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Comparison of photopolymerization temperature increases in internal and external positions of composite and tooth cavities in real time: Incremental fillings of microhybrid composite *vs.* bulk filling of bulk fill composite

Ryan Jin-Young Kim[a,1], Sung-Ae Son[b,1], Ji-Yun Hwang[c], In-Bog Lee[d], Deog-Gyu Seo[d,*]

[a] Department of Conservative Dentistry, Seoul National University Gwanak Dental Hospital, 1 Gwanak-ro, Gwanak-gu, Seoul, South Korea
[b] Department of Conservative Dentistry, School of Dentistry and Dental Research Institute, Pusan National University, 20, Geumo-ro, Mulgeum, Yangsan, Gyeongnam, South Korea
[c] Nutrition Education Major, Graduate School of Education, Sangmyung University, 20 Hongjimun 2-gil, Jongno-gu, Seoul, South Korea
[d] Department of Conservative Dentistry and Dental Research Institute, School of Dentistry, Seoul National University, 101 Daehak-ro, Jongno-gu, Seoul, South Korea

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ABSTRACT

Objectives: This study evaluated temperature increases in the composite and pulpal side of dentin from incremental and bulk fillings in composite restorations.
Methods: Class-1 cavities (5 mm × 4 mm × 3 mm) were prepared in ten extracted third molars, filled with composite, and restored with two separate horizontal layers of Filtek Z250 (3M ESPE) in the incremental group or a single layer of SureFil SDR Flow (Dentsply) in the bulk-fill group ($n = 5$). After placing the specimens in a 36.5 °C water bath, temperatures were measured with eight thermocouples at the bottom center (BC), middle center (MC), top center (TC), bottom corner (BE), middle corner (ME), and top corner (TE) of the cavity, at the pulpal side of the dentin within the pulp chamber (PD), and in the curing light (CL) tip during light curing at 750 mW/cm^2 for 20 s and then analyzed with one-way analysis of variance and Tukey's HSD tests ($\alpha = 0.01$).
Results: Maximum temperatures ranged from 39.0 °C (PD 1st increment) to 60.0 °C (MC 1st increment) in the incremental group and from 42.0 °C (PD) to 74.9 °C (TC) in the bulk-fill group. In the incremental group, temperatures were similar between the 1st and 2nd increments, except at MC and BC.
Conclusions: Bulk-fill group exhibited a greater increase in temperature during composite restoration. Regardless of the filling technique, more heat was generated at the center than at the corner and at the top than at the bottom of the composite. PD temperatures increased by 3.1 °C and 5.5 °C in the incremental group and bulk-fill group, respectively.
Clinical significance: Although bulk fillings save clinical chair time, clinicians should be aware of the greater heat that is generated with increasing amounts of composites during polymerization, which can jeopardize the pulpal health, especially when a large and deep cavity is being restored.

1. Introduction

Composite resins are the direct restorative material that is most commonly placed because of its superior esthetics and ability to adhere to the tooth with proper application of bonding agents. Composites, however, inevitably shrink during polymerization, and this generates stress at the tooth and composite interface. Debonding occurs at the interface when the shrinkage stress exceeds the bond strength [1]. As a result, a number of problems, such as discoloration, hypersensitivity, secondary caries, and pulp inflammation, may arise. In order to minimize the harmful stress from polymerization shrinkage, the incremental technique, in which each layer of a 2-mm-thick composite is light cured, is recommended. This technique allows the flow of the composite from the unbonded surface to the

* Corresponding author. Fax: +82 2 2072 3859.
E-mail address: dgseo@snu.ac.kr (D.-G. Seo).
[1] These authors contributed equally to this work.

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bonded interface, thus relieving the stress at the tooth-composite interface [2,3].

Bulk-fill composites have been developed to simplify the rather cumbersome and time-consuming incremental layering. The composites contain modified monomers and fillers that allow high light-transmission [4], which in turn allow the placement of a single bulk layer and adequate photopolymerization up to a depth of 4–5 mm. In addition, bulk-fill composites, especially low-viscosity (flowable), have been shown to exhibit lower shrinkage stress [5] and cuspal deflection [6] compared with the conventional type.

Irrespective of the type of composite, heats production during polymerization is another disadvantage of composite material because excessive heat during dental procedures may cause pulp inflammation, pulp necrosis [7,8], or even bone resorption and tooth ankylosis [9]. Exothermic reactions of the composite resin and radiant heat from the light-curing unit contribute to heat production [10].

Temperature increases during the polymerization of composite resin have been measured with differential scanning calorimetry [11], differential thermal analyses [12,13], infrared thermography [14,15], thermistors [16,17], and thermocouples [18–25]. However, these studies measured the temperature changes only at the bottom surface of the composites [16,17,19], at the pulpal surface of the dentin [20,21,23,24], or at the center of the composites [18,22]. Chang et al. [26] performed temperature measurements at multiple spots in a Class-II cavity with infrared thermography. However, they measured the temperatures only on the external surface of the cavity in the Teflon mold.

