

Original Article



Preheating Bulk-Fill Composite Resins: Effects on Microtensile Bond Strength to Dentin in High C-Factor Cavities

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Abstract

Introduction: Preheating composite resins has been suggested as a practical strategy to reduce material viscosity and improve adaptation to cavity walls. This approach may be particularly advantageous in deep Class I cavities with a high C-factor, where reliable dentin bonding remains challenging. Nevertheless, evidence on the influence of composite resin preheating on the dentin bond strength of bulk-fill composite resins under these conditions remains limited. Therefore, this study evaluated the effect of composite resin preheating on the microtensile dentin bond strength of a bulk-fill composite resin in such cavities.

Methods: Thirty-six sound human mandibular third molars, extracted for orthodontic reasons, were included in this in vitro study. After debridement, the cusps were removed to obtain flat occlusal surfaces. Following acid etching and adhesive application, a 1-mm-thick composite resin layer was placed on the occlusal surface. Class I cavities were then prepared with the pulpal floor located in the mid-dentin region. The specimens were randomly allocated to two groups based on the composite resin preconditioning temperature. Composite resin syringes (x-tra fil) were stored in distilled water at either 23°C or 60°C for 30 minutes before placement. The cavities were subsequently restored, and the specimens were subjected to thermocycling prior to microtensile bond strength testing. Bond strength values (MPa) were compared using an independent-samples t-test.

Results: The preheated composite group demonstrated significantly higher microtensile bond strength than the room-temperature group ($P=0.002$).

Conclusion: Preheating the x-tra fil bulk-fill composite to 60°C significantly enhanced microtensile dentin bond strength in deep Class I cavities. Further studies are required to confirm the clinical relevance.

Introduction

Increasing patient demand for esthetic restorations, along with advances in adhesive dentistry and composite resin technology, has led to the extensive use of tooth-colored restorative materials, particularly composite resins.¹ High-viscosity bulk-fill composite resins were introduced to enable placement in increments of up to 4–5 mm while providing adequate depth of cure and favorable mechanical properties.^{2,3} Additionally, the use of bulk-fill composite resins has been shown to reduce clinical procedure time by up to 20%.⁴ These characteristics make high-viscosity bulk-fill composite resins a suitable option for restoring posterior cavities with a high configuration factor (C-factor).^{2,4,5}

Composite resin preheating is a practical clinical approach for reducing the viscosity of composite resins

before placement. By increasing material flowability, preheating facilitates adaptation to cavity walls and helps minimize void formation, particularly in deep cavities or those with a high C-factor.^{6–8} In addition to improving handling characteristics, preheating may enhance the degree of conversion by increasing monomer mobility and accelerating polymerization kinetics at elevated temperatures.⁹ These changes can also contribute to improved mechanical properties, including surface hardness and stiffness.^{6,7,10} However, the extent of these effects depends on the preheating temperature, heating protocol, composite resin formulation, and testing conditions. These differences may partly account for the inconsistent findings across previous studies.^{8,10,11}

Previous studies have evaluated a wide range of preheating temperatures, typically ranging from 37°C

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to 68°C.^{8,12} However, the most appropriate preheating temperature and its potential influence on bond strength have not yet been clearly established.^{8,11,13,14} Moreover, limited evidence is available regarding the dentin bond strength of bulk-fill composite resins in high C-factor cavities.² Therefore, this study aimed to investigate the effect of composite resin preheating on the dentin bond strength of bulk-fill composite resins in deep Class I cavities with a high C-factor.

Methods

Thirty-six sound human mandibular third molars, extracted for orthodontic reasons and free of caries or restorations, were collected. The teeth were stored in 0.5% chloramine T trihydrate solution for 1 week, then cleaned of debris and residual soft tissues using a periodontal curette and stored in distilled water until further processing. The cusps were removed using a low-speed diamond disc (Diamant GmbH, D&Z, Berlin, Germany) under continuous water cooling to obtain flat and smooth occlusal surfaces.

The flattened occlusal surfaces were then etched with 37% phosphoric acid (Marvabon, Iran) for 15 s, rinsed thoroughly, and gently air-dried for 30 s and 3 s, respectively. Adper Single Bond (3M, ESPE, St. Paul, MN, USA) was applied to the occlusal surfaces according to the manufacturer's instructions using a microbrush. The adhesive layer was gently air-thinned for 2–5 s and light-cured with an LED curing unit (Demi, Kerr, USA) at an intensity of 800 mW/cm² for 10 s. To provide sufficient remaining dentin thickness and prevent pulp exposure during cavity preparation, a 1-mm-thick layer of microhybrid composite resin (Filtek Z250, 3M ESPE, St. Paul, MN, USA) was placed on the prepared flat occlusal surface and polymerized using the same LED curing unit at 800 mW/cm² for 20 s.¹⁵

Class I cavities (3.5×3.5 mm in width and 4 mm in depth) were prepared on the occlusal surfaces of the teeth using a high-speed 0.8-mm tapered fissure diamond bur (Tizkavan, Tehran, Iran) under continuous water spray cooling. The pulpal floor was located within the mid-dentin region. A new bur was used for every five cavity preparations.

