10.5005/jp-journals-10015-1534

ORIGINAL RESEARCH

Evaluation of Coronal Leakage of Preheated Nanohybrid and Bulk Fill Composites in Endodontically Treated Teeth: An *in vitro* Study

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ABSTRACT

Aim: The aim of this study was to evaluate coronal leakage of preheated nanohybrid and bulk fill composites in endodontically treated teeth.

Materials and methods: A total of 100 human mandibular premolars were divided into six groups after standardized root canal treatment protocol: group I (n = 20): nanohybrid composite (Filtek Z250XT); group II (n = 20): preheated nanohybrid composite; group III (n = 20): bulk fill composite (Filtek Bulk fill); group IV (n = 20): bulk fill composite (Filtek™ Bulk fill); group V (negative control) (n = 10): Gutta-percha was kept intact till orifice and covered with nail polish; and group VI (positive control) (n = 10): Gutta-percha was kept intact till orifice. The samples were thermocycled followed by dye penetration with 2% methylene blue. Scoring was done under stereomicroscope at 10× magnification. Kruskal–Wallis test, Wilcoxon signed-rank test, and Mann–Whitney U test were applied. There was significant difference among all the groups.

Results: Preheated bulk fill composites sealed significantly better. Nanohybrid composites displayed the highest microleakage followed by preheated nanohybrid composite. Bulk fill composites were better than preheated nanohybrid composites.

Conclusion: Preheating decreases microleakage of nanohybrid and bulk fill composites. Bulk fill composites, especially when preheated, are superior in performance to nanohybrid composites in terms of microleakage.

Clinical significance: Preheated bulk fill composites are a suitable alternative to nanohybrid composites for the improvement of marginal integrity of restorations in endodontically treated teeth.

Keywords: Bulk fill, Composites, Endodontically, Microleakage, Nanohybrid, Preheating.

How to cite this article: Arora P, Arora V, Soliman M. Evaluation of Coronal Leakage of Preheated Nanohybrid and Bulk Fill Composites in Endodontically Treated Teeth: An *in vitro* Study. World J Dent 2018;9(3):201-207.

Source of support: Nil

Conflict of interest: None

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INTRODUCTION

Endodontically treated teeth pose a big challenge when it comes to restoration, rehabilitation, and reinforcement. An ideal restoration for such teeth should meet all these requirements.[1-4] Over the years, dental composites have emerged as one of the most favorable restorative options for the endodontically treated teeth as far as restoration, rehabilitation, and reinforcement are concerned.[3,4] This can be attributed to the vast research and development which has ultimately led to the refinement of these materials and placement techniques over a period of five decades.[5,6] Despite the advancements, microleakage with dental composites still remains one of the limiting factors in the longevity of postendodontic restorations, thus compromising coronal seal which is an equally important determinant as the apical seal in the long-term favorable prognosis of such teeth.[7]

In recent times, nanohybrid composites with improved physical properties and decreased polymerization shrinkage have revolutionized the restorative world, but in endodontically treated teeth, depth of access preparation and high C factor are also a challenge requiring multiple increments to restore.[7,8] The initial layers of composite may be as far as 5 to 7 mm from light source during curing; thus, the degree of conversion also gets compromised in such situations.[9]

Several manufacturers have recently introduced novel resin composites, so called "bulk fill" composites, which can be applied to the preparation and light cured to a maximal increment thickness of 4 to 5 mm along with enhanced curing, reduced shrinkage, and improved physical and mechanical properties.[9] These restorative materials have reduced polymerization stress, better flow, easy placement with excellent adaptation to the preparation walls, and low modulus of elasticity which can further decrease the stress generated on the preparation walls.[10-15] The protocol for layering technique is also not required and, thus, they

have emerged as the most suitable alternative for the postendodontic restorations.[9]

Another recent trend involving the composites is preheating. As supported by published research, preheating of dental composites significantly reduces shrinkage force in high-viscosity bulk fill and conventional resin composites, while maintaining or increasing the degree of monomer conversion.[16-30]

With these advancements in materials and innovative techniques, such as preheating, composites have become even more promising materials for postendodontic restorations.

With this premise, the present study was undertaken to evaluate coronal leakage of preheated nanohybrid and bulk fill composites in endodontically treated teeth.

