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Bonding Interaction and Shrinkage Stress of Low-viscosity Bulk Fill Resin Composites With High-viscosity Bulk Fill or Conventional Resin Composites

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Clinical Relevance

The use of high-viscosity bulk fill associated with low-viscosity bulk fill resin composites presents an adequate bonding interaction and results in better margin stability due to lower shrinkage stress at the occlusal enamel margin.

SUMMARY

Objective: To analyze the shrinkage stress, bonding interaction, and failure modes between different low-viscosity bulk fill resin composites and conventional resin composites produced by the same manufacturer or a high-viscosity bulk fill resin composite used to restore the occlusal layer in posterior teeth.

Methods & Materials: Three low-viscosity bulk fill resin composites were associated with the conventional resin composites made by the

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same manufacturers or with a high-viscosity bulk fill resin composite, resulting in six groups (n=10). The bonding interaction between resin composites was tested by assessing the microshear bond strength (μSBS). The samples were thermocycled and were tested with 1-mm/min crosshead speed, and the failure mode was evaluated. The post-gel shrinkage (Shr) of all the resin composites was measured using a strain gauge (n=10). The modulus of elasticity (E) and the hardness (KHN) were measured using the Knoop hardness test. Two-dimensional finite element models were created for analyzing the stress caused by shrinkage and contact loading. The μSBS, Shr, E, and KHN data were analyzed using the Student *t*-test and one-way analysis of variance. The failure mode data were subjected to chi-square analysis (α=0.05). The stress distribution was analyzed qualitatively.

Results: No significant difference was verified for μSBS between low-viscosity bulk fill resin composites and conventional or high-viscosity bulk fill composites in terms of restoring the occlusal layer (p=0.349). Cohesive failure of the low-viscosity bulk fill resin composites was the most frequent failure mode. The Shr, E, and KHN varied between low-viscosity and high-viscosity resin composites. The use of high-viscosity bulk fill resin composites on the occlusal layer reduced the stress at the enamel interface on the occlusal surface.

Conclusions: The use of high-viscosity bulk fill resin composites as an occlusal layer for low-viscosity bulk fill resin composites to restore the posterior teeth can be a viable alternative, as it shows a similar bonding interaction to conventional resin composites as well as lower shrinkage stress at the enamel margin.

INTRODUCTION

Resin composites are widely used in posterior restorations with optimum longevity.[1-7] To simplify and streamline the restorative process, bulk fill resin composites were created to reduce the clinical steps and consequently the length of chair time.[8-10]

Bulk fill resin composites represent an innovative class of resin-based materials. These resin composites are commercialized in high viscosity and are easily sculpted, and they can fill a cavity using 4- to 5-mm increments.[8,11,12] Low-viscosity bulk fill resin composites are usually indicated as a base, filling up to 4.0 mm of the dentin portion of the cavity, and most of the bulk fill composite resin needs a coverage of 2 mm of conventional resin composites, which exhibit better wear strength and tensile strength.[8,13-15] Low-viscosity bulk fill resin composites have shown good adaptation to the cavity walls[9] and lower porosity compared to the conventional resin composite when using an incremental technique.[16-18] The mechanical properties of bulk fill resin composites promote lower polymerization shrinkage stress, better stress distribution, and high fracture resistance.[8] However, this performance is clearly material dependent.[8,19] The chemical structures do not differ substantially from those of conventional resin composites since their base monomers are bisphenol A diglycidylmethacrylate (Bis-GMA), bisphenol A polyethylene glycol diether dimethacrylate (Bis-EMA), triethylene glycol dimethacrylate, urethane dimethacrylate (UDMA), and silanized glass filler particles. However, bulk fill resin composites contain modified UDMA and other modulators of the reaction that possess photoactive groups that control the polymerization kinetics and retard the accumulation of the polymerization shrinkage stress.[19,20]

Combinations of resin composites are becoming more frequent due to the association of the low-viscosity bulk fill with the conventional resin composite.[8,13,14] The manufacturers recommend the use of conventional resin composite to cover the low-viscosity bulk fill resin composites at the occlusal surface of the posterior teeth.[21-23] However, clinicians have frequently questioned if the association of the high-viscosity bulk fill and low-viscosity bulk fill resin composites could be a good alternative, aiming to facilitate clinical procedures and to reduce the shrinkage stress.[19] It can be questioned if the chemical interaction between different composites is compromised. No information, to the authors' knowledge, is available regarding the interaction between different low-viscosity bulk fill with conventional or high-viscosity bulk fill resin composites.

Therefore, this study aimed to analyze the shrinkage stress, the bonding interaction, and the failure modes among different low-viscosity bulk fill resin composites with the conventional resin composites produced by the same manufacturer or with one high-viscosity bulk fill resin composite used for restoring the occlusal layer in the posterior teeth. The null hypothesis was that the low-viscosity bulk fill resin composites with the occlusal layer covered using high-viscosity bulk fill or conventional resin composites inserted incrementally would have no effect on bond strength and shrinkage stress.

