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Fracture resistance of weakened premolars restored with different preheated bulk fill composites (A comparative *in vitro* study)

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Key words: Fracture resistance; bulk fill technique; preheated bulk fill composite materials.

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Abstract

Objective: This was performed to evaluate the preheating effect of different bulk fill composite materials on the fracture resistance of the maxillary premolars. A 64 caries & crack-free maxillary premolar teeth were divided into groups and subgroups with eight teeth each: group 1, sound unprepared teeth; group 2, teeth received (MOD) cavity and left unrestored; group 3-A, restored with Filtek ™ bulk fill posterior restoration; group 3-B, restored with preheated Filtek ™ bulk fill posterior restoration; group 4-A, restored with Beautifil –Bulk ™ composite; group 4-B, restored with preheated Beautifil –Bulk ™ composite; group 5-A, restored with Tertic Evo Ceram® Bulk Fill composite; and group 5-B, restored with preheated Tertic Evo Ceram® Bulk Fill composite. The teeth subjected to compression load with the long axis of the teeth until fractured using a universal testing machine. The data were statistically analyzed using one-way ANOVA, LSD test and t-test. The specimens in groups 3–5 were examined to evaluate the mode of failure. Group 1 showed the highest fracture resistance compared with other groups at room temperature and preheated composite materials. The differences among groups were statistically highly significant (P<0.01).Group 2 showed the lowest fracture resistance. Among the restored groups, group 4 recorded the highest fracture resistance than others, and statistically significant difference was found (*P*<0.05).No statistically significant differences were found (P<0.05) among the restored groups when preheated composite materials were used. No statistically differences were found (P<0.05) among the subgroups except group 5-A at room temperature and group 5-B at 54±1 °C.

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Introduction

The favored restorative materials and methods utilized to reestablish weakened maxillary premolars to enhance their resistance to fracture under occlusal load remains controversial. The advancement in composite materials and adhesive technique has impressively changed the approach to rebuilding efforts in the posterior region. The preferences of adhesive restorations are not only of an aesthetic nature but are also related to the conceivable outcomes of preserving a more sound tissue and reinforcing the leftover dental structure. Dental practitioners have continuously explored for a quick and dependable filling procedure that facilitates the reduction of layers, effort, and time. New materials, named bulk fill materials, have been presented to diminish the time and effort required for layering and adjustment when placing posterior composites (Fahad and Majeed 2014). Bulk fill composite resins are further classified into high-viscosity and low-viscosity (flowable) materials. High-viscosity bulk fill composites include greater amounts of filler particles compared with low-viscosity bulk fill composites. Hence, the flowable composite resins exhibit better adaptation on the cavity walls but greater polymerization shrinkage and lower mechanical properties (Dionysopoulos 2016).

Most of these resins, such as Surefil™ SDR (Dentsply Caulk), X-trafil (VOCO, Cuxhaven, Germany), Venus® Bulk Fill (HeraeusKulzer), and Filtek™ Bulk Fill Flowable Restorative (3M ESPE) are based on a low-viscosity composite. These fillers are applied in a bulk layer of 4 mm thickness and light-cured. Then, another composite is used to fill the rest of the cavity. Consequently, the restorative procedure is prolonged and becomes more complex. Therefore, these materials should not be classified as true bulk fill materials. True bulk fill composite resin materials, such as QuixFill™ posterior restorative (Dentsply) and Tetric EvoCeram® Bulk Fill (Ivoclar Vivadent), have been introduced. QuixFill™ posterior restorative offers an extremely high filler load (66% by volume and 86% by weight). Moreover, this filler offers a complete 4 mm cure in as short as 10 s while still offering prolonged working time to allow the creation of a precure anatomy ((Fahad and Majeed 2014). Preheated composite resins show reduced viscosity and increased polymerization efficiency. Heating composite resins before placement in the cavity and immediately light-curing increase the monomer conversion rate. Thus, the duration of the irradiation period may be decreased. The increase in the degree of polymerization of the composite resins may lead to better internal adaptation to cavity walls, improved mechanical properties, and increased wear resistance. A recent study has demonstrated that pre-heating significantly reduces shrinkage force formation of high-viscosity bulk-fill and conventional composite resins but maintains or increases the degree of monomer conversion, dependent on the specific composite material used [2]. This study was performed to evaluate the preheating effect of different bulk fill composite materials on the fracture resistance of the maxillary premolars.

