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Assessment of current adhesives in class I cavity: Nondestructive imaging using optical coherence tomography and microtensile bond strength

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ABSTRACT

Objectives. To evaluate the sealing ability and the microtensile bond strength (MTBS) of different adhesive systems bonded to dentin in class I cavities.
Methods. Round tapered dentin cavities (3-mm diameter, 1.5-mm height) prepared in extracted human molars were restored using composite resin (Clearfil Majesty Posterior) with two-step etch-and-rinse adhesive system (Adper Single Bond 2: ASB2), two-step self-etch adhesive (Clearfil SE Bond: CSEB), all-in-one adhesives (G-Bond Plus: GBP; Tri-S Bond Plus: TSBP), or no adhesive (Control), or bonded using low-shrinkage composite with its proper adhesive (Filtek Silorane, Silorane Adhesive System: FSS). After 24-h water storage or 10,000 cycles of thermal stress, the specimens were immersed into a contrast agent. Two and three-dimensional images were obtained using optical coherence tomography (OCT). The mean percentage of high brightness (HB%) at the interfacial zone in cross-sectional images was calculated as an indicator of contrast agent or gap at the interface. The specimens were then sectioned into beams and the MTBS measured.
Results. The HB% (ASB2 = TSBP = CSEB < FSS = GBP) and MTBS (CSEB = ASB2, CSEB > TSBP = GBP = FSS, ASB2 > FSS) differed significantly among the adhesives. After aging, HB% increased for GBP and FSS specimens, and the MTBS decreased for FSS specimens

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(ANOVA, Tukey's post hoc, $p < 0.05$). The HB% and MTBS were significantly and negatively correlated ($p = 0.002$). Confocal laser scanning and scanning electron micrographs confirmed contrast agent infiltration within the gap.

Significance. There was a significant correlation between sealing performance and bond strength of the adhesives in the whole cavity. After aging, the two-step systems showed equal or superior performance to the all-in-one and Silorane systems.

1. Introduction

Restorative dentistry has evolved in recent years with improvements in resin composite and adhesive formulations. However, polymerization shrinkage of methacrylate-based resin composites during curing may result in contraction stress and a loss of marginal adaptation [1]. The main challenge for dental adhesives is to provide an equally effective bond to both the tooth tissue and resin composite. Inadequate marginal sealing of the restoration can lead to microleakage [2], postoperative sensitivity [3], and debonding [4], which ultimately reduce the longevity of the restoration.

The bonding performance of restorative systems can be evaluated by various parameters, including marginal adaptation, bond strength, and the interaction with the tooth substrate [5]. Marginal adaptation tests often require multiple sectioning of the samples, followed by immersion into a staining solution, and surface polishing before observation using light microscopy, or scanning electron microscopy (SEM), or ultrathin sectioning for observation using transmission electron microscopy (TEM) [6–8]. These procedures are time-consuming and are limited to *in vitro* studies. Microtensile bond strength tests are also commonly used to evaluate the strength of resin-tooth tissue bonds [9,10]; however, the clinical significance of this test over time is unknown [11].

Optical coherence tomography (OCT) has been proposed as a new non-destructive method of producing high-resolution, cross-sectional images of the internal biological structures at the micron scale [12]. Recently, this technology has been applied in dentistry to characterize caries [13–15], assess gaps between the composite-tooth interface in two-dimensional (2D) and three-dimensional (3D) images [16,17], and evaluate voids and internal defects in restorations [18]. While several studies have evaluated the marginal adaptation of the restorations using OCT [16,17,19–21], few studies have investigated the association between OCT findings and the bond strength [22].

Based on these concerns, in the current study, we evaluate the sealing ability and the bond strength of different restorative systems in class I cavities after 24 h or 10,000 thermocycles using OCT. Silver nitrate solution was used as an infiltrating agent to enhance the contrast in OCT images [17]. The null hypotheses were that there was no difference in sealing ability between all adhesives tested, and there was no relationship between the sealing ability and bond strength.

2. Materials and methods

2.1. Specimen preparation

Thirty-six extracted intact human third molars were used according to the guidelines set by the Ethics Committee of Tokyo Medical and Dental University (Protocol number 725). The occlusal one-third and root of each tooth were cut with a diamond saw (Isomet, Buehler Ltd., Lake Bluff, IL, USA) underwater. The exposed coronal flat dentin surface was polished with 600-grit silicon carbide paper under running water to ensure that the enamel isles were completely removed. Standardized class I cavities (3 mm diameter × 1.5 mm deep) with rounded margins located in the occlusal dentin, tapered walls, and angled at approximately 130° were created using a flat-end, tapered cylinder diamond bur (custom-made FG#3132, KG Sorensen, Cotia, SP, Brazil) and finished with a fine diamond bur (FG #3132F, KG Sorensen). The bur was attached to a high-speed air turbine hand piece, and the cavities were prepared under water coolant.

The cavities were randomly assigned to six groups ($n = 6$ per group) according to the material used: two-step, etch-and-rinse adhesive using Adper Single Bond 2 (ASB2; 3M ESPE, St. Paul, MN, USA); two-step, self-etch adhesive using Clearfil SE Bond (CSEB; Kuraray Noritake Dental, Tokyo, Japan); all-in-one adhesive using G-Bond Plus (GBP; GC Corp., Tokyo, Japan); all-in-one adhesive using Tri-S Bond Plus (TSBP, Kuraray Noritake Dental); and no adhesive (Control). The cavities were then restored with resin composite; Clearfil Majesty Posterior (Kuraray Noritake Dental). The last group was restored with a low-shrink composite and its silorane-based adhesive system; Filtek Silorane Adhesive System (FSS; 3M ESPE). The specimens were prepared according to each manufacturer's instructions (Table 1) and cured using a halogen light curing unit (Optilux 501, Kerr, CA, USA; 600 mW/cm^2 intensity). After polymerization, all the specimens were slightly polished once more with 2000-grit silicon carbide paper to remove the excess of resin composite and standardize the occlusal surface. The specimens were stored in water at 37 °C for 24 h.

2.2. Thermocycling procedure

Half of the specimens in each group were randomly selected to undergo thermocycling ($n = 3$/per material). The specimens were fatigued with 10,000 thermocycles between 5 °C and 55 °C at a dwell time of 30 s per temperature and a transfer time of 4 s between baths (K178-08 Tokyo Giken, Tokyo, Japan).