Table 1: *Resin Composites Used in This Study*

Material	Code	Resin Composite Type	Organic Matrix[a]	Filler[a]	Filler% Wt/Vol[a]	Manufacturer	Lot Number
Filtek Z350XT	Z350	Nanofilled	Bis-GMA, Bis-EMA, UDMA, TEGDMA	Silica and zirconia nanofillers, agglomerated zirconia-silica nanoclusters	78.5/63.3	3M ESPE (St Paul, MN, USA)	N603650
TPH-3	TPH3	Nanohybrid	Bis-EMA, Bis-GMA	Barium glass, barium aluminum silicate, silica	75/57	Dentsply Sirona (Konstanz, Germany)	157722H
Opallis	OPAL	Nanohybrid	Bis-GMA, Bis-EMA, TEGDMA, UDMA	Barium aluminum, silicate, sílica	79/58	FGM (Joinville, Brazil)	300316
Filtek Bulk Fill Posterior	POST	High-viscosity bulk fill	UDMA, DDDMA, EDMAB	Silica, zirconia, YbF3	76.5/58.4	3M ESPE	N690323
Surefil SDR Flow	SDR	Low-viscosity bulk fill	Modified UDMA, dimethacrylate and difunctional diluents	Barium and strontium alumino-fluoro-silicate glasses	68/44	Dentsply Sirona	1508283/150831
OPUS Bulk Fill Flow	OPUS	Low-viscosity bulk fill	TEGDMA, Bis- EMA, UDMA	Silica with urethane dimethacrylate, salinized silica dioxide, salinized barium glass, YbF3	68/—	FGM	060616
Filtek Bulk Fill Flow	FBF	Low-viscosity bulk fill	UDMA, Bis-GMA, EBPADMA, Procrylat resin	Silane-treated ceramic, YbF3	64/42.5	3M ESPE	N768439

[a] *Composition as given by manufacturers.*
Abbreviations: Bis-GMA, bisphenol A diglycidylmethacrylate; Bis-EMA, bisphenol A polyethylene glycol diether dimethacrylate; UDMA, urethane dimethacrylate; TEGDMA, triethyleneglycol dimethacrylate; DDDMA, 1, 12-Dodecanediol dimethacrylate; YbF_3, ytterbium fluoride; EDMAB, tertiary amine ethyl-4-dimethylaminobenzoate; EBPADMA, ethoxylated bisphenol A dimethacrylate.

METHODS AND MATERIALS

The characteristics of the three low-viscosity bulk fill resin composites, three conventional resin composites made by the same manufacturers, and one high-viscosity bulk fill resin composite used in this study are described in Table 1.

Microshear Bond Strength Test

To test the bonding interaction between low-viscosity and the conventional resin composites made by the same manufacturer or the one high-viscosity bulk fill resin composite, a microshear bond test was used. The combinations between resin composites resulted in six groups (n=10):

- FBF/Z350: Filtek Bulk Fill Flow (3M ESPE, St Paul, MN, USA) and Filtek Z350 XT (3M ESPE)
- FBF/POST: Filtek Bulk Fill Flow and Filtek Bulk Fill Posterior (3M ESPE)
- SDR: Surefill SDR (Dentsply Sirona, Konstanz, Germany) and TPH3 Spectrum (Dentsply Sirona)
- SDR: Surefill SDR and Filtek Bulk Fill Posterior
- OPUS: Opus Bulk Fill Flow (FGM, Joinville, Brazil) and Opallis (FGM)
- OPUS: Opus Bulk Fill Flow and Filtek Bulk Fill Posterior

The resin composite samples were embedded into the polystyrene resin cylinders that were 30 mm in height and 20 mm in diameter after flattening and finishing the base and top surfaces using abrasive grit sandpaper of grit sizes 180, 320, and 600 (Norton, Campinas, Brazil). Using a no. 1052 diamond bur (KG Sorensen, Barueri, Brazil), a cylindrical cavity 1 mm thick and 4 mm in diameter was prepared to be filled by the low-viscosity bulk fill resin composites. The low-viscosity resin composites were inserted into the cylindrical cavity and light cured using a broad-spectrum LED light-curing unit (LCU) (VALO, Ultradent, South Jordan, UT, USA) with average irradiant intensity of 1400 mW/cm^2 checked by using a MARC Resin Calibrator (Blue-Light Company, Halifax, NS, Canada). The LCU was rigidly fixed by using a support device (Odeme, Luzema, Brazil) at a distance of approximately 1.0 mm from the cylinder to standardize the distance to the LCU.

To standardize the size of the specimens and to delimit the bonding area, transparent flexible tubes 1.0 mm in diameter and 4.0 mm high were used

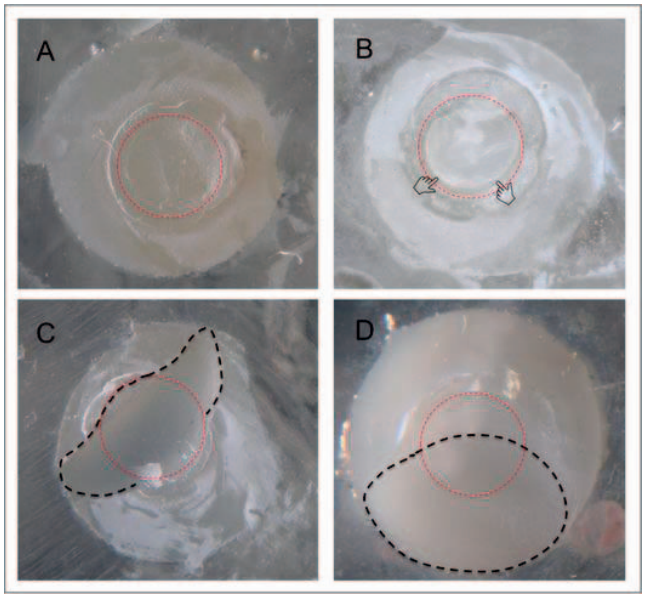


Figure 1. *Failure modes. (A): Adhesive failure. (B): Cohesive failure of occlusal resin composite layer. (C): Cohesive failure of low-viscosity bulk fill resin composite. (D): Mixed failure involving cohesive failure and adhesive failure.*