MATERIALS AND METHODS

A total of 100 intact, human mandibular premolars with fully formed apices and free of caries, resorption, previous restorations, fracture, or structural deformities extracted recently for orthodontic treatment were selected for the study. The teeth were cleaned of biological debris and were stored in a solution of 1% chloramine-T until use for disinfection. Prior to the final selection, all teeth were examined by transillumination with 5× magnification for fractures/defects to eliminate such teeth from the study. The teeth were radiographed and those presenting with multiple canals, calcifications, or abnormal curvatures were not included.

The root canal treatment for all the teeth in the study was performed by the same researcher to reduce the operator variability. The standardized access was prepared with Endo access bur size 2 (Dentsply/Maillefer, Ballaigues, Switzerland) and Endo Z (Dentsply/Maillefer, Ballaigues, Switzerland) bur with cutting surface length: 9 mm; total length: 21 mm in a high-speed hand-piece under water spray. The burs were changed after every five preparation. The final dimensions of the preparation were kept as 2.5 mm buccolingually and 1 mm mesiodistally.

The root canal instrumentation technique for cleaning and shaping was performed by rotary ProTaper universal files by the same operator as described.

The access preparation was flooded with sodium hypochlorite 5.25% and a size 10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) was inserted in each canal until it appeared at the foramen. The working length was established by subtracting 1 mm from this length. All teeth were prepared with ProTaper rotary files (Dentsply/Maillefer, Ballaigues, Switzerland). The cervical and middle thirds of all canals were prepared with the SX instrument. Thereafter, S1, S2, FI, F2, F3, and F4 files were used in sequence with parameters for torque and speed as recommended by the manufacturer. The rotary files were attached to an electric motor (X Smart, Dentsply/Maillefer, Ballaigues, Switzerland) at a speed and torque as recommended by the manufacturer and the automatic autoreverse function was also used. Between each rotary file, the root canal was irrigated by a 30-gauge side-vented needle with 5.25% NaOCl, and a #10 K-file was used to check the patency. The nickel–titanium files were replaced after every five instrumentations.

After the preparation, the root canals were irrigated with 5 mL 17% ethylenediaminetetraacetic acid solution for 30 seconds followed by 5 mL of 5.25% sodium hypochlorite. The last and final irrigation was done with normal saline. All teeth were instrumented in the same manner as described.

The root canals were dried with the matching size paper points and obturated with matching size gutta-percha cone (Dentsply/Maillefer, Ballaigues, Switzerland) and AH Plus sealer (Dentsply/Maillefer, Ballaigues, Switzerland) by using single cone obturation technique. After obturation, the chamber was cleaned of all the residual sealer and the gutta-percha.

The samples were randomly divided into six groups. First four were experimental groups with 20 teeth and the fifth and sixth groups were control groups with 10 teeth each. The control group consisted of 10 positive and 10 negative controls. In all the groups undergoing the restorative procedures, manufacturer's instructions were followed.

The split-etch technique was used for etching in which etchant (Scotchbond, 3M™ ESPE™, St. Paul, Minnesota, USA) was applied for 15 seconds to enamel first followed by 15 seconds to dentin, so that the dentin was conditioned only for 15 seconds and enamel for 30 seconds.

The preheating of the composites was done in the modified wax melter filled with salt as used by Arora et al[31,32] and Arora et al[33] at 54°C. The syringe was placed in the wax melter and the temperature of the composite was confirmed with the help of a digital thermometer before use. The instruments for composite placement were also preheated at the same temperature to avoid heat loss[31] and minimal time was used to transfer the composite from the syringe to the preparation to further limit the heat loss. The manipulation was done immediately without any delay. The composite syringes were continuously kept in the preheating device till the completion of all the samples and were removed only for dispensing.

In all the samples, light curing for adhesive was done for 10 seconds and each increment was cured for 20 seconds with light-emitting diode (LED) curing light (Valo, Ultradent Products, Inc.) at an output of 1,000 mW/cm^2. The composition of materials used is summarized in Table 1.