Materials and methods

Teeth selection

A total of 64 sound maxillary first premolars (with two roots) were extracted for orthodontic treatment with comparable size. The teeth were collected and tested within three months (Javheri *et al.,* 2012; Silva *et al.,* 2012). The teeth stored in 0.1 vol % thymol for 2 days (Kikuti *et al.,* 2012), and then in distal water at room temperature to avoid the dehydration of the specimens (Santos and Bezerra 2005; Abdo *et al.,* 2012).

All teeth were caries- and crack-free, which were ascertained with trans-illumination using fiber-optic light of a light curing system (Mortazavi *et al.,* 2012). The comparable size and shape of the teeth were measured using the digital vernier (chains) to calculate the mesidistal and buccopalatal dimension (Soares *et al.,* 2006; Taha *et al.,* 2009). Thus, the teeth used in the study had regular occlusal anatomy and approximately similar size of the crown with completely apical formation (Mortazavi *et al.,* 2012). Any calculus deposits were carefully removed by a scaler (Wood Pecker, China) and then polished with

polishing paste (Prisma Gloss, Dentsply) (Hamouda and Shehata 2011).

Teeth mounting

The teeth were embedded in a custom-made mold (2×2×2.5 mm^3) fabricated from condensation silicon (Zhermack, Italy) filled with self-cure acrylic resin (VERACRIL, Colombia). The teeth were embedded with their long access using the dental surveyor. To approximate the support of the alveolar bone in the healthy teeth, the teeth embedded in the acrylic to the level 2 mm beyond the CEJ (Salameh *et al.,* 2006; Taha *et al.,* 2011).

Sample grouping

The teeth were randomly divided into five groups (8 teeth in each group) according to the type and the temperature of the restorative material used.

Group 1: This group comprised 8 sound unprepared teeth. This group served as the control positive group.

Group 2: An extensive class II mesio-occluso-distal (MOD) cavity was prepared, but the cavity was left unrestored (control negative group).

Group 3: **A:** The same as group 2, but the MOD cavity was restored with Filtek ™ bulk fill posterior restoration (3M ESPE) at room temperature (24±1 °C).

B: The same as group 2, but the MOD cavity was restored with preheated Filtek ™ bulk fill posterior restoration (3M ESPE) at (54±1 °°C).

Group 4: This group was further divided into 2 subgroups.

A: The same as group 2, but the MOD cavity was restored with Beautifil-Bulk (shofu) at room temperature (24±1 ° C).

B: The same as group 2 but the MOD cavity was restored with preheated Beautifil-Bulk (shofu) at (54±1 °C).

Group 5: This group was further divided into 2 subgroups.

A: The same as group 2, but the MOD cavity was restored with Tetric Evo Ceram Bulk-Fill (Ivoclar Vivadent) at room temperature (24±1 °C).

B: The same as group 2, but the MOD cavity was restored with preheated Tetric Evo Ceram Bulk-Fill (Ivoclar Vivadent) at (54±1˚C).

Stamp technique

Before the cavity preparation of groups 3–5, a clear silicon impression material was used to take the impression for the occlusal surface (stamp technique). This technique is used to restore the teeth with composite restoration to the original occlusal anatomy with minimal requirement of finishing and polishing and minimal voids at the occlusal anatomy (Haimilton *et al.,* 1998). The clear silicon impression material was injected on the occlusal surface of the teeth and a disposable bond brush inserted in the silicon to facilitate the removal and application of the stamp.

Cavity preparation

All groups, except group 1 which served as the intact control, were prepared with MOD cavity using a flat-end fissure bur in a high-speed handpiece turbine, which was fixed in the modified dental surveyor. The depth of the cavity was standardized 3 mm from the center of the occlusal surface to the pulpal floor and the gingival seat at 1 mm below the pulpal floor (4 mm in depth). The depth of the gingival seat was 1 mm mesiodistally. The width of the cavity was standardized at 3 mm buccopalatally. The buccal and palatal walls were prepared parallel to each other as shown in Figure 1 (Campos *et al.,* 2009; Moorthy *et al.,* 2012; Karaman and Ozgunalty 2013; El-Helali *et al.,* El-Helali 2013). The outline of the cavity was drawn with a super color marker before the preparation [19]. To standardize the cavity preparation, the preparation was performed with the aid of a modified dental surveyor. The specimen was placed on the plate of the surveyor (the plate was fixed with the horizontal plane). The specimen was

prepared by moving the modified arm of the surveyor, to which the high-speed turbine was attached mesiodistally, to form MOD cavity.