(Embramac, Campinas, Brazil). The conventional and high-viscosity bulk fill resin composites were inserted into the plastic tube, previously positioned over the center of the low-viscosity bulk fill resin composite samples, and were light cured following the same protocol described above. The plastic tubes were cut longitudinally with a no. 12 scalpel blade (Swann Morton, Rio de Janeiro, Brazil) and were carefully removed by the same operator. The samples were thermally cycled (ER 26000, Erios, São Paulo, Brazil), following a protocol of 6000 cycles between the temperatures of 5°C and 55°C. The specimens were stored at 37.7°C for 24 hours in distilled water before thermal cycling.

The specimens were attached to a specific device fixed to a universal testing machine (Microtensile Machine OM 100, Odeme) so that the resin cylinder's long axis was parallel to the horizontal plane. A 0.3-mm-diameter wire (Morelli, Sorocaba, Brazil) was placed around the resin cylinder over its interface with the surface of the low-viscosity bulk fill composite resin. A 50 N load cell was used to apply an increasing parallel force to the adhesive area at a speed of 1 mm/min until the specimen failure occurred. At the time of fracture, the force was recorded (N) and divided by the area ($A=\pi r^2$, mm) that corresponded to the interface between both resin composites, resulting in microshear bond strength (μSBS) values in MPa.

Failure Mode Analysis

After the μSBS test, the specimens were analyzed using stereomicroscopy at 40× magnification (Mitutoyo, Kawasaki, Japan) to classify the failure mode as follows: type I, adhesive failure between both resin composites; type II, cohesive failure of the covering resin (high-viscosity bulk fill or conventional resin composites); type III, cohesive failure of the low-viscosity composite resin; and type IV, mixed fracture involving part of the low-viscosity bulk fill resin composite and cover composite resin (Figure 1).

Post-Gel Shrinkage

The post-gel shrinkage (Shr) was calculated for all the tested resin composites (n=10) using the strain gauge method.[24] The materials were shaped into semispheres on the top of a biaxial strain gauge (CEA-06-032WT-120, Measurements Group, Raleigh, NC, USA) that measured shrinkage strains in two perpendicular directions. A strain conditioner (ADS05000IP, Lynx Tecnologia Eletrônica, São Paulo, Brazil) converted electrical resistance changes in the strain gauge to voltage changes through a quarter-bridge circuit with an internal reference resistance (120 Ω). The strain values measured along the two axes were averaged since the material properties were homogeneous and isotropic on a macro scale. All the materials were light cured using an LED LCU (VALO, Ultradent) with the light tip held at a 1-mm distance from the surface of the composite. The strain values were collected for five minutes. The maximum shrinkage strain at five minutes was used as the linear post-gel shrinkage input for finite element analysis and could be converted to volumetric percentage by multiplying by 3 and 100%.

Knoop Microhardness (KHN) Measurements

For calculating the modulus of elasticity and the hardness of the tested resin composites, the Knoop hardness test was used.[25] A microhardness tester (FM-700, Future-Tech Corp, Kanagawa, Japan) was used with a diamond indenter to apply a static charge of 100 g (0.98 N) for 10 seconds. For each specimen, the average of five indentations was used on the top surface. The following formula was used: $KHN = 14.229 \times \text{Load (kg)}/(\text{long diagonal in mm})$.[25] In addition to the hardness determination, Knoop indentations were also used to determine the modulus of elasticity.[25,26] The decrease in the length of the indentation diagonals caused by elastic recovery of a material are related to the hardness:modulus ratio (H/E) by the equation

Table 2: *Mechanical Properties Applied for the Dental Structures and Materials*

Structure/ Materials	Modulus of Elasticity (MPa)	Poisson's Ratio	Compressive Strength (MPa)	Diametral Tensile Strength (MPa)	References
Enamel	84,100	0.30	—	—	44
Dentin	18,600	0.30	—	—	45
Pulp	2	0.45	—	—	46
FBF	—	0.24*	229.1	43.8	47
OPUS	—	0.24*	152.5	34.3	47
SDR	—	0.24*	182.3	43.5	8
Z350 XT	—	0.24*	257	47.3	8
OPALLIS	—	0.24*	141	42.1	47
TPH3	—	0.24*	136.2	40.5	47
POST	—	0.24*	169.3	42.4	47

* *Reference 50.*

$$b'/a' = b/a - \infty 1(H/E)$$

where b/a is the ratio of the diagonal dimensions a and b in the fully loaded state, given by a constant 0.140647; b′/a′ is the ratio of the altered dimensions when fully recovered; and $\infty 1 = 0.45$ is a proportionality constant.[26]

Two-Dimensional Modeling of Dynamic Finite Element Molars

Two-dimensional models were created for finite element analysis, simulating a model of a maxillary human first molar in occlusal antagonist contact, from a transverse cone beam tomographic image of a patient with normal occlusion from a bank of dental school images. An occlusal cavity 6 mm in depth was simulated. The coordinates and points of the structures were drawn using processing software (IMAGEJ, public domain, National Institutes of Health, Bethesda, MD, USA) and were imported into a finite element analysis package (Marc & Mentat 2010.2 software, MSC, Santa Ana, CA, USA). Cube spline curves were then created through these coordinates to re-create the contours of the structures for the model.