Table 1: Characteristics of the materials used in this study (as per the manufacturer)

Material	*Manufacturer*	*Composition*
Nanohybrid Composite Filtek Z250 (shade A2)	3M, ESPE, St. Paul, MN, USA	Bis-GMA, Bis-EMA, TEGDMA, PEGDMA, UDMA zirconia, silica (82wt%, 60 vol%)
Bulk fill composite Filtek Bulk fill (shade A2)	3M, ESPE, St. Paul, MN, USA	AUDMA, UDMA and 1,12-DDDMA Ytterbium trifluoride, zirconia, silica (76.5% by weight, 58.4% by volume)
Bonding agent Adper™ Single Bond 2	3M, ESPE, St. Paul, MN, USA	Bis-GMA, HEMA, dimethacrylates, ethanol, water, a novel photoinitiator system and a methacrylate functional copolymer of polyacrylic and polyitaconic acids. 10% by weight of 5 nm diameter spherical silica particles

GMA: Glycidyl methacrylate; HEMA: 2-Hdroxymethyl methacrylate; TEGDMA: Triethylene glycol dimethacrylate; PEGDMA: Poly(ethylene glycol) dimethacrylate

Preparation of Samples for Experimental Groups

- Group I: The access preparations after etching, rinsing, and drying with cotton pellets were applied with nanofilled Adper™ Single Bond 2 Adhesive (3M™ ESPE™, St. Paul, Minnesota, USA) followed by light curing. Thereafter, preparation was restored with the nanohybrid composite (Filtek™ Z250XT, 3M™ ESPE™, St. Paul, Minnesota, USA) in 2 mm increments.
- Group II: The same procedure as group I except that the preparation was restored with the preheated nanohybrid composite.
- Group III: The same procedure as group I except that the preparation was restored with the bulk fill composite (Filtek™ bulk fill composite,3M™ ESPE™, St. Paul, Minnesota, USA) in two increments. The access preparation depth was measured and any depth more than 4 mm was first restored with the variable increment of 2 to 3 mm as per the sample to bring it to a depth so that the remaining depth is 4 mm for the second increment. Then, the 4 mm increment was placed as the final increment and light cured.
- Group IV: The same procedure as group I except that the preparation was restored with the preheated bulk fill composite.

Preparation of Specimens for Control Groups

- Group V (Negative): Gutta-percha was kept intact at the canal orifice of samples after obturation.
- Group VI (Positive): Gutta-percha was kept intact at the canal orifice of samples after obturation.

Preparation of Specimens for Dye Leakage Test

After the root canal treatment and the restorations, all the teeth were stored in 100% humidity in an incubator for 48 hours to allow for the root canal sealer to set. The tooth apices were sealed with two layers of cyanoacrylate adhesive Thermocycling of the different groups was carried at 5°C and 55°C for 500 cycles with a dwell time of 30 seconds and transfer time of 15 seconds as per the International Standards Organization protocol.[34]

Subsequently, samples were coated with three layers of nail polish excluding the 1 mm area of access preparation. The negative control group, on the contrary, were coated with three coats of nail polish including the gutta-percha filled access preparation completely. The teeth were then immersed in 2% methylene blue dye for 24 hours. After 24 hours, the samples were rinsed in the running tap water and subsequently dried.

All teeth were sectioned longitudinally along their long axis with a diamond disk under water spray and both the sections of each sample were evaluated under a stereomicroscope (Motic SMZ-168, McDowell Avenue, Roanoke, VA) at 10× magnification. The photographs were also made. The degree of microleakage was scored by an endodontist in the occlusal margins.

Dye leakage was graded into following categories as per the following criteria:

- No leakage: If leakage was not there and the dye never penetrated along the gutta-percha and pulp chamber
- Slight leakage: If leakage was just reaching the dentin
- Moderate Leakage: If leakage was reaching till the pulp chamber
- Extensive Leakage: If leakage was penetrating up to the floor of the pulp chamber and root canal

RESULTS

Statistical Analysis

Confidence interval was within the interval of 95%.

The degree of dye penetration for each group is presented in Table 2. When the scoring data from groups were compared for microleakage using Kruskal–Wallis test, there was a significant difference among the groups. Pairwise comparison was done using Wilcoxon signed-rank test and Mann–Whitney U test (Table 3).

