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The effect of bulk-fill flowable composites on the fracture resistance and cuspal deflection of endodontically treated premolars

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The aim of this study was to evaluate the effect of bulk-fill flowable composites on cuspal deflection and fracture resistance of endodontically treated teeth. Forty-two maxillary premolars were subjected to endodontic treatment followed by the preparation of mesioocclusodistal cavities. Teeth were divided into six groups according to restorative materials as follows: Group 1: Clearfil Majesty Flow and Clearfil Majesty Posterior; Group 2: Venus Bulk Fill and Clearfil Majesty Posterior; Group 3: Clearfil Majesty Posterior; Group 4: Vertise Flow and Clearfil Majesty Posterior; Group 5: SDR and Clearfil Majesty Posterior; and Group 6: x-tra base and Clearfil Majesty Posterior. A single-step self-etch adhesive (OptiBond All-in-One) was applied to all groups, except Group 4. The cavities were restored with a centripetal incremental insertion technique and flowable composites using a 2-mm-thick base material, except for Group 3. The distance between cusp tips was measured before and after the cavity preparations, after the restorations, and after thermal cyclus with a digital micrometer. After measuring, each tooth was subjected to compressive loading with a stainless steel ball (4 mm diameter) perpendicular to the occlusal surface with a crosshead speed of 1 mm/min, and mean loads necessary to fracture were recorded in Newtons. The data were statistically analyzed by Kruskal–Wallis test. No statistically significant differences were found between groups in fracture strength or cuspal deflections ($p > 0.05$). Bulk-fill flowable composite bases did not change the cuspal deflection or fracture resistance of endodontically treated teeth, compared with that of a conventional flowable base and conventional resin composite.

Keywords: bulk-fill composite; fracture resistance; cuspal deflection; endodontically treated teeth

1. Introduction

The extraction of restored endodontically treated teeth generally depends on crown fractures, secondary caries, and failed restorations because they are more susceptible to tooth fractures due to the coronal destruction observed after removing of deep caries or previous restorations, endodontic treatments [1,2] that lead moisture loss and increased brittleness.[1] The restorative techniques for endodontically treated teeth have varying

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drawbacks such as the amount of remaining tooth structure that have resulted in important criticisms.[3] Mesioocclusodistal preparations generally caused the formation of extended cavity size that are subjected to cuspal fracture. It was revealed in the literature that adhesive restorations might have the potential to restore sound tooth stiffness and has to mimic the missing tooth structure and also increase fracture resistance.[4,5] Current adhesive technology offers direct adhesive restorations for endodontically treated teeth as an alternative, low-cost esthetic technique. Surely, the decision of restorative technique would depend on the missing tooth structure and it is also definitely that in addition to the esthetic expectations, an acceptable restoration must assure function and maintain the tooth structure against fracture.[3]

One important disadvantage of resin composite restorations is polymerization shrinkage that may cause shrinkage stress on the tooth and tooth–restoration interfaces. Cuspal deflection is result of the interactions between this shrinkage stress and the adaptation of restorative material to cavity. This may breakdown the adhesion at the tooth–restoration interface, generally leading to nanoleakage and recurrent caries.[6,7] Cuspal deflection influenced from two different category of factors. The factors of material itself (polymerization shrinkage, flow, marginal adaptation) and geometric properties (cavity size and remaining tooth structure) \[6,8–10\] could be accepted as the first category. The other category includes clinical factors for the use of cavity liner \[6,10\] restorative \[11,12\] and polymerization \[13\] technique. Cuspal deflection increases parallel with cavity size. With larger restorations, the stress is occurred higher on the tooth, while it is observed lower on the restoration and tooth–restoration interface. The risk of tooth fracture is also influenced by this stress distribution.[6,7]