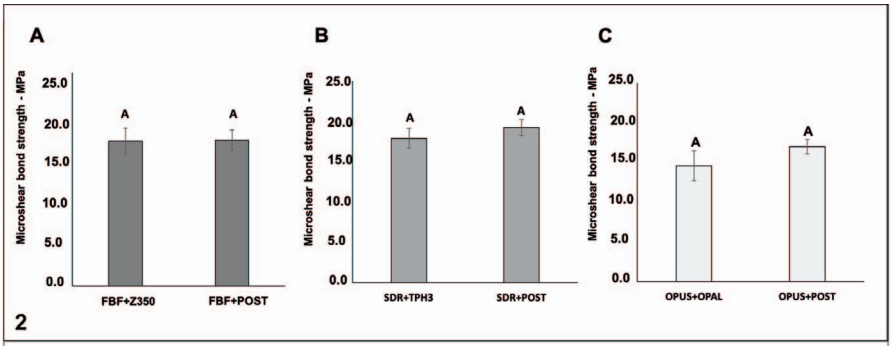
The models were generated following two conditions: 1) cavity restored with 4.0 mm of low-viscosity bulk fill resin composites to replace dentin and covered with 2.0 mm of a high-viscosity bulk fill resin composite in a single increment and 2) molar restored with 4.0 mm of low-viscosity bulk fill resin composites to replace dentin and covered with two increments of 2.0 mm of conventional resin composite. The mesh was created through a manual process that used isoparametric four-node arbitrary quadrilateral deformation elements with reduced integration (one integration point per element), using a no. 115 element type in the software Marc. All the interfaces were attached, considering bonded interfaces. Displacement was limited at the nodes of the base of the maxillary and mandibular bone in the X and Y directions. All the materials were considered linear, isotropic, and homogeneous. The applied mechanical properties are listed in Table 2.[8,27-30] The insertion of the composite resin layers was simulated, and their Shr values were previously calculated. The occlusal contact of 100 N of the mandibular molar with the maxillary molar, followed by a sliding movement, was simulated by using friction contact between the mandibular and maxillary occlusal surfaces (frictional coefficient 0.5). Stress distributions were analyzed using modified von Mises (MVM) stresses, which integrate all the tension components in a value equivalent to stress.

