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Sealing performance of resin cements before and after thermal cycling: Evaluation by optical coherence tomography

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ABSTRACT

Objectives. Self-adhesive resin cements have been recently introduced; however, there is little data available on their long-term performance. In this in vitro study, swept-source optical coherence tomography (OCT) at 1310 nm center wavelength was used for monitoring adaptation of indirect resin restorations after thermal cycling.

Methods. Resin inlays were luted to class-I cavities of extracted human teeth using three resin cements; Clearfil SA Luting (SA; Kuraray), Bistite II DC or Multibond II (Tokuyama Dental). Each cement was applied with or without pre-coating of dentin by a self-etch adhesive (Clearfil SE Bond) and a low-viscosity microfilled resin. OCT imaging was performed after 24 h, after 2000 and after 10,000 thermocycles ($n = 5$). Selected samples were sectioned for interfacial observation by confocal laser scanning microscope (CLSM). Floor adaptation (percentage) was analyzed by software on 20 B-scans throughout each specimen, and subjected to statistical analysis by three-way ANOVA test at a significance level of 0.05.

Results. Resin cement type, resin coating and thermal aging all significantly affected adaptation ($p < 0.05$). Initially, SA showed the highest adaptation; however, thermal aging significantly affected its sealing. The best results for all the cements were consistently achieved when the resin coating technique was applied where no deterioration of interfacial integrity was observed in the coated groups. CLSM closely confirmed OCT findings in all groups.

Significance. OCT could be used for monitoring of composite inlays with several interfacial resin layers. The application of a direct bonding agent in the resin-coating technique improved interfacial sealing and durability of all resin cements.

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1. Introduction

The aesthetic aspect of dental treatment has become increasingly popular in the recent years, especially with the development of improved materials and adhesive techniques using composite resins. The indirect composite resin restoration technique involves extra-oral fabrication of an inlay and its placement with a resin cement. It has been reported that for large cavities, indirect restorations bear advantages over direct techniques such as improvements in anatomic form, contour, fracture resistance and wear resistance [1]. Furthermore, extra-oral fabrication aids in the relief of residual stresses and ensures that the negative effects of polymerization shrinkage are confined to the thin layer of resin cement [2].

On the other hand, it is believed that the viscous resin cements may not provide dentin bonding comparable to dentin-bonding system (DBS) used for direct composite [3–5]. This may affect the sealing ability of these cements and lead to lower penetration to tooth substrate and hence, lower bonding performances in comparison to DBS. Therefore, a resin coating technique for indirect restorations was introduced in which DBS and a low viscosity microfilled resin are applied to seal dentin surface after preparation, decreasing pulp irritation and postoperative sensitivity and improving bond strength [6–9]. Meanwhile, the effectiveness of this technique for the newly introduced resin cement products (such as self-adhesive resin cements) has not been investigated. The self-adhesive resin cement is proposed to simplify the cementation procedure; it bonds to dentin in one step without the need of conditioning or pre-treatment (priming) of the surface [10,11].

Adhesion tests have been routinely used for laboratory evaluation of these biomaterials. However, the success of a restoration also greatly depends on its sealing ability of the dental tissue in an actual cavity [12]. Different methods are conventionally used to evaluate the marginal integrity and sealing of restorations. The most common method is detecting dye penetration depth under a stereoscopic microscope and/or scanning electron microscope (SEM). However, these methods are considered as destructive methods since they require sample sectioning, and may be subjective. More recently, three-dimensional and in-depth imaging methods have been introduced and utilized for characterization of dental composites [13–18]. Optical coherence tomography (OCT) can provide noninvasive, high resolution cross-sectional images for biologic microstructures and materials based on light backscattering from within the structure. Dental composites and hard tissues are scattering media and therefore can be suitable substrates for OCT imaging [16–24]. Tooth-restoration interface under direct resin restorations has been investigated using this technique [18,19,21,25]; however, there are few reports on evaluation of indirect restorations.

Thermal cycling procedure has been accepted as an effective means of artificially aging composite restorations to study their interfacial characteristics in the long-term. In this regard, imaging of resin restorations by OCT before and after thermal aging appears to be an attractive research method. Therefore, the aim of this laboratory study was to evaluate the effect of thermal cycling and resin coating technique on the adaptation of indirect composite inlays luted with resin cements under OCT, and confirmation of OCT findings by cross-sectional confocal laser scanning microscopy (CLSM). The null hypotheses tested were as follows: (1) there was no difference in the interfacial sealing of the composites inlays between different resin cements; (2) the resin coating could not improve the interfacial integrity; and (3) There were no changes in the interfacial integrity of different test groups after thermal aging.

2. Materials and method

2.1. *Specimen preparation*

For this study, thirty extracted human third molars, free of cracks, caries and restorations were selected after the patients' informed consent, as approved by the Institutional Review Board of Tokyo Medical and Dental University, Human Research Ethics Committee, protocol no. 725. The root structure was removed below the cement-enamel junction and in order to expose a flat dentin substrate; the occlusal thirds were removed by trimming the crowns at right angles to the long axis of the teeth using a model trimmer (Y-230; Yoshida, Tokyo, Japan). Round class I cavities were prepared on the flat occlusal surfaces by using a cylindrical diamond bur attached to a high-speed air turbine under water coolant (carborundum points, 50 μm grain size, SHOFU, Kyoto, Japan). Finishing diamond burs were used afterward to have a fine surface finish (SF114, SHOFU, Kyoto, Japan). To maintain cutting efficacy, the bur was replaced every five preparations. The cavity was approximately 4 mm in width and 2 mm in depth. The teeth were then randomly divided into two groups of fifteen teeth each according to the surface treatment. For the first group (control group), dentin surface was kept untreated. In the second group (resin-coated group), the cavity surface was prepared using the self-etching bonding system, Clearfil SE Bond (Kuraray Noritake Dental, Tokyo, Japan) and a low viscosity microfilled resin (Clearfil Protect Liner F, Kuraray Noritake Dental, Tokyo, Japan). According to the manufacturer's instructions, SE primer was applied first to the cavity for 20 s and gently air dried. Then, SE bond was applied; mildly air dried and light cured for 20 s using a conventional halogen light curing unit (Optilux 501, Kerr, CA, USA; 550 mW/cm^2). After that, Protect Liner F was placed on the already cured adhesive surface with a brush and light cured for 20 s.

The cavities in both groups were then lined (covered) with a separating film (Pechiney Plastic Packaging, Chicago, IL, USA), filled with one increment of composite (Clearfil Majesty Posterior, Kuraray Noritake Dental, Tokyo, Japan), and light cured for 40 s using the light curing unit. After curing, the composite inlays were carefully removed from the cavities and checked for fit. The resin inlays were monitored under OCT prior to cementation and the defective ones were excluded and refabricated.

The prepared cavity surfaces in group 1 and the coated surfaces in group 2 were both temporized with a water-setting non-eugenol temporary filling material (Caviton EX, GC, Japan) and stored in an incubator at 37 °C in a humid condition to simulate the clinical situation for indirect composite restorations. After 24 h, the temporary filling material was carefully