No studies to date have evaluated the simultaneous temperature changes at various sites within the composite and pulp chamber with multiple thermocouples during the composite restoration of human teeth with different filling techniques (bulk fill *vs.* incremental fill). Therefore, the aims of the present study were the following: (1) to evaluate the influences of incremental *vs.* bulk placement of the composite on the temperature increases and (2) to compare the temperatures at various sites within the composite resin and pulpal chamber during composite restoration in real time with multiple thermocouples. The null hypotheses of this study were that the temperatures would not vary with filling method between incremental and bulk placement and that the temperatures measured at various sites would not be different.

2. Materials and methods

2.1. Specimen preparation

The experimental setup is shown in Fig. 1. Ten caries-free third molars were extracted and used in the study. This study protocol was fully approved by the Institutional Review Board of Seoul National University Dental Hospital (No. ERI13002). The occlusal surface of each tooth was ground to a flat surface, and Class I-cavities (mesiodistal length, 5 mm; buccolingual width, 4 mm; depth, 3 mm) were produced on the tooth surface with a flat-end cylindrical diamond bur. The specimens were randomly assigned to two groups of five teeth that were treated with different filling methods (incremental filling *vs.* bulk filling). In order to standardize the remaining dentin thickness, the lower portion of the crown was horizontally sectioned 3.5 mm below the occlusal surface of the cavity, thus leaving 0.5 mm of dentin between the cavity floor and the horizontally sectioned external surface.

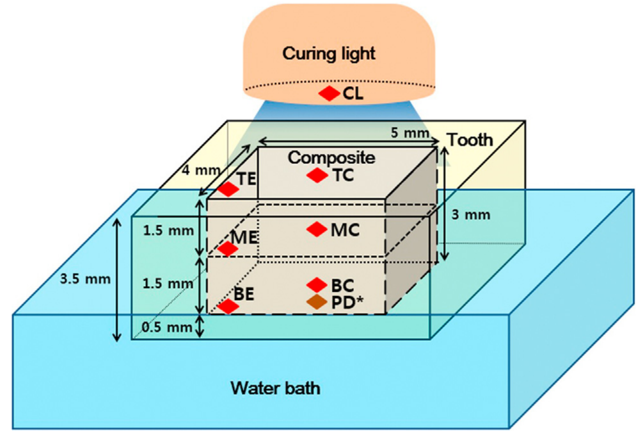

Fig. 1. Schematic diagram of the specimen set up showing the positions of the thermocouples and the dimensions of the tooth cavity. An asterisk indicates that the thermocouple at the pulpal side of the dentin within the pulp chamber (PD) was positioned underneath the remaining 0.5-mm-thick dentin that was in contact with water.
BC, bottom center; MC, middle center; TC, top center; BE, bottom corner; ME, middle corner; TE, top corner of the cavity; PD, pulpal side of dentin in the water bath; and CL, center of the curing light tip.

Temperature measurement sites were assigned according to the position of the thermocouples, as shown in Table 1 and Fig. 1. Two vertical grooves (one for the measurement sites at the bottom center (BC), middle center (MC), and top center (TC) and another for the measurement sites at the bottom corner (BE), middle corner (ME), and top corner (TE)) that extended from the occlusal surface to the bottom of the cavity were made in each tooth by cutting the corners of the teeth with a diamond bur in order to accommodate K-type thermocouples with a 0.5-mm diameter (TT-K-36, OMEGA Engineering, Inc., Stamford, CT, USA) within the cavity. A flowable composite resin (Charisma, shade A2, Lot 10128, Heraeus Kulzer GmbH, Hanau, Germany) was applied around the thermocouple wires within the grooves and light cured for 20 s in order to secure the thermocouples, which were then connected to a thermocouple conditioner and set point controller (AD597, Analog Devices, Inc., Norwood, MA, USA). An additional measurement site was located in the curing light (CL) tip during light curing. The thermocouple signals were digitized in real time with a data acquisition board (cDAQ-9174, National Instruments Co., TX, USA) that was equipped with an analog input module (NI 9205, National Instruments Co.)

Table 1
Measurement sites during incremental filling and bulk-filling of composite.

Code	Incremental filling	Bulk filling
BC	Bottom center of 1st layer	Bottom center of cavity
MC	Top center of 1st layer	Middle center of cavity
TC	Top center of 2nd layer	Top center of cavity
BE	Bottom corner of 1st layer	Bottom corner of cavity
ME	Top corner of 1st layer	Middle corner of cavity
TE	Top corner of 2nd layer	Top corner of cavity
PD	Bottom center on pulpal aspect of dentin (underneath the 0.5 mm thick remaining dentin)	
CL	Curing light guide tip	