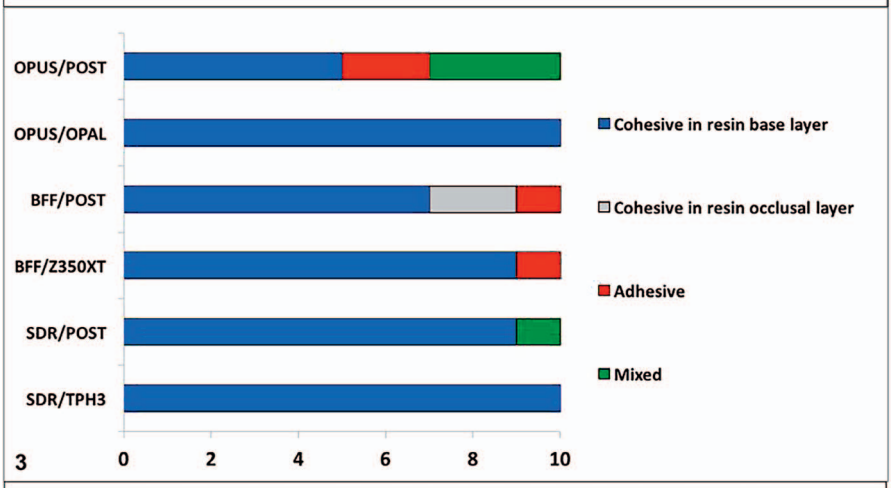
Statistical Analysis

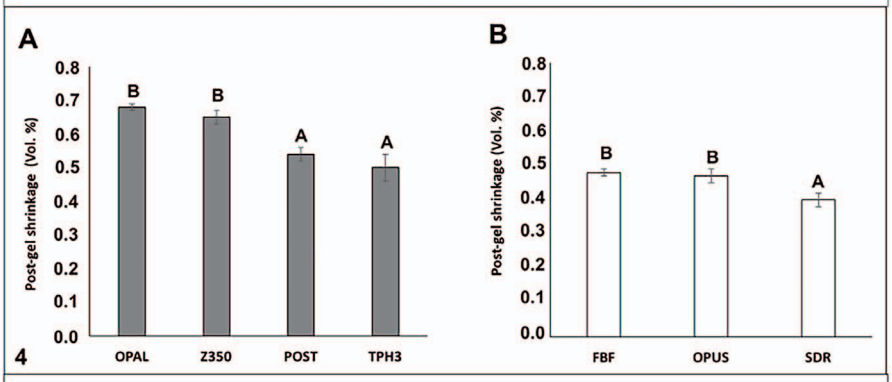
The μSBS, Shr, and KHN data were tested for a normal distribution (Shapiro-Wilk) and for equality of variances (Levene test), followed by parametric statistical tests. The Student *t*-test was performed for the μSBS values. One-way analysis of variance (ANOVA) was performed for the KHN and Shr values. Multiple comparisons were made using the Tukey test. The failure mode data were subjected to chi-square analysis. All the tests employed an $\alpha = 0.05$ significance level, and all the analyses were carried out with the statistical package Sigma Plot version 13.1 (Systat Software Inc, San Jose, CA, USA). Stress distribution was analyzed qualitatively.

RESULTS

The mean μSBS and standard deviation values between the low-viscosity bulk fill and the conven-







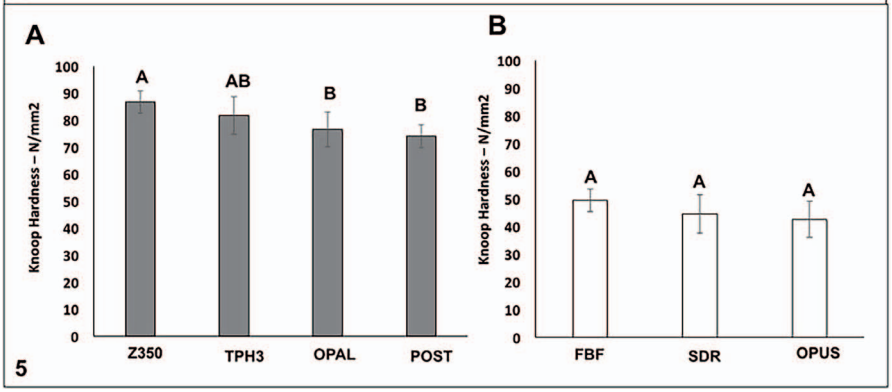


Figure 2. *Mean and standard deviation microshear bond strength (μSBS) for the two experimental conditions tested for each low-viscosity bulk fill resin composites. (A): FBF. (B): SDR. (C): OPUS covered by conventional resin composites (Z350, TPH3, and OPAL, respectively) or high-viscosity composite resin (POST). Different letters indicate significant differences tested by the Student* t*-test (*$p<0.05$*).*

Figure 3. *Distribution of failure modes for the different experimental conditions.*

Figure 4. *Mean and standard deviation of post-gel shrinkage. (A): Conventional resin composites and high-viscosity bulk fill resin composite. (B): Low-viscosity bulk fill resin composites. Different letters demonstrate significant differences among the tested resin composites for each group (low and high viscosity).*

Figure 5. *Means and standard deviations of the microhardness Knoop (KHN) of the composites. (A): Conventional and high-viscosity bulk fill resin composites. (B): Low-viscosity bulk fill resin composites. Different letters demonstrate significant differences among the tested resin composites for each group (low and high viscosity).*

tional resin composites made by the same manufacturer as well as the Filtek Bulk Fill Posterior resin composite are shown in Figure 2. The Student *t*-test showed no significant difference for the bonding strength between low-viscosity bulk fill resin composites and the conventional resin composites produced by the same manufacturer or the high-viscosity bulk fill resin composite. The failure mode distribu-

tions for the tested samples are shown in Figure 3. No significant difference was found for the failure mode among the groups ($p=0.134$). Cohesive failures of low-viscosity bulk fill resin composites were the prevalent failure mode observed for all the groups.

The mean Shr and standard deviation values for all the resin composites are shown in Figure 4. One-way ANOVA showed that the SDR had lower Shr values than the FBF and OPUS. POST and TPH3 had similar Shr values and lower values than the FZ350 and OPAL resin composites.

The mean KHN and standard deviation values for all the resin composites are shown in Figure 5. One-way ANOVA showed that Z350 had higher KHN values than OPAL and POST as well as similar values to that of TPH3 ($p<0.01$). POST, TPH3, and OPAL had similar KHN values ($p=0.231$). Comparing the low-viscosity bulk fill resin composites, one-way ANOVA showed no significant difference among KHN means ($p=0.341$).

The mean E and standard deviation values for all the resin composites are shown in Figure 6. Comparing the low-viscosity bulk fill resin composites, one-way ANOVA showed that SDR showed higher E values than FBF and OPUS ($p<0.01$). Comparing the resin composites used for the occlusal layer, TPH3 and Z350 had higher E values than OPAL and POST.