The prepared Class I cavities were etched with 37% phosphoric acid for 15 s, rinsed with water for 30 s, and gently air-dried for 3 s. Adper Single Bond adhesive was applied to the cavity walls using a microbrush, gently air-thinned to achieve a uniform layer, and light-cured with an LED curing unit at 800 mW/cm² for 10 s. A2-shade x-tra fil bulk-fill composite resin (VOCO, Cuxhaven, Germany) was used for cavity restoration. The teeth were randomly assigned to two groups according to the temperature condition of the composite resin. The composite resin syringes were conditioned in distilled water at 23°C (group A) or preheated at 60°C (group B) for 30 min before restoration. Figure 1 presents the overall experimental workflow. The water temperature was monitored every 5 min using a thermometer. After

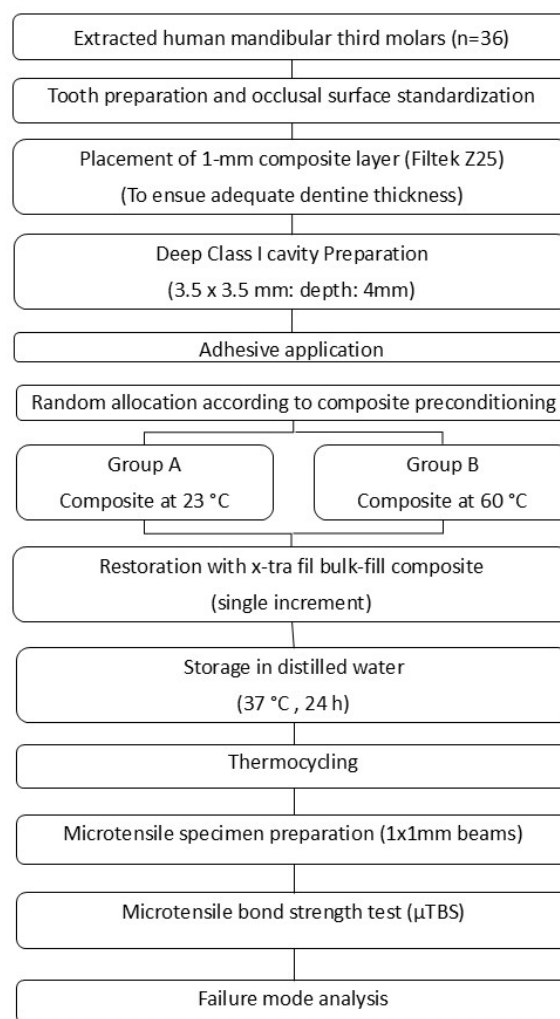


Figure 1. Schematic diagram of the experimental workflow

the 30-min conditioning period, the cavities were restored with composite resin in a single increment and light-cured for 40 s using the same LED curing unit at 800 mW/cm².

After restoration, the specimens were stored in distilled water at 37°C for 24 h and then thermocycled (Nomov Co., Mashhad, Iran) for 500 cycles between 5°C and 55°C, with a dwell time of 30 s per cycle and a transfer time of 10 s.

Subsequently, three teeth were embedded together in self-curing acrylic resin (Acropars, Tehran, Iran), leaving the restoration surface exposed. Each acrylic block containing three teeth was attached to the cutting plate using adhesive (Starbond, Tehran, Iran). The specimens were sectioned into 1×1-mm² blocks using a CNC cutting device (Nomov Co., Mashhad, Iran) equipped with a 0.3-mm-thick diamond disc under continuous water cooling. At least three microtensile blocks were obtained from each tooth, resulting in a total of 55 blocks per group.

The specimens were stored in distilled water until testing. Tensile loading was applied using a universal testing machine (Hounsfield Test Equipment Ltd., H5KS, UK) at a crosshead speed of 1.5 mm/min until

failure. Microtensile bond strength values were calculated in MPa by dividing the failure load (N) by the cross-sectional area of the bonded interface (mm²). Following the test, the fractured surfaces were examined using a stereomicroscope (Nikon SMZ800, Tokyo, Japan) at different magnifications. Failure modes were classified as adhesive (failure at the adhesive interface), cohesive (failure within the dentin or composite resin substrate), or mixed (a combination of adhesive and cohesive failures).

An independent-samples t-test was used to compare microtensile bond strength values between the two groups. Statistical analyses were performed using SPSS 17. Statistical significance was defined at $P < 0.05$.