Flowable composites can be a different alternative material for increasing fracture resistance. One of the advantages of these composites is their close adaptation with cavity walls. It has also been reported that the use of flowable composites as cavity liners reduces cuspal flexure.[14] Elastic cavity wall concept that is explained with the application of flowable composites generally to the cervical part of the tooth as an intermediate layer and suggested for direct restorative techniques.[15] In this concept, the shrinkage stress of a resin composite which shows higher elastic modulus can be compensated by this elastic flowable increment.[10] It was also known that the cuspal displacement was affected by the elastic modulus of the composites.[16]

To simplify the restoration procedure, nowadays contribution to adhesive dentistry is bulk-fill flowable composites that can be placed up to 4 mm thick.[17,18] The polymerization kinetics of these materials are claimed to be better due to the enhanced translucency and enable them to be cured up to a 4 mm depth. The polymerization stress of bulk-fill flowable composites was lower than conventional flowable composites,[19,20] and the marginal integrity of these materials are observed like conventionally layered composite restorations.[18,19,21]

The aim of the current study was to evaluate the fracture strength, failure modes, and cuspal deflection of endodontically treated maxillary premolars restored with different types of bulk-fill flowable and flowable resin-based composites. The null hypothesis were that bulk-fill flowable composites did not have an effect on the cuspal deflection of direct restorations of endodontically treated teeth and there was not statistically significant difference on the fracture resistance of conventional flowable base, conventional resin composite and bulk-fill flowables.
2. Materials and methods

The tooth samples were collected from a pool of extracted teeth of Dental Clinics of İstanbul Medipol University. The teeth were examined under 10× stereomicroscope for cracks, developmental defects, caries, and forty-two maxillary single-rooted premolars were selected for the study. Teeth of similar sizes (width varied between 6.38 and 7.08 mm) were chosen by measuring the buccolingual width in millimeters with using a digital micrometer gauge (Series 480-505, resolution 1 μm; SHAN TM Precision Measuring Instruments, Guilin, China) and allowing a maximum deviation of 10% from the determined mean. The teeth were washed in tap water and stored in distilled water at 37 °C, which was changed every 5 days during the study.

2.1. Cuspal deflection measurement

The buccal and palatal cusp tips of each specimen were acid-etched (Prime-Dent, Prime Dental, USA) for 30 s, washed for 30 s, and dried. A two-step etch and rinse adhesive (Single Bond 2, 3M ESPE, USA) was applied according to the manufacturer’s recommendations and polymerized for 20 s. Conventional flowable composite (Clearfil Majesty Flow, Kuraray, USA) was applied to the buccal and palatal cusps as reference balls to measure the intercuspal distance followed by polymerization (20 s). The distance between the reference balls was measured with a digital micrometer and recorded as the ‘initial distance’ and measurements were done after all restorative procedures (before the endodontic and restorative procedure, after restorations and the data were recorded).[22]

2.2. Preparation procedure

Before the preparations, the outlines of the cavities were drawn with pencil, and parallel-sided MOD standardized cavities were prepared with a 1 mm gingival cavosurface margin coronal to the cementoenamel junction (CEJ). The bur (835-012-4, Diatech, Switzerland) was replaced after every fourth cavity preparation in order to ensure high-cutting efficacy. The cavities have a flat floor, with a width that was one-third of the intercuspal distance for the occlusal portions of the preparations and one-third of the total faciolingual dimension for the proximal boxes. The cavosurface margins were prepared at 90°, and all internal angles were rounded.

2.3. Endodontic treatment

After the preparations, a conservative, endodontic access was performed on the pulp chamber wall. After that, all canals were prepared with Pro-Taper Ni-Ti Rotary System (Dentsply Malleiffer) and obturated with an AH 26 sealer (Dentsply; DeTrey, Konstanz, Germany) and gutta-percha using a lateral compaction technique. Gutta-percha was removed, and excess sealer was removed by cotton pellet with alcohol. Following the endodontic treatments, the teeth were randomly divided into six groups (n = 7) according to the restorative materials. The materials for the restorative procedures are listed in Table 1.