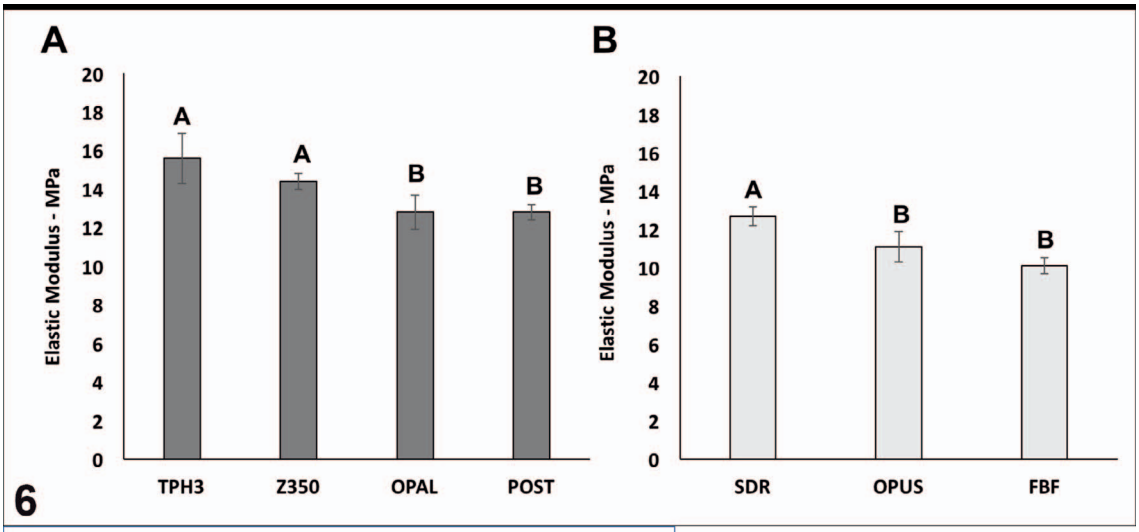
The stress distributions during restoration and at 100 N occlusal loading (modified von Misses stress) are shown in Figure 6. The use of the high-viscosity bulk fill (POST) on the occlusal layer resulted in lower shrinkage stress concentration at the enamel interface than when conventional resin composites inserted incrementally were used regardless of the tested resin composite combinations. OPAL had a higher critical von Mises stress at the enamel interface and at the walls of the restoration, mainly on the lingual cusp, than all the other conventional resin composites (Figure 6).

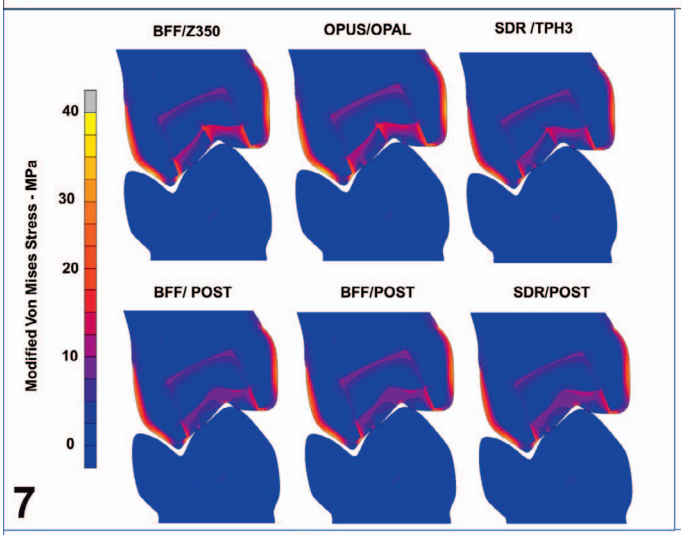
The stress distribution during restoration and occlusal function in the enamel, dentin, low-viscosity composite resin, and occlusal composite resin layers is shown in Figure 7. The maximum peak stress was observed on the enamel structure during the restoration procedure and during the antagonist tooth contact with the enamel/composite resin interface. The stress level of the enamel and dentin structures was lower when POST was used to restore the occlusal layer. The MVM stress was recorded at 18 points along the composite resin/tooth structure interface, as shown in Figure 8. The use of the high-viscosity bulk fill resin composite for restoring the occlusal layer reduced the stress at the margin of the restoration.

DISCUSSION

The bond strengths between low-viscosity bulk fill resin composites and high-viscosity bulk fill or a conventional resin composite were similar; therefore, the first null hypothesis was not rejected. However, the shrinkage stress generated at the enamel/restoration occlusal margins was lower when using the high-viscosity bulk fill resin composite for covering the low-viscosity bulk fill resin composites; therefore, the second null hypothesis was rejected. The combination of different low-viscosity bulk fill resin composites with high-viscosity bulk fill or conventional resin composites used to cover the occlusal surface had no influence on the bonding interaction among these materials. Although the bulk fill resin composites have the chemical modifications in their formulations to facilitate deep polymerization, the monomer interaction with the bulk fill low-viscosity resin was similar when compared with resin composites produced by the same manufacturer. The tested materials presented similar variations of the monomers and modulators in their compositions. However, the UDMA and Bis-GMA or Bis-EMA monomers were present in most resin composites, facilitating the interaction between different low-viscosity resin composites with the occlusal-layer resin composites.[31-33] The present study confirmed that the interaction with conventional and bulk fill resin composites performed similarly to the interaction between high-viscosity bulk fill resin composite.