Adhesive procedure

Prior to the placement of the composite restoration, the single bond universal adhesive (3M ESPE) was used for groups 3–5 for standardization. The prepared cavities were washed with deionized distilled water using the triple syringe of a portable dental unit and dried with air. Then, the self-etch technique was used with the single bond universal adhesive following the manufacturer's instructions. A drop of the adhesive was dropped in the mixing well, and a disposable bond brush was used to apply the adhesive to the whole cavity and rubbed for 20 s. Subsequently, a gentle stream of air was focused over the liquid for approximately 5 s, until the specimen no longer moved, and the solvent agent has been completely evaporated. The adhesive was then light cured with an LED light curing unit (XL lite II, China) with a power intensity of more than 1000 mW/cm² for 10 s according to the manufacturer's instructions. The intensity of light was checked prior to curing using a radiometer (HE) (Dionysopoulos 2016).

Application of composite resin

Super Mat® Adapt® Super Cap® Matrix system (Kerr Hawe SA, Switzerland) was used and discarded after each restoration. Three different types of bulk fill composite materials, namely, Filtek ™ bulk fill (3M ESPE, Germany), Beautifil-Bulk (Shofu, Japan), and Tetric Evo Ceram® Bulk Fill (Ivoclar Vivadent, Liechtenstein), were applied into the prepared cavity at room temperature with a single layer up to 4 mm according to the manufacturers' instructions. The composites were compacted and adapted using Ash Nos.6 and 49. Afterward, the Teflon and the stamp of the teeth were placed and pressed to take the same shape of the original tooth anatomy without over and under filling. The stamp was displaced to remove the excess material by dental probe, and then the teeth were occlusally cured for 10 s. The Super Mat® band was removed, and the buccal and palatal surfaces were cured for 10 s again according to the manufacturers' instruction.

The same steps and materials used to restore the groups were repeated, but the composite material was placed into commercially available composite warmer set to 54 °C before being placed into the cavity (Dionysopoulos *et al.,* 2014; Hasson and Abdulameer 2017). The composite material was applied immediately after removing it from the heating device, because approximately 14 °C reduction in temperature occurs in the first 2 min after the composite tube is removed from the warming device (Daronch *et al.,* 2006).

Mechanical testing

All teeth were subjected to compressive axial loading until fracture occurs in a computer-controlled universal testing machine (LARYEE, China).

The crosshead speed was 0.5 mm/min. A metal bar (8 mm in diameter) with rounded end was applied parallel to the long axis of the tooth and to the cusps slope (rather than the restoration) (Kikuti *et al.,* 2005). A piece of rubber was placed between the metal bar and the tested tooth to act as a stress breaker that prevents damage from the direct contact of the tooth and the bar. Thus, the cushion action of the load between the opposing teeth was simulated (Beuer *et al.,* 2012).

All samples were loaded until fracture, while maximum breaking loads were recorded in newtons (N) by a computer connected to the loading machine. The mode of failure was evaluated under a stereomicroscope (Altay Biovision Line, Italy) at 20× magnification. The mode of failure was recorded and classified as adhesive, cohesive, or mixed mode failure (Sorrentino *et al.,* 2007; Taha *et al.,* 2011).

Fracture mode assessment

The mode of failure was evaluated under the stereomicroscope at 20× magnification. The mode of failure was recorded and classified as adhesive,

cohesive, or mixed mode failure (Sorrentino *et al.,* 2007; Taha *et al.,* 2011).

Adhesive failure is the fracture of an adhesive interface between the tooth and restorative material, while cohesive failure is the fracture inside the bulk of tooth tissue or restorative material with no exposure of any adhesive layer. Mixed failure involves both adhesive and cohesive fractures (Taha *et al.,* 2011).

Results

Analysis of subgroups A (at room temperature 24±1 °C)

The descriptive statistics of fracture resistance of all groups and the percentages of increase in the fracture resistance are shown in Table 1.

Table 1. Descriptive statistics of fracture resistance (in newtons) of each subgroup A.