Results

The mean $\pm$ standard deviation of microtensile bond strength values was 19.73 ± 4.01 MPa in the preheated group and 17.34 ± 3.96 MPa in the non-preheated group. The independent-samples t-test showed significantly higher bond strength in the preheated group than in the non-preheated group ($P = 0.002$).

Table 1 presents the distribution of fracture modes.

Discussion

The present study aimed to evaluate the effect of composite resin preheating on microtensile dentin bond strength in deep Class I cavities.

Bulk-fill composite resins were developed to simplify restorative procedures by allowing placement of thicker increments while maintaining adequate polymerization. However, achieving reliable bonding in deep cavities with a high C-factor remains challenging due to increased polymerization stress and limited cavity adaptation.^{2,16,17}

The present study demonstrated that preheating significantly improved microtensile dentin bond strength compared with the non-preheated condition. The higher frequency of cohesive failures in the preheated group may suggest improved interfacial integrity.

The findings of the present study are consistent with previous studies demonstrating the beneficial effects of composite resin preheating on bond strength. Demirbuga et al.¹⁸ examined the microshear bond strength of methacrylate and silorane-based composite resins to dentin and reported that the preheated group, heated to 68°C, exhibited the highest microshear bond strength. Loumprinis et al.¹⁹ examined the effect of preheating on the viscosity and adhesiveness of flowable, packable, conventional, and bulk-fill thermoviscous composite resins. They found that preheating reduced the viscosity of packable composite resins by 30–82%. Preheating substantially reduced the viscosity of thermoviscous

materials at 45 and 54°C, reaching values comparable to those of flowable composite resins at room temperature.

Nevertheless, Davari et al.¹⁴ examined the effect of preheating on the microtensile bond strength of a composite to dentin at 4, 23, and 37°C. They reported that the microtensile bond strength of a particular composite resin did not change significantly across temperatures. Additionally, Botros et al.²⁰ investigated the effect of preheating on the microshear bond strength and degree of conversion of a dual-cured composite resin core. They found that increasing the composite resin temperature to 40°C did not significantly affect microshear bond strength, although it significantly increased the degree of conversion.

The effect of preheating varies by composite resin type and its constituents. Oskoei et al.²¹ studied the impact of frequent preheating on two kinds of composite resins: dimethyl methacrylate and silorane-based composites on the marginal gap of class V restorations. They reported that preheating and composite resin type significantly affected marginal gap and gap formation at the gingival margin of these cavities. After preheating, gap formation at the gingival margin diminished in both composite resin types, and preheating silorane-based composite resins led to better gingival compatibility than methacrylate composite resins.

x-tra fil bulk-fill composite resin contains 86 wt% inorganic filler, representing a relatively high filler loading compared with many commercially available bulk-fill composite resins. This high filler content contributes to a relatively high elastic modulus, which may increase polymerization stress and affect interfacial adaptation, particularly in high C-factor cavities.²² Preheating may help overcome these limitations by reducing composite resin viscosity and improving adaptation to cavity walls. Enhanced adaptation may increase the effective contact area between the composite resin and cavity walls, thereby reducing stress concentration at the adhesive interface during polymerization. Nevertheless, the duration of the temperature effect after preheating and the need for repeated heating cycles require further investigation.

Malekipour et al.²³ examined the effects of 23 and 55°C irrigation water temperatures and preheated composite resins with two different bonding agents on the microleakage of class V restorations. They found that preheating the composite resin effectively improved workability and reduced microleakage in composite resin restorations. Nevertheless, microleakage did not differ significantly between groups irrigated at different water temperatures. Thus, controlling water temperature during preheating can help harness the advantages of this method. Nevertheless, the benefits of composite resin preheating vary with the composite resin type and composition. In the present study, preheating the x-tra fil bulk-fill composite resin to 60°C improved bond strength to deep dentin in Class I cavities with a high C-factor. Increasing the temperature to reduce composite resin viscosity may inversely affect specific composite resin

Table 1. Distribution of failure modes

Failure Mode	Non-preheated group N (%)	Preheated group N (%)
Adhesive	18 (32.7)	8 (14.5)
Mixed	15 (27.3)	18 (32.7)
Cohesive	22 (40.0)	29 (52.7)

properties, depending on the composite resin type and preheating frequency. Therefore, further investigations are warranted to clarify the optimal heating protocols, including temperature, frequency, and timing.

Conclusion

Preheating the bulk-fill composite resin to 60°C as a simple method significantly enhanced its microtensile bond strength to deep dentin in high C-factor cavities under the conditions of this in vitro study.

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Competing Interests

The authors declare they have no conflict of interest.

Ethical Approval

The present study was conducted after receiving the ethical code (IR.TBZMED.REC.1400.977) from Tabriz University of Medical Sciences.

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