Table 2: Microleakage scores for experimental and control groups

	Microleakage scores			
Groups	*0*	*1*	*2*	*3*
Group I (n = 20)	1	3	9	7
Group II (n = 20)	2	9	6	3
Group III (n = 20)	3	10	6	1
Group IV (n = 20)	9	9	1	1
Group V (n = 10)	9	1	0	0
Group VI (n = 10)	0	0	1	9

Table 3: Statistical difference of microleakage scores between experimental groups

	Experimental groups for comparison					
	I vs II	*I vs III*	*I vs IV*	*II vs III*	*II vs IV*	*III vs IV*
Mann–Whitney U	124	94	52	170.5	100	121
Wilcoxon W	334	304	262	380.5	310	331
Z	−2.161	−3.015	−4.142	−0.859	−2.88	−2.303
p-value	0.031	0.003	<0.001	0.39	0.004	0.021
Significance ($p < 0.05$)	S	S	HS	S	S	S

The statistical difference between all experimental, positive, and negative groups was significant. It was omitted from this table for simplification; S: Significant; HS: Highly significant

There was no dye penetration for teeth in the negative control group, whereas the positive control group showed dye penetration in all specimens. There was leakage in all experimental groups. When the groups were compared for microleakage using Kruskal–Wallis test, there was a significant difference among the groups with $p < 0.05$. Groups I and IV displayed highly significant difference. All the preheated groups were better than the groups in which composite was used at room temperature. Bulk fill composites groups were better in performance than the nanohybrid composites.

Preheated bulk fill composites sealed significantly better than the other groups followed by bulk fill composite. Nanohybrid composite group displayed the highest microleakage followed by preheated nanohybrid composite group. Bulk fill composites were even better than preheated nanohybrid composites.

DISCUSSION

Dental composites have emerged as the most recommended materials for the reinforcing restoration of structurally compromised endodontically treated teeth.[3-6] The major factor limiting the use of dental composites for such restorations is the compromised coronal seal owing to the inherent polymerization shrinkage.[7]

With the fast pace of changing technology, new materials and techniques with the claims of decreased microleakage have flooded the dental field. These materials and techniques require rigorous academic research to verify the claims made by the manufacturer.

The conclusions of microleakage studies vary owing to the inability to control all the variables and inability to mimic the clinical conditions. Within the limits of the present study, it was attempted to standardize the parameters by strict and careful selection of the teeth, standardized access preparation, and strict adherence to the manufacturer's instructions. To best simulate the clinical oral conditions, thermocycling was undertaken.[33]

The dye penetration method was used in this study to assess microleakage. A plethora of studies have used methylene blue because it is inexpensive, easy to use and handle, has a high degree of staining, and molecular weight lower than bacterial toxins. Some academic researchers have suggested that this dye exhibits microleakage similar to butyric acid which is a microbial metabolic product.[35]

In the present study, bulk fill composites, whether preheated or not, were better in sealing as compared with the nanohybrid composites, and preheating improved sealing for both the tested composites.

The access preparations are deep and present a difficult situation for restorations as they have a high C factor.[7] The inherent challenges to bonding with dentin also pose a challenge. The nanohybrid composite used in our study when applied to the base of access preparation which was 6 to 7 mm deep posed a challenge to light curing at that depth leading to weak bond with the dentin in that region and the degree of conversion was also questionable.[7,8] Another factor, which can significantly affect the marginal microleakage is the distance between the light curing tip and the resin surface. When the distance between the curing light tip and the resin surface is more than 2 mm, the light intensity is significantly reduced. This can prevent polymerization of composite resin materials and compromising the bond between the adhesive and composite.[8]

On the contrary, the bulk fill composites with improved chemistry did well even without preheating when compared with nanohybrid composites in deep access cavities. Similar results were obtained by Van Ende et al[7] when they compared bulk fill composites with nanohybrid composites in preparations of different C factor. They found that bulk fill composites were better in performance as compared with other composites in cavities with more depth and high C factor.[7]

