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Immediate *versus* water-storage performance of Class V flowable composite restoratives

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ABSTRACT

Objectives. The aims of this investigation were to clarify the effects of 24 h water-storage and finishing time on mechanical properties and marginal adaptation to a Class V cavity of eight modern flowable resin-composites.

Methods. Eight flowable composites, plus two controls (one microfilled and one hybrid composite), were investigated with specimen sub-groups ($n = 10$) for each property measured. The principal series of experiments was conducted in model Class V cavities with interfacial polishing *either* immediately (3 min) after setting *or* after 24 h water-storage. After the finishing procedure, each tooth was sectioned in a buccolingual direction through the center of the restoration, and the presence or absence of marginal-gaps was measured (and then *summed* for each cavity) at 14 points (each 0.5 mm apart) along the cavity restoration interface ($n = 10$ per group; total points measured = 140). The shear bond-strengths to enamel and to dentin, and flexural strengths and moduli data were also measured at 3 min *and* after 24 h water-storage.

Results. For all flowable composites, polished immediately after setting, 14–30 *summed* gaps were observed (controls: 64 and 42). For specimens polished after 24 h, a significantly ($p < 0.05$) reduced number of 8–17 *summed* gaps occurred for only 3 flowable composites; whereas for 5 flowable composites there were *non*-significantly-different ($p > 0.05$) numbers (11–17) of *summed* gaps (controls: 28 and 22). After 24 h storage, shear bond-strengths to enamel and to dentin, flexural strengths and moduli increased highly significantly ($p < 0.001$) for all materials, except Silux Plus.

Significance. A post-cure interval of 24 h resulted in enhanced mechanical and adhesive properties of flowable dental composites. In a minority of cases there was also a reduced incidence of marginal-gap formation. However the latter effect may be partly attributed to 24 h delayed polishing, even though such a delay is not usual clinical practice.

1. Introduction

Marginal adaptation and bonding of restorative filling materials to the tooth cavity may not be secure in the initial stage. Restoration failure may occur immediately after setting or during the initial stage of restoration [1] and early gaps may lead to bacterial penetration and pulpal damage [2,3]. Therefore, protocols for measuring marginal-gap formation were devel-

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oped to evaluate the marginal adaptation of resin-composite restorations. The incidence of gap-formation with composites in a butt-joint cavity may be determined by: (1) the adhesion-forces between the restorative material and cavity walls, (2) the volumetric-shrinkage magnitude of the restorative materials and (3) their viscosity or ability to flow. Polymerization shrinkage and flow were found to be significant determinants of gap-formation around resin-composite [1,4,5]. In the initial stage of setting, when a restorative material still adheres to the cavity walls, the shrinkage may be released as a flow of material from the free surface. Comparing restorative materials with the same volumetric shrinkage, but with different fluidity, the flow from the free surface will decrease with decreasing fluidity of the restorative material and consequently give an increased contraction at the margin.

A new class of low-viscosity resin-composites, commonly called "flowable composites", has become established for restorative dentistry. Flowability is regarded as a desirable handling property which allows the material to be injected through small-gauge dispensers, thus simplifying the placement procedure and amplifying the range of possible clinical applications. These have been critically reviewed in relation to usefulness beyond flow, after a preliminary screening of in vitro physical properties [6,7]. These authors expressed some concern regarding their inferior mechanical properties when compared to traditional hybrid composites, and discouraged their use in high-stress applications. However, composites with a lower filler-content and/or elastic modulus have shown better marginal sealing in Class V restorations compared to composites with a higher filler-content [8,9], and it is generally accepted that using materials with a low modulus of elasticity reduces the cervical gap-formation and marginal leakage. Microfilled composites with a relatively low elastic modulus, have also been speculated to reduce stresses at the adhesive interfaces generated by occlusal forces associated with cervical lesions [10]. Therefore, flowable composites might be expected to demonstrate reduced marginal-gap formation in Class V restorations.

Contemporary self-etching adhesives and the recently introduced all-in-one adhesives vary in their acidity by differences in the composition and concentration of polymerizable acids and/or acidic resin-monomers. They are generally less technique sensitive compared with systems that utilize separate acid-conditioning and rinsing steps [11–14]. Masticatory and parafunctional stresses vary markedly in different clinical situations. Thus, thresholds in mechanical properties needed for success may vary considerably from case to case, with stronger restorative materials being required where greater stresses are anticipated. Flexural tests are appropriate to assess the mechanical properties of restorative materials [5,6,15,16]. In our previous studies [15–17], restorative materials and luting agents were proposed to improve their marginal seal or gap-formation by enhancement of their flexural strength during 24 h after light-activation. Moreover, delaying the finishing procedure for 24 h resulted in reduced gap-formation for Class V restorations of conventional and resin-modified glass-ionomers and a microfilled composite [18,19].

The principal aims of the present study, therefore, were: (1) to evaluate both gap-formation integrity around butt-joints in model restorations, analogous to Class V, with self-etching adhesives, compared to microfilled and hybrid types, using conventional bonding agents; and (2) determination of the early development of their flexural and adhesive properties. An important clinical variable was to be assessed in this connection: namely, the effect on these properties of an immediate *versus* a 24 h delayed finishing procedure. Hence, a major hypothesis to be tested was that *premature finishing would significantly reduce gap-formation integrity*, *relative to delayed finishing*. Flexural properties and shear bond-strengths, to both enamel and dentin substrates, were also to be measured to further elucidate the effects of the 24 h delay and to discriminate between flowable and conventional resin-composite restorative types.

2. Materials and methods

Ten light-activated restorative materials, including eight flowable composites, one microfilled composite and one hybrid composite, as controls, are listed in Table 1. This range of materials was not only representative of major clinical types but provided a range of values for the parameters under investigation. Tooth preparation procedures, bonding, mixing and handling were carried out according to the manufacturers' recommendations (Table 2). A visible-light curing unit (New Light VL-II, GC, Tokyo, Japan; irradiated diameter: 8 mm) was used for light-activated materials with an irradiation time of 40 s. The irradiance was checked immediately before each application of the adhesive-resin and restorative material, using a radiometer (Demetron/Kerr, Danbury, CT, USA). During the experiment the irradiance was maintained at 450 mW/cm^2. Human premolars, extracted for orthodontic reasons, were used throughout this study. After extraction and cleaning, teeth were immediately stored in cold distilled water at 4 °C for 1–2 months before testing, then mounted in a holder using a slow setting epoxy resin (Epofix Resin, Struers, Copenhagen, Denmark).

2.1. *Class V restoration*

Cavity preparations were placed in the premolar teeth on the facial surface (Fig. 1). A cylindrical cavity was prepared with a tungsten carbide bur (200,000 rpm) and a fissure bur (8000 rpm) under wet conditions to a depth of 1.5 mm with a diameter of 3.5 mm. A cavity preparation was placed parallel to the cemento-enamel junction (CEJ) with the preparation extended 1.0 mm above the CEJ (Fig. 1). Cavosurface walls were finished to a butt-joint. This design differed from a Class V clinical cavity in that cavity corners were geometric-box angles to prepare a constant-volume model. One cavity was prepared in each of 200 teeth (10 materials × 2 polishing or inspecting times × 10 repeats = 200). The cavity walls and surrounding enamel margin were pretreated according to the manufacturers' instruction as described in Table 2. Each cavity was filled with various restorative materials using a syringe tip (Centrix C-R Syringe System, Centrix, CT, USA). Cavities were filled with mixed materials using a syringe tip (Centrix C-R Syringe System) and covered with a plastic strip and hardened by light-curing.