A At room temperature	Mean	Standard Deviation	Percentage of increase in fracture resistance
Group 1	1242.625	174.27887	100%
Group 2	572.0000	54.74095	00%
Group3(A)	707.6250	175.33147	20.22%
Group4(A)	870.2500	89.23124	44.47%
Group5(A)	707.6250	121.26940	20.22%

Table 2. ANOVA test for the mean values of the fracture resistance for all subgroup A.

ANOVA					
A					
	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2143177.850	4	535794.463	30.871	.000
Within Groups	607455.125	35	17355.861		
Total	2750632.975	39			

One-way ANOVA showed a statistically significant difference among the groups (Table 2). The least significant difference (LSD) test was used to compare among the groups to determine where the significant difference occurred (Table 3).

Table 3. Least significant difference (LSD) test for the fracture resistances between subgroups A.

A	groups	Mean Difference (I-J)	Std. Error	Sig.
group 1	group 2	670.62500*	65.87082	.000 (HS)
	group 3	535.00000*	65.87082	.000 (HS)
	group 4	372.37500*	65.87082	.000 (HS)
	group 5	535.00000*	65.87082	.000 (HS)
group 2	group 3	-135.62500-*	65.87082	.047 (S)
	group 4	-298.25000-*	65.87082	.000 (HS)
	group 5	-135.62500-*	65.87082	.047 (S)
group 3	group 4	-162.62500-*	65.87082	.019 (S)
	group 5	0.00000	65.87082	1.000(NS)
group 4	group 5	162.62500*	65.87082	.019 (S)

*The mean difference is significant at the 0.05 level.

Analysis of subgroups B (preheated to 54±1 °C).

In this study, the highest fracture resistance was recorded in group 1 (unprepared teeth), which was statistically highly significant compared with the other groups (P<0.01), while the lowest fracture resistance was observed in group 2 (prepared unrestored teeth) compared with other groups. In the restored subgroups at room temperature, the teeth restored with Beautifil-Bulk™ composite (group 4-A) recorded the highest fracture resistance compared with all other restored groups. The difference was statistically highly significant when compared with the control negative group (group 2) (P<0.01). The teeth restored with Filtek™ bulk fill posterior restoration (group 3-A) and that restored with Tetric Evo Ceram Bulk-Fill™ (group 5-A) showed the same fracture resistances, and the difference was statistically significant when compared with control negative group (group 2) (P<0.05).

Table 4. Descriptive statistics of fracture resistance (in newtons) of each subgroup B.

B Preheated at 54±1˚C	Mean	Standard Deviation	Percentage of increase in fracture resistance
Group 1	1242.6250	174.27887	100%
Group 2	572.0000	54.74095	00%
Group3(B)	799.1250	149.96041	22.71%
Group4(B)	896.3750	139.02203	48.36%
Group5(B)	854.3750	97.18750	42.10%

The descriptive statistics of the fracture resistance of all groups and the percentages of increase in fracture resistance are shown in Table 4. One-way ANOVA revealed a statistically significant difference among the groups as shown in Table 5. The LSD test results are shown in Table 6.

In this study, the highest fracture resistance was recorded in group 1 (unprepared teeth) and statistically highly significant compared with other groups (P<0.01), while the lowest fracture resistance was observed shown in group 2 (prepared unrestored teeth) compared with the other groups. Between the restored subgroups at 54±1 °C, the teeth restored with Beautifil-Bulk™ composite (group 4-B) recorded the highest fracture resistance compared with all other restored groups, followed by the teeth restored with Tetric Evo Ceram Bulk-Fill™ (group 5-B).

Table 5. ANOVA for the mean values of the fracture resistances of all subgroup B.

ANOVA					
B					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	1868595.100	4	467148.775	27.599	.000
Within Groups	592412.500	35	16926.071	---	---
Total	2461007.600	39	---	---	---

The teeth restored with Filtek™ bulk fill posterior restoration (group 3-B) showed the lowest fracture resistance, and the difference where statistically highly significant when compared with control negative group (group 2) (P<0.01).

Discussion `

The intact teeth (group 1) recorded the highest fracture resistance. This characteristic contributed to the presence of sound buccal and palatal cusps with intact mesial and distal marginal ridges that reinforced the tooth structure [25]. This result is in

agreement with previous studies (Casselli *et al.,* 2008; Yashwanth *et al.,* 2012).