The microshear method allows small areas to be effectively tested; however, during the test, stress was most concentrated at the base substrate,[34,35] in this study represented by the low-viscosity composite resin. These facts induced premature failure of the specimens.[35-37] The lower filler content present in low-viscosity bulk fill resin composites is reflected in their mechanical properties, resulting in decreased modulus of elasticity and hardness values.[10,11,37] These aspects may explain the high frequencies of the observed failure mode involving low-viscosity bulk fill resin composites. The presence of a high frequency of cohesive failure can mask the real difference on the bonding interaction between different resin composites. This study found no difference for the failure mode for all the tested combinations, probably because of the large similar-





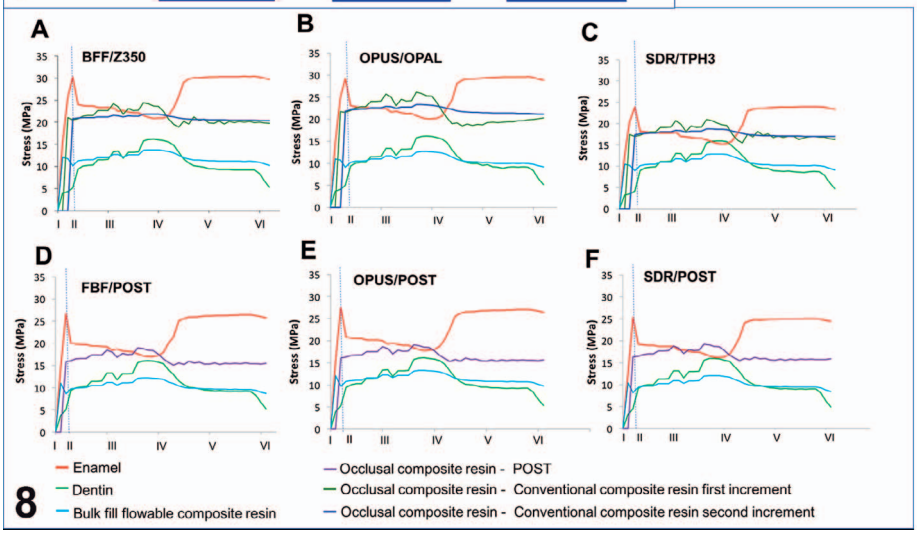


Figure 6. *Mean and standard deviation of the modulus of elasticity. (A): Conventional and high-viscosity bulk fill resin composites. (B): Low-viscosity bulk fill resin composites. Different letters demonstrate significant differences among the tested resin composites for each group (low and high viscosity).*

Figure 7. *Modified von Mises stress distribution generated by shrinkage and occlusal loading for different resin composite combinations tested at the maximum intercuspation of the molar teeth.*

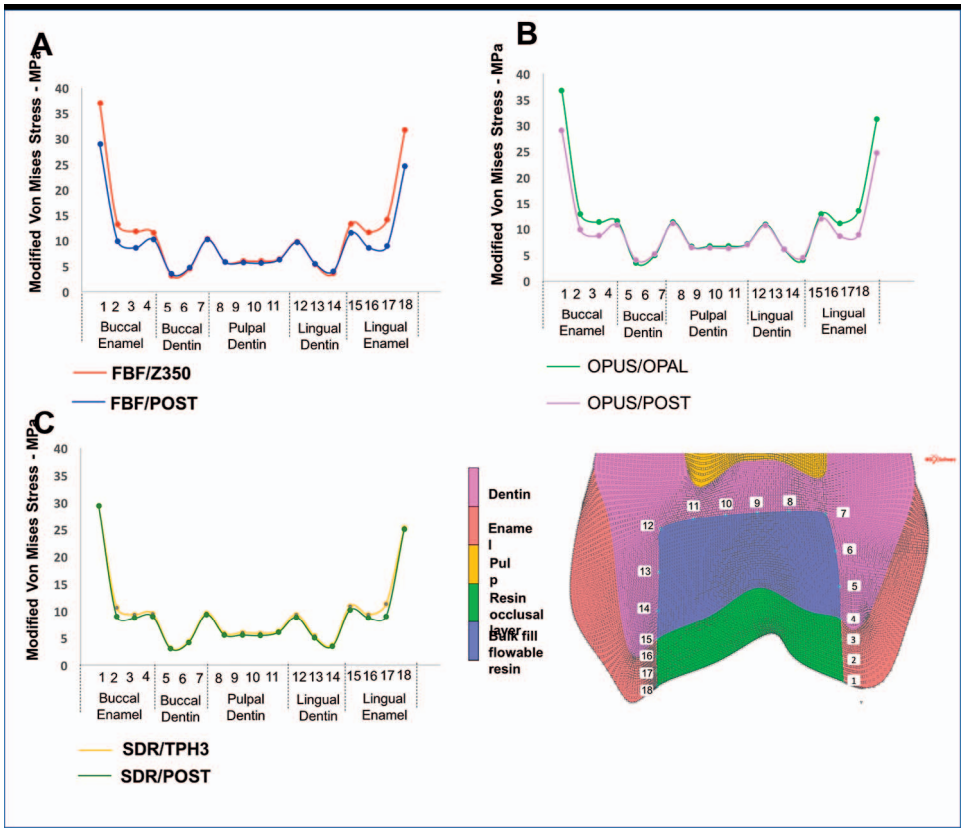


Figure 9. *The values of modified von Mises stress generated at the tooth structure/resin composite interface caused by shrinkage and occlusal loading for different resin composite combinations.*

ity on the filler content of the low-viscosity bulk fill resin composites.