Regarding the improved chemistry of Filtek™ bulk fill posterior restorative as mentioned in the technical details by the manufacturer, it contains two novel methacrylate monomers which together can lower polymerization stress.[36] High molecular weight aromatic urethane dimethacrylate (AUDMA) reduces the number of reactive groups in the composite to moderately decrease volumetric shrinkage as well as increase the flexibility of the polymer matrix. Polymerization stress gets reduced with

this strategy. The second unique methacrylate (addition fragmentation monomers, AFMs) reacts with any methacrylate during polymerization, including the development of crosslinking in between resin chains. The AFM also has a third site which is reactive and breaks through during polymerization by fragmentation. This leads to stress relief in the developing matrix. The fragments after this still retain the ability to react with the reactive sites in the developing resin matrix. This leads to stress relief without affecting the properties of the composite.[36]

The 1,12-dodecanediol dimethacrylate (DDDMA) is a low-viscosity resin, fast cure with low exothermic reaction and low shrinkage. This is a high-modulus resin with good flexibility and the impact resistance is high. Urethane dimethacrylate (UDMA) also reduces the viscosity of the resin and its high molecular weight decreases the shrinkage while still forming a highly cross-linked structure.[36]

This improved chemistry not only helped in bulk curing but also helped to limit the polymerization shrinkage as depicted by less microleakage in our results.

Similar results with bulk fill composites presenting with improved marginal sealing and decreased microleakage were published by Guo et al,[10] Savadi Oskoee et al,[11] Agarwal et al,[12] Scotti et al,[13] Peutzfeldt et al,[14] and Orłowski et al.[15]

In all the groups with the preheating, the results were better than the composites used at the room temperature. Our results are in agreement with the previous published research related to preheating of composites and its beneficial effect on decreasing microleakage.[16-30] Preheating leads to reduced viscosity and improved flowability, leading to improved adaptation to walls of the preparation.[18,19,27-29] This results in decreased microleakage and improved durability of the restoration.[27,28] Preheating also enhances both radical and monomer mobility, postponing the start of vitrification to a later stage of the polymerization cycle.[24,25] Before vitrification, emerging shrinkage stresses so formed can be relieved by flow of resin and polymer chain relaxation of polymer chain in pregel phase, leading to lower shrinkage forces. A highly cross-linked polymer network with superior properties is formed because of improved polymerization rate with improved monomer conversion.[16,20-23,30]

In our study, group IV was best in performance in which preheating of bulk fill composites was done. The reason attributed to this observation could be due to the fact that preheating with the benefits of reduced viscosity and enhanced radical mobility further potentiated the effects of the polymerization modulators present in the bulk fill composites. This led to restorations with reduced microleakage even in the deeper access preparations. Similar results with potentiated effects of preheating of bulk fill composites were also observed in the studies conducted by Theobaldo et al,[37] Tauböck et al,[38] Dionysopoulos et al,[39] and Dionysopoulos et al[40] who concluded that both the composite material and the precure temperature affect the shrinkage force formation. Preheating of bulk fill and other resin restorative composites prior to photoactivation decreases polymerization shrinkage without compromising the degree of conversion. Daronch et al[21] reported that preheating of composite allows for decreased light exposure time up to 75% and still resulting in similar or even better monomer conversion when compared with resin at room temperature with normal exposure time. This was an additional advantage in our study in which the preheating of bulk fill composites helped in improved the degree of conversion even when the access preparation was too deep and the light source was far away.

This study clearly indicates a case for the use of preheated bulk fill composites in deeper access preparations without compromising the marginal integrity of the restorations. There is not much research to support our study, as it is a relatively new concept and still some more clinical studies are needed to further validate our research.

CONCLUSION

Within the limitations of the present study, it can be concluded that both the composite material and preheating affect microleakage in postendodontic restorations. Composite preheating prior to photoactivation decreases microleakage of nanohybrid and bulk fill composite restorations. Bulk fill composites are better than nanohybrid composites in reducing microleakage. Preheated bulk fill composites are comparatively much better than nanohybrid composites in reducing microleakage even in deeper access preparations of endodontically treated teeth.

CLINICAL SIGNIFICANCE

Composite preheating significantly reduces microleakage in restorations with bulk fill and nanohybrid composites. Bulk fill composites, preheated or used at room temperature, are better in performance than nanohybrid composites in terms of microleakage for the restoration of endodontically treated teeth presenting with deep access preparations.

ACKNOWLEDGMENTS

Authors would like to thank the Deanship of Research, Taif University, Taif, Kingdom of Saudi Arabia for financially supporting this research through 2017 to 2018 grant for the research project number 14385923.

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