Cuspal deflection and depth of cure in resin-based composite restorations filled by using bulk, incremental and transtooth-illumination techniques

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Polymerization shrinkage of restorative resin-based composites has been associated with microleakage, debonding, secondary caries and postoperative sensitivity.[1-5] Among the techniques suggested to reduce polymerization shrinkage stress is the incremental placement of composite material, in which the clinician typically places the material in small increments of 2 millimeters or less and then photoactivates it from an occlusal direction.[6,7] Although the incremental technique may be necessary for adequate light penetration, its disadvantages include the possibility of trapping voids or contamination between layers and the increased time required to place the restoration. The benefit of using an incremental technique for reducing shrinkage stresses has been questioned on the basis of numerical and experimental analyses.[8,9] Idriss and colleagues[10] found no significant difference between bulk and incremental filling techniques when they examined marginal gap size in Class II composite restorations in vitro.

Besides filling techniques, the direction of shrinkage also often is regarded as an important factor in controlling shrinkage patterns in restorations. It once was believed that resin-based composite shrinks toward the source of light and thus could be manipulated to obtain a beneficial shrinkage orientation during photo-

ABSTRACT

Background. Restoration techniques affect shrinkage stress and depth of cure. The authors tested cuspal deflection and depth of cure resulting from the use of different techniques (bulk, incremental, bulk/transtooth illumination) and two resin-based composites (deep curing and conventional).

Methods. The authors restored extracted teeth with deep-curing X-tra fil (VOCO, Cuxhaven, Germany) (by using bulk and incremental techniques) and Filtek Supreme Plus (3M ESPE, St. Paul, Minn.) (by using bulk, incremental and bulk/transtooth-illumination techniques). The sample size for each technique was five. They determined cuspal deflections as changes in buccal and lingual surfaces before and after restoration. To determine the extent of cure, they measured hardness 0.5 to 3.5 millimeters deep on the sectioned restorations.

Results. The authors found no difference in cuspal deflection between filling techniques within the same materials ($P > .05$). They found no difference in hardness for X-tra fil at any depth with either the bulk or the incremental technique ($P > .05$). Filtek Supreme Plus had higher hardness values at depths of less than 1.5 mm with the bulk/transtooth-illumination technique, whereas the bulk technique resulted in lower hardness values at depths of 2.0 mm and below ($P < .05$).

Conclusions. Cuspal deflection was not affected by filling techniques. X-tra fil cured up to a depth of at least 3.5 mm; Filtek Supreme Plus had lower curing values below a depth of 2 mm. The transtooth-illumination technique improved curing depth for restorations placed in bulk.

Clinical Implications. When using resin-based composite restorative materials, clinicians should be more concerned about the effect of filling techniques on curing depth than about how these techniques affect shrinkage stresses.

Key Words. Composite; cuspal flexure; cure; bulk; increment; transtooth illumination; hardness.
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activation. Versluis and colleagues[11] pointed out that composite does not shrink toward the light and that, rather, the direction of shrinkage is determined predominantly by the presence or absence of a bond. This observation has been helpful for rationalizing curing protocols. Belvedere[12] proposed that a transenamel illumination technique involving light curing of a bulk-placed composite from buccal and lingual directions, and thus through the tooth enamel, can achieve the advantages of bulk placement while avoiding the disadvantages of incremental techniques. Light transmitted through the tooth structure initially polymerizes the most critical areas along the interfaces, establishing adequate bonding before polymerization shrinkage of the inner bulk interferes.[12]

Although low residual stress and good adaptation are important, thorough polymerization is an equally important consideration for any filling technique. The main concern regarding a bulk technique is whether the composite cures fully enough in the deeper portions to create a material that has acceptable physical and biocompatible properties. Using microhardness at various restoration depths as an indicator, Lazarchik and colleagues[13] showed that the extent of polymerization was not different between bulk-filled and incrementally filled restorations of a light-shade composite, whereas the bulk technique resulted in significantly lower microhardness values in a material of a darker shade. However, Amaral and colleagues[14] found no difference in microhardness at any depth between the bulk-placed or incrementally placed restorations, provided that the restorations were exposed to light from occlusal, buccal and lingual directions. Thus, the transtooth-illumination technique also may overcome the concern regarding depth of cure that is associated with bulk placement.

We conducted an in vitro study to investigate whether a bulk-placement technique affects shrinkage stress, and whether the clinician can prevent a compromised depth of cure by using a more deeply curing composite or by using the transtooth-illumination technique. Because shrinkage stress itself cannot be measured directly, we assessed its effect by measuring cuspal deflection of restored teeth. We assessed the extent of cure by measuring microhardness at various depths. To compare the effect of shrinkage stress between bulk-restored and incrementally restored teeth, we used a composite designed to cure up to a depth of 4 mm.

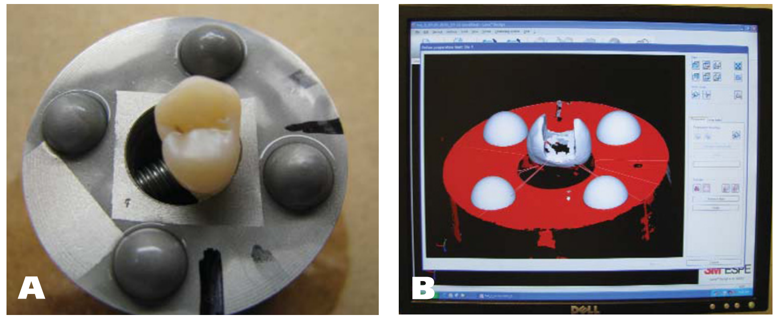

Figure 1. A. Mounted tooth in custom-made stainless steel ring with reference spheres. **B.** Cavity preparation, digitized with the LavaScan ST optical scanning system (3M ESPE, St. Paul, Minn.). Image B reproduced with permission of 3M ESPE.

This provided sufficient depth of cure to allow comparison of shrinkage stress effects from the two techniques. We used a conventional composite to compare the effects of transtooth illumination of a restoration placed in bulk with conventional bulk and incremental techniques.

METHODS

We chose for the study a hybrid composite that its manufacturer claims has a curing depth of 4 mm (X-tra fil, Universal shade, VOCO, Cuxhaven, Germany) and a nanocomposite (Filtek Supreme Plus, A2D shade, 3M ESPE, St. Paul, Minn.).

Sample preparation and digitization. The study protocol, which the institutional review board of the University of Minnesota, Minneapolis, designated as exempt, involved the use of 25 extracted human teeth. We secured the teeth in stainless steel rings (Figure 1A) and kept them immersed in water throughout the protocol to prevent desiccation. Each ring contained four embedded spheres surrounding the tooth sample, which functioned as stable reference areas. We sandblasted the spheres and etched the tooth enamel with 37 percent phosphoric acid solution to obtain dull surfaces suitable for optical scanning.

We prepared a large, slot-shaped mesioocclusodistal cavity (4 mm deep, 4 mm buccolingual width) with a no. 245 carbide bur in a high-speed handpiece under copious amounts of water. The mean (standard deviation [SD]) wall thickness, measured at the middle of the restoration wall, was 2.39 (0.34) mm. After preparation, we digitized images of the teeth along with their reference spheres with an optical scanning system (LavaScan ST, 3M ESPE); the digital models had an estimated resolution of 60 micrometers and 5-µm accuracy (Figure 1B). We calibrated the scanner each day before conducting the experiments.

ABBREVIATION KEY. TT: Transtooth.