During the polymerization of the resin composites, the modulus of elasticity develops when the material becomes rigid and its original capability for plastic flow as a paste decreases.[39,40] Shrinkage stress is generated when the composite material becomes solid enough to transfer stresses that can no longer be relieved by flow.[19,25] The modulus of elasticity tends to correlate with the hardness of the material as well as with the filling content.[38-40,41] The post-gel shrinkage and the modulus of elasticity of the material can influence the magnitude of the stress generated during polymerization.[19,25] Manufacturers incorporate inorganic fillers in resin composites with the aim of improving the mechanical properties of resin composites.[43] Bulk fill resin composites have a chemical composition similar to that of conventional resin composites in both the organic and the inorganic matrix.[44] However, these materials have modulators for the reaction that can explain the lower post-gel shrinkage and modulus of elasticity values compared with the conventional resin composites. Low-viscosity bulk fill resin composites exhibited the lowest post-gel shrinkage and modulus of elasticity because of decreased filler content and a higher capacity for intrinsic deformation, releasing the stress generated during polymerization shrinkage.[8] The shrinkage stress calculated at final restoration was the combination of the performance of both resin composites used in each group. The SDR/TPH3 or SDR/POST were the groups with the lowest shrinkage stress, probably because of the combination between the lowest shrinkage of SDR among low-viscosity bulk fill resin composites and lower Shr values of TPH3 Spectrum and Filtek Bulk Fill Posterior.

Considering that shrinkage stresses are concentrated at the occlusal margin,[42,45] the combination of shrinkage stresses and occlusal loading may be a determining factor in the mechanical performance of a restorative complex.[45] The stress concentrated at the enamel/occlusal margin may determine the marginal fracture or the marginal debonding.[19] If

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Figure 8. *The 10% highest values of modified von Mises stress generated on the enamel, dentin, the low-viscosity bulk fill resin composite, and the occlusal resin composite, caused by shrinkage and occlusal loading for different composite resin combinations. (A): FBF/Z350. (B): OPUS/OPAL. (C): SDR/TPH3. (D): FBF/POST. €: OPUS/POST, SDR/POST.*

the occlusal contact is located at the margin of a composite restoration, the increased stress concentration may increase the risk of marginal fracture. A retrospective clinical study showed that the fracture of restorations was the main reason for failure in "occlusal-stress-risk" patients.[45] Even if marginal deterioration is too small to be perceived clinically, it may increase the retention of pigments, increasing marginal discoloration. As marginal staining can be confused with marginal caries, such restorations may be replaced prematurely.[46]

It has frequently been indicated that low-viscosity bulk fill resin composites should be covered with a 1.5- to 2.0-mm layer with conventional resin composite.[8,11,12] The hardness of the material is one of the factors for the selection of the material when restoring posterior teeth[8,11,12] as well as the wear resistance.[37,47] It has been reported that bulk fill resin composites have adequate polymerization and hardness of the material not only on the surface of the resin composite but also in the depth of the restoration,[8,42] which was demonstrated in the present study, where the high-viscosity bulk fill composites had KHN values similar to those of conventional resin composites. However, the low-viscosity bulk fill resin composites had lower KHN values, which can be attributed to the low modulus of elasticity and filler content in its chemical composition. The results of the present study confirmed the difference in KHN hardness and that lower values of the low-viscosity resin composites reflect the necessity for the covering, preventing wear and bulk fracture.[47-49] Additionally, this study demonstrated that the use of high-viscosity bulk fill could be an adequate alternative for restoring the occlusal surface of posterior restorations.

This study has the limitation of testing only one high-viscosity resin composite. The shrinkage stress impacts are observed during the early stages regarding bond strength; hence, bond strength data gathered before the thermal cycling could add important information. Unless all factors can be modeled, the results of a finite element analysis should still be carefully interpreted within the clinical context.[18,24] Observing these clinical procedures with an understanding of the balance between mechanical properties offered by various composites may improve the clinical performance of posterior resin composite restorations. The use of low-viscosity bulk fill resin composites results in better adaptation and lower bubble formation.[17] When high-viscosity bulk fill material is used for restoring the occlusal surface, this tends to be a good option for posterior restorations.

CONCLUSIONS

Within the limitations of this *in vitro* study, the following conclusions were drawn:

1) There was no difference in bond strength between conventional or high-viscosity bulk fill resin composite with low-viscosity bulk fill resin composites. The cohesive failure mode was the most frequent mode in all the groups.
2) High-viscosity bulk fill resin composites had lower Shr values than conventional resin composites.
3) The modulus of elasticity varied substantially among the low-viscosity bulk fill resin composites.
4) High-viscosity bulk fill composite resin (Filtek Posterior) has similar KHN values to the conventional resin composites, which are normally recommended to fill the occlusal surface of low-viscosity bulk fill resin composites.
5) The use of high-viscosity bulk fill resin composites on the occlusal layer resulted in a decreased stress concentration at the enamel interface compared to the conventional resin composites inserted incrementally.

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Regulatory Statement

This study was conducted in accordance with all the provisions of the local human subjects oversight committee guidelines and policies of the Federal University of Uberlândia, School of Dentistry.

Conflict of Interest

The authors of this article certify that they have no proprietary, financial, or other personal interest of any nature or kind in any product, service, and/or company that is presented in this article.

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