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Non-destructive evaluation of an internal adaptation of resin composite restoration with swept-source optical coherence tomography and micro-CT

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ABSTRACT

Swept-source optical coherence tomography (SS-OCT) and micro-CT can be useful non-destructive methods for evaluating internal adaptation. There is no comparative study evaluating the two methods in the assessment of internal adaptation in composite restoration.

The purpose of this study was to compare internal adaptation measurements of SS-OCT and micro-CT. Two cylindrical cavities were created on the labial surface of twelve bovine incisors. The 24 cavities were randomly assigned to four groups of dentin adhesives: (1) three-step etch-and-rinse adhesive, (2) two-step etch-and-rinse adhesive, (3) two-step self-etch adhesive, and (4) one-step self-etch adhesive. After application, the cavities were filled with resin composite. All restorations underwent a thermocycling challenge, and then, eight SS-OCT images were taken using a Santec OCT-2000™ (Santec Co., Komaki, Japan). The internal adaptation was also evaluated using micro-CT (Skyscan, Aartselaar, Belgium). The image analysis was used to calculate the percentage of defective spot (%DS) and compare the results. The groups were compared using one-way ANOVA with Duncan analysis at the 95% significance level. The SS-OCT and micro-CT measurements were compared with a paired *t*-test, and the relationship was analyzed using a Pearson correlation test at the 95% significance level.

The %DS results showed that Group 3 ≤ Group 4 < Group 1 ≤ Group 2 on both SS-OCT and micro-CT images. The %DSs on micro-CT were lower than SS-OCT ($p < 0.05$) and the Pearson correlation coefficient between SS-OCT and micro-CT was $r = 0.787$ ($p < 0.05$).

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1. Introduction

Polymerization shrinkage of the resin composite can create open margins at the outer interface of the restoration and can also affect the integrity of internal adaptation between the resin composite and the tooth substrate [1]. Marginal microgaps can be identified by inspection from the outside. However, detecting internal defective interfaces caused by polymerization shrinkage requires other techniques. To find the microgaps inside a tooth, dye and tracer penetration methods have been used [2,3]. Tracers, such as methylene blue, rhodamine, erythrosin and silver nitrate, can be infiltrated into teeth. These methods are very simple and definite, but the restorations must be cut for examination [4]. In addition, once the teeth are sectioned, they cannot be evaluated again. Another drawback of this method is that some degree of dentin staining should be differentiated from actual microleakage between the cavity and restoration [5].

Current dentin bonding systems can be divided into two categories: etch-and-rinse system and self-etch system. Etch-and-rinse adhesives may be three-step or two-step system. Self-etch adhesives can be two-step or one-step system. Three-step etch-and-rinse adhesives are generally considered the gold standard when they are compared with other systems. Although two and three steps etch-and-rinse adhesives show similar strength of dentin bonding immediately following application, long-term bond strength was found to be different between the two adhesives [6]. As two-step etch-and-rinse adhesive has combined hydrophilic components of primer and hydrophobic components of bonding agent, it makes its hybrid layer semipermeable [7]. This characteristic influences long-term bond strength negatively. Two-step self-etch adhesives can have a problem with enamel bonding. If two-step self-etch system with mild or moderate acidity ($pH > 1$) is applied, there cannot be the same extent of demineralization obtained with the use of phosphoric acid [8]. One-step self-etching adhesives are known to have several shortcomings; a reduced immediate bond strength, lower long-term effectiveness, phase-separation, enhanced water-sorption and increased nanoleakage [9]. For their different features, these dentin bonding systems may not show the same extent of internal adaptation.

Optical coherence tomography (OCT) was introduced as a non-invasive cross-sectional imaging method for biological systems [10,11]. It provides real time visualization of the restoration or tissue without the need of X-ray radiation exposure. After a laser source is projected over a restoration, the backscattered light is transformed into a signal intensity that can be shown as an image. OCT is based on the coherent properties of light. The OCT signal is based on the interference of light reflections from the reference mirror and backscattered light from the tissue. It shows cross-sectional images based on the depth-resolved optical reflective property. OCT is a non-invasive method that can be used for different purposes such as detecting dental caries or cracks [12,13]. A specific type of OCT is a swept-source optical coherence tomography (SS-OCT). SS-OCT has a better image resolution and scanning speed using a wavelength-tuned laser as the light source [14]. It should be noted that the imaging depth of OCT is limited to less than 3 mm of tissue.

The OCT system has been utilized to investigate the cavity floor for the evaluation of internal adaptation. On the OCT image, interfacial microgap is observed as bright spot or line with high signal intensity [15,16]. The change in the signal intensity at the interface appears as a white cluster on the image. When light passes the interface between two media with different refractive indices, a portion of light is reflected. This is known as the Fresnel phenomenon and depends on the incidence angle and refractive index (n). The refractive index of air is 1.0 (n) and that of a tooth or resin composite is 1.5–1.6 (n) [17]. If there is a microgap formed by incomplete adhesion, air or water may exist at the interface. When light transverses the air at the interface, a portion of light is reflected and the OCT system shows a higher signal intensity. If the microgap is filled with another medium, such as water 1.33 (n), the reflection would not be as strong as that of the air.

Microfocus X-ray computed tomography (micro-CT) is another useful method to evaluate the internal adaptation of restorations [18]. Recently, Kwon and Park proposed a method in which silver nitrate was penetrated from the pulp space through the dentinal tubules, and the amount of silver nitrate penetration was assessed by micro-CT [19]. The authors reported it as a new measuring method for evaluating the internal adaptation without any destruction. In another study, the internal adaptation of dentin-composite was analyzed using micro-CT, and the correlation of internal adaptation with polymerization shrinkage was evaluated [20]. Due to the penetrating ability of X-rays, micro-CT enables the evaluation of dental hard tissue irrespective of its depth.

Micro-CT and SS-OCT can be useful non-destructive methods for evaluation of internal adaptation. There are currently no comparative studies evaluating the two methods in the assessment of internal adaptation in composite restoration. The purpose of this study was to compare internal adaptation from SS-OCT and micro-CT. For this purpose, bovine cavities were restored with resin composite using different adhesive systems, and the internal adaptation was evaluated using SS-OCT and micro-CT.

The null hypotheses tested in the study were the following:

(1) There is no difference in internal adaptation among the restorations in which different dentin adhesive systems are used
(2) There is no difference between the internal adaptations measured by SS-OCT and those measured by micro-CT.

2. Materials and methods

2.1. *Specimen preparation*

This study used twelve extracted bovine mandibular incisors. The labial surface of each tooth was flattened with a trimmer and 600-grit sandpaper. Two round cylinder-shaped class I cavities (3 mm diameter, 2 mm depth) were made on the labial surface of each tooth. First, a flat-end tapered diamond burr attached to a high-speed air-turbine handpiece and a water