The lowest mean value of the fracture resistance was observed in the prepared unrestored teeth (group 2). This characteristic contributed to the quality and type of the remaining tooth structure after MOD tooth preparation because of the loss of the reinforcing tooth structures especially the marginal ridges and cusps. This finding is consistent with the results from previous studies (Blaser *et al;* 1983; Ausiello *et al.,* 1997; Dalpino *et al.,* 2002; Santos and Bezerra 2005; Sorrentino *et al.,* 2007; Fahad and Majeed 2014).

Table 6. LSD test for the fracture resistance between subgroup B.

B	groups	Mean Difference(I-J)	Std. Error	Sig.
Group 1	group 2	670.62500*	65.05012	.000 (HS)
	group 3	443.50000*	65.05012	.000 (HS)
	group 4	346.25000*	65.05012	.000 (HS)
	group 5	388.25000*	65.05012	.000 (HS)
Group 2	group 3	-227.12500-*	65.05012	.001 (HS)
	group 4	-324.37500-*	65.05012	.000 (HS)
	group 5	-282.37500-*	65.05012	.000 (HS)
group 3	group 4	-97.25000	65.05012	.144 (NS)
	group 5	-55.25000	65.05012	.401 (NS)
group 4	group 5	42.00000	65.05012	.523 (NS)

* The mean difference is significant at the 0.05 level.

In addition, the increase in the cavity depth increased the degree of cuspal deflation. Therefore, the application of the force acted as a wedge action between the buccal and palatal cusps. This phenomenon promoted more catastrophic types of fractures (Santos and Bezerra 2005).

All teeth restored with the composite resin recorded higher fracture resistance than the prepared unrestored teeth with different percentages of increase in fracture strength regardless of the type of the composite materials. Statistically significant difference was found in the fracture resistance between the prepared unrestored and restored groups because of the micro-mechanical bonding between the adhesive system and the tooth structure and the formation of hybrid layer.

This layer tended to reinforce the remaining tooth structure by binding the walls of the cusps together and distributing the force more evenly among the various interfaces in composite restorative material that has been bonded to the dentin and enamel by the adhesive bonding agent. The decrease in the localized forces offers greater opportunity to reinforce the remaining tooth structure and increase the fracture resistance of the cusps (Fahad and Majeed 2014). Among the groups restored with bulk fill composite restoration, group 4-A, that is, the teeth restored with Beautifil–Bulk, showed the highest fracture resistance (statistically highly significant difference) with mean value of 870.25 N and highest percentage of increase in fracture resistance (44.47%) compared with the group 2, which consisted of prepared unrestored teeth. Statistically significant difference was found when group 4-A was compared with groups restored with Filtek ™ bulk fill posterior restoration (group 3-A) and Tetric Evo Ceram® Bulk Fill (group 5-A). The fracture resistance with mean value of 707.625 N was recorded for the two groups, and the percentage of increase in the fracture resistance was 20.22% for the two groups.This result could be attributed to the following reasons:

1- Resin components in Beautifil –Bulk (group 4-A) were Bis-GMA, UDMA, Bis-MPEPP, and TEGDMA, while resin components in Filtek ™ bulk fill composite (group 3-A) were ERGP-DMA, diurethane-DMA, and 1,12-dodecane-DMA. The resin composites in Tetric EvoCeram® Bulk Fill (group 5-A) were Bis-

GMA, UDMA, and Bis-EM. The differences in the resin components could effect on fracture resistance.

2- Filler loading: The highest percentage of fillers loading was Beautifil –Bulk [87% by weight (74.5% by volume)], followed by Tetric Evo Ceram® Bulk Fill [80% by weight (61% by volume)] and Filtek ™ bulk fill [76.5% by weight (58.4% by volume)]. The in the filler loading may increase the fracture resistance.

3- The particle in Beautifil –Bulk is giomer (glass ionomer+ polymer). This particle has been introduced as the true hybrid of composite resin and glass ionomer. The giomer possesses the benefits of each parent material and simultaneously minimizes the disadvantages of each one separately.

This particle contains surface pre-reacted glass ionomer (S-PRG) filler particles within the resin matrix. Meanwhile, the nanohybrid and nanofill contained nanoparticles that bonded strongly to each other (agglomeration) or to other materials because of their huge surface free energy. This characteristic enhances the physical and mechanical properties.

