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Effect of bulk/incremental fill on internal gap formation of bulk-fill composites

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ABSTRACT

Objectives: To examine the effects of composite type (bulk-fill/conventional) and placement (4-mm bulk/2-mm increments) on internal marginal adaptation of Class I preparations.
Methods: Cylindrical, Class I, 4-mm × 4-mm preparations were made on 50 recently extracted human molars and restored using either a bulk-fill (SureFil SDR Flow (SDR), Quixx (QX), SonicFill (SF), Tetric EvoCeram Bulk (TEC)) or a conventional composite designed for 2-mm increments (Filtek Supreme Ultra (FSU)). Restorations were placed in 1 or 2 increments using the manufacturer's bonding agent and curing light ($n = 5$). Teeth were sectioned occluso-gingivally and dye was placed on the internal margin and visually examined by 3 observers. Gap-free marginal lengths were analysed within three different regions of the sectioned tooth: enamel, mid-dentine, and pulpal floor.
Results: Marginal integrity was unaffected by placement method. Bulk-placement demonstrated significantly fewer gap-free margins at the pulpal floor than in enamel, for all materials except SDR. Greater percentages of gap-free margins were found within the mid-dentine than at the pulpal floor for FSU. QX had more gap-free margins in enamel compared with the mid-dentine. Proportion of gap-free margins within enamel and mid-dentine was not significantly different for any incrementally placed product. Excluding FSU, gap-free margins within enamel were significantly greater than at the pulpal floor. Notably, significantly more gap-free margins were found within mid-dentine than at the pulpal floor for SF.
Conclusions: No significant differences in gap-free margins were found between placement methods within a given product per location. Except for SDR, percentage of gap-free margins was significantly lower at the pulpal floor interface than at the enamel interface for bulk-fill.
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1. Introduction

Recently, several new restorative materials have been advertised as 'bulk-fill' composites. Many clinicians, however, have long adopted an incremental cure philosophy, when placing light-cured composites. In light of recent marketing efforts promoting "bulk-fill," light-cured composites, the judicious clinician should question what has changed that now allows composites to be placed in increments exceeding 2-mm thickness. The concept of "bulk-filling" a preparation is not a novel idea,[1] and has been evaluated numerous times in the literature.[2–5] Historically, several disadvantages of bulk-filling preparations with light-cured composites are recognised: the

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inability to adequately cure composite to depths greater than 2 mm,[6,7] challenges related to preparation design on the C-factor,[8,9] as well as potential complications due to polymerisation shrinkage and increased gap formation, both internally and at the cavo-surface margins.[8,10,11] The clinical implication of marginal gap formation is related to discomfort in conjunction with occlusal forces, which may be attributed to fluid accumulation within the gap and the subsequent fluid movement within the tubules.[12,13]

One reason for the recommended 2-mm thick incremental composite placement relates to compromised light penetration through this material, which is especially true when using darker shades.[6] While the surface of the composite is adequately cured, the material may not polymerise well in depth.[14,15] Insufficiently polymerised composite has been shown to be cytotoxic and may pose a negative risk to the longevity of the restoration.[16,17]

Cavity preparation design affects the internal stresses of light-cured composite restorations.[8] The C-factor refers to the ratio of bonded-to-unbonded restoration surfaces, with a direct correlation shown between preparation C-factor and internal polymerisation stress development at the bonded interface.[11] Placing and light-curing composite in increments is thought to decrease its total volumetric shrinkage, and to potentially decrease stresses resulting from this shape change.[3] Other studies however, challenge this concept.[18] If the force of polymerisation shrinkage exceeds the strength of the bonding agent and composite interface, then a marginal gap can form to accommodate this strain.[4] In addition, stress fractures in enamel and dentine have been observed and are thought to occur when the interfacial bond strength surpasses the physical properties of adjacent tooth structure.[19] Therefore, a variety of restorative techniques have been recommended to reduce polymerisation stress. One such strategy includes the use of liners/bases in the preparation.[20] A recent study detected internal marginal debonding events using acoustic emission and correlated shrinkage, modulus, and stress development with the potential for observing such events.[21] However, if marginal gaps do develop, they will compromise the long-term durability of the restoration and have the potential to create post-insertion sensitivity, increase the incidence of secondary caries, and encourage marginal staining.[11]

Marginal gap formation is the end product of a number of clinical factors. Poor placement techniques [18] and the variety of incremental and light curing scenarios may lead to such discrepancies as well as polymerisation shrinkage and the cumulative effects of polymerisation stress.[8] Marginal integrity has been evaluated using high magnification,[5,9,20] while other studies used penetrating dyes to reveal marginal gaps, both externally and internally.[9,22] In addition, the effects of using a variety of curing light types and various light exposure techniques on their potential to generate or minimise marginal gap formation and depth of cure have been studied.[6,14,23]

The recent introduction of many ''bulk-filled'' restorative materials has re-ignited the controversy of ''bulk vs incrementally'' placed composites. While the main interest in marketing this class of products is based on time and thus cost savings, other clinically related aspects are relevant as well. An ideal bulk-fill composite would be one that could be placed into a preparation having a high C-factor design and still exhibit very little polymerisation shrinkage stress, while maintaining a high degree of cure throughout. As a result, reduced polymerisation stress should minimise internal and external marginal gap formation, compared to conventional incrementally placed composites.

The newly developed ''bulk-filled'' resins claim to offer single increment placement thicknesses ranging from 4 to 6 mm, instead of the conventional 2 mm value commonly used. However, the potential development of internal marginal gap formation exists with bulk placement and the proportion of gaps relative to use of conventional 2-mm increments has yet to be determined. In addition, no studies have correlated use of the manufacturer-specific dentine bonding agent and manufacturer-specific curing light unit, as they relate to the potential for maintenance of internal interfacial margins. If the bulk-fill restorative materials are to provide a true clinical advantage, then they require high depths of cure while simultaneously demonstrating a decrease in internal stress, and subsequently decreased incidence of internal gap formation. Only products demonstrating such superior performance over the use of traditional, incrementally placed composites, should then be considered as viable alternatives.

The purpose of this research was to examine the potential for maintenance of gap-free internal interfacial bonds within the enamel, mid-dentine, and pulpal floor areas in controlled-size, Class I preparations made in extracted human molars when restored using a variety of the newly marketed ''bulk-filled'' products. Restorations were placed in either two, 2-mm thick increments, or as a single, 4-mm thick bulk-fill placement, utilising the respective manufacturer's total-etch bonding agent and curing light. The experimental control material was a conventional composite recommended for only 2-mm thick increments.

Three research hypotheses were tested: (1) for bulk-fill materials, marginal integrity at the enamel and mid-dentine restoration interfaces would not be significantly different with respect to type of fill (incremental or bulk), (2) at the pulpal interface, marginal integrity of the bulk-fill materials would be significantly better using the bulk fill technique than with use of the incremental fill technique, and (3) there would be no significant difference in marginal adaptation of the commercial product designed for incremental placement between bulk and incremental placement, except at the pulpal floor, where it is expected that bulk placement would result in less gap-free interface (more interfacial gaps) than when incremental placement was used.

2. Materials and methods

2.1. *Tooth preparation*

Freshly extracted, intact, non-carious and non-restored, human maxillary and mandibular molars were obtained from the Oral Surgery Department of the College of Dental Medicine at Georgia Regents University College of Dental Medicine. The protocol for use of teeth for this purpose was approved by the

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