 3.5 greater in composite group. The authors concluded that amalgam performed better than did composite, especially in large restorations. Amalgam is recommended in multisurface restorations of posterior teeth. These clinical results are correlated with the reduced marginal gap of amalgam restorations observed on OCT images in our study.

A Cochrane systematic review published in 2014 examined restoration failure of direct composite fillings versus amalgam fillings [26]. The results from two parallel group trials used to draw conclusion in this review indicated a higher risk failure of resin composite restorations compared to amalgam restorations, and also an increased caries risk. Even if this review considered a low-quality evidence for a better performance of amalgam compared with composites, the authors reinforced the benefit of amalgam restorations. Although without a difference in adverse effects between composite and amalgam, amalgam use will be reduced as a consequence of Minamata Convention on Mercury [27].

With the advantage of tooth colour, resin composites proved to be a reliable replacement material for amalgam, yet the direct restoration has to comply with some specific requirements in order to obtain optimal results. A major obstacle was marginal gap resulted from composite shrinkage after polymerization. Restorative materials based on composite resins contract during the polymerization process, creating a gap at the resin-tooth interface, or a crack in the enamel at the cavosurface margin [28]. The magnitude of the polymerization contraction depends on many factors, including: the geometry of the prepared cavity, the properties of the resin composite material, and the polymerization strategy [29]. According to Christensen [28], the chemical composition of the composite resin was most strongly associated with the polymerization shrinkage. The OCT images obtained in our study showed a larger marginal gap for composite fillings, which could be a consequence of polymerization shrinkage.

A recent study investigated the performance of dental amalgam comparative with dental composite in extensive posterior restorations [30]. Different risk factors for restoration failure like age, sex, alcohol consumption, smoking, diabetes, periodontal status and also matrix metalloproteinase genetic polymorphisms were analysed [34-52]. Data obtained from this study showed similar rates of failure for amalgam and composites up to 5 years, the authors concluding that resin composites could replace amalgam for posterior extensive restorations. According to this study smoking tobacco, alcohol consumption and the presence of matrix metalloproteinase 2 (MMP2 or gelatinase A) were associated with higher rates of failure of composite direct restorations.

SS-OCT was used and validated as an alternative non-invasive method to assess marginal gap of resin composite fillings [31, 32]. A clinical study [33] analysed resin composite direct restorations with SS-OCT in a group of 52

patients. Marginal adaptation, large porosity and gap formation were investigated. The results showed that only 18.9% of restorations had no defects, and 65.2% of restorations had problems of marginal fit. Their results are correlated with our results.

The value of the study relies on the first comparative analysis of marginal gap at tooth-filling interface of glass-ionomer, amalgam and composite direct dental restorations. The study has its own limitations, gave by the small number of samples.

Conclusions

In posterior direct dental restorations, amalgam had the smallest marginal gap, followed by glass-ionomer cement, and after that by dental composite. OCT could be a valuable method to detect marginal restorations failure and secondary caries.

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