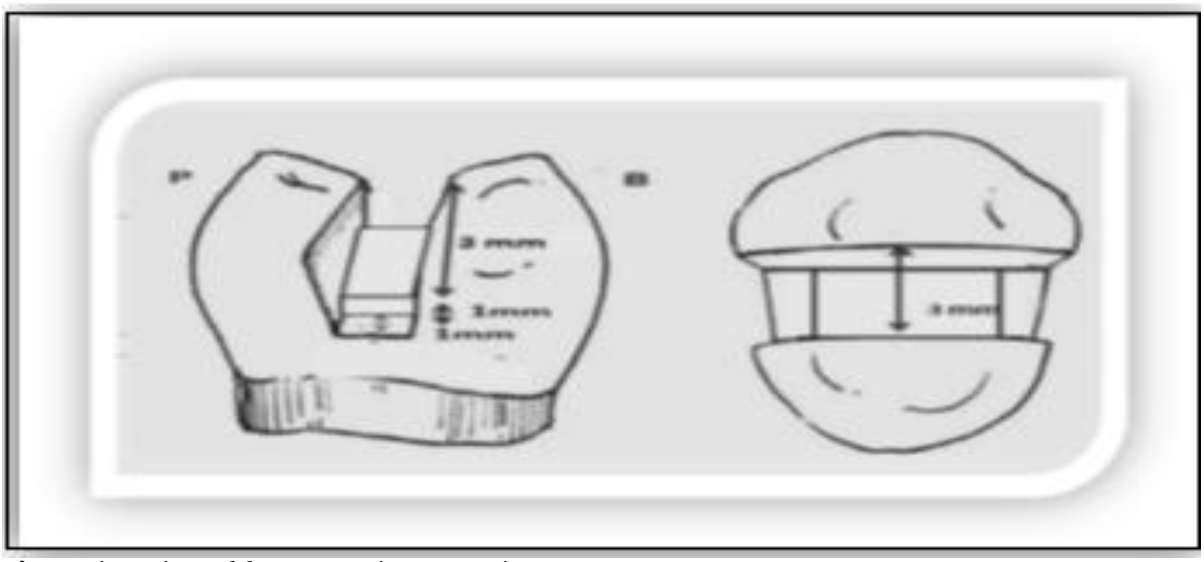

Fig. 1. Dimensions of the MOD cavity preparation.

No statistical significant difference was found in the fracture resistance between the teeth restored with nanofill (group 3-A) and nanohybrid (group 5-A) composite restoration. This finding agrees with those of a previous study (Atalay *et al.,* 2016).

The bond strength of the Filtek ™ bulk fill composite (group 3-A) was higher than that of Tetric Evo Ceram® Bulk Fill (group 5-A). This result is consistent with a previous study (Mandava *et al.,* 2017).

In general, the fracture resistance of all groups increased when preheating was performed. This result may be due to the fact that pre-heating composites prior to photo activation generally increased their flow ability, which has been shown to increase marginal adaptation. Moreover, increased polymerization temperature enhanced both radical and monomer mobility, resulting in higher overall conversion. This process may promote the improvement of mechanical and physical properties, such as enhanced flexural and diametral tensile strength and higher surface hardness, of pre-heated composite materials (Dionysopoulos *et al.,* 2014; Joshua *et al.,* 2016).

The fracture resistances of all groups showed statistically highly significant difference with the prepared unrestored group (group 2). No statistically significant difference was found in the fracture resistance between the room temperature and preheated composite of groups 3 and 4. By contrast, statistically significant difference was found in the fracture resistance in group 5 between the room

temperature and preheated composite and the approximate fracture resistance of Giomer at room temperature (group 4-A).

Conclusions

The highest fracture resistance was recorded in the intact teeth, while the lowest fracture resistance was observed in the prepared unrestored teeth. All bulk fill composite materials improved the fracture resistance compared with the prepared unrestored teeth. The teeth restored with Beautifil –Bulk ™ composite material showed the highest fracture resistance among all restored teeth at room temperature and 54±1 °C. Teeth restored with Tertic Evo Ceram® Bulk Fill composite material showed the same fracture resistance of Filtek™ bulk fill posterior restoration at room temperature, while with preheated Tertic Evo Ceram® Bulk Fill was slightly lower than that restored with BEAUTIFIL –BUIK ™ composite material at room temperature. The teeth restored with preheated Filtek ™ bulk fill posterior restoration showed slight increase in fracture resistance compared with that restored at room temperature.

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Conflict of interests

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