2.4. Restorative procedure

Group 1: A single-step self-etch adhesive (OptiBond All-in-One, Kerr, Italy) was applied to the enamel and dentin according to the manufacturer’s instructions. The
surfaces were dried with gentle air blowing and then with a medium for at least 5 s and light cured for 10 s (Elipar Free Light, 3M ESPE, AG, Germany, 1007 mW/cm²). After adhesive polymerization, a metal matrix band (Adapt SuperCap Matrices, Kerr, Switzerland) was placed around the tooth. A thin layer of a composite (Clearfil Majesty Esthetic, Kuraray, Japan) was applied toward the metallic matrix contacting the cavosurface of the proximal box up to half of the occlusal-cervical extension. The second layer was applied over the previous increment contacting the cavosurface margin of the proximal box and forming the marginal ridge. This procedure was applied for both the mesial and distal margins and applied resin composites were polymerized for 40 s according to the manufacturer’s instruction. Thus, the cavity turned into a class I as mentioned in centripetal technique. The flowable composite, Clearfil Majesty Flow, was applied at a 2 mm thickness horizontally to the resulting class I cavity and cured for 20 s. After the flowable composite application, two increments of composite (Clearfil Majesty Esthetic, Kuraray, Japan) were applied to the buccal and palatal sides of the occlusal cavity obliquely and cured for 40 s.

Table 1. Materials tested in the study.

<table>
<thead>
<tr>
<th>Materials</th>
<th>Material type</th>
<th>Composition</th>
<th>Manufacturer</th>
<th>Lot number</th>
</tr>
</thead>
<tbody>
<tr>
<td>OptiBond All-in-One</td>
<td>Single-step self-etch adhesive</td>
<td>Acetone, hydroxyethylmethacrylate (HEMA), ethyl alcohol, disodium hexafluorosilicate</td>
<td>Kerr Corporation, USA</td>
<td>3514858</td>
</tr>
<tr>
<td>Clearfil Majesty Flow</td>
<td>Flowable composite</td>
<td>Triethylene glycol dimethacrylate (TEGDMA), hydrophobic aromatic dimethacrylate, silanated barium glass filler, silanated colloidal silica, dl-Camphorquinone, accelerators, pigments, others</td>
<td>Kuraray Dental, Japan</td>
<td>00310B</td>
</tr>
<tr>
<td>Clearfil Majesty Esthetic</td>
<td>Nanohybrid composite</td>
<td>Bisphenol A, diglycidylmethacrylate, hydrophobic aromatic, dimethacrylate hydrophobic, aliphatic methacrylate, silanated barium glass filler, pre-polymerized organic filler, dl-camphorquinone Initiators, accelerators, pigments others</td>
<td>Kuraray Dental, Japan</td>
<td>00041B</td>
</tr>
<tr>
<td>Venus Bulk Fill</td>
<td>Bulk-fill flowable composite</td>
<td>Methacrylate monomers (UDMA, EBADMA), Ba–Al–F silicate glass, YbF₃, SiO₂</td>
<td>Heraeus Kulzer, Germany</td>
<td>66046795</td>
</tr>
<tr>
<td>Vertise Flow</td>
<td>Bulk-fill flowable composite</td>
<td>hydroxyethylmethacrylate (HEMA), 4 methoxyphenol (MEHQ), zinc oxide (ZnO), pigments</td>
<td>Kerr Corporation, USA</td>
<td>3500809</td>
</tr>
<tr>
<td>SDR Posterior bulk-fill flowable base</td>
<td>Posterior bulk-fill flowable base</td>
<td>Polymerizable dimethacrylate resins, polymerizable urethane dimethacrylate, barium boron fluoro alumino silicate glass, silicon dioxide – amorphous, strontium aluminosilicate glass, titanium dioxide, synthetic inorganic iron oxides (colorants)</td>
<td>DENTSPLY Caulk, USA</td>
<td>1208224</td>
</tr>
<tr>
<td>x-trabase Bulk-fill flowable composite</td>
<td>Bulk-fill flowable composite</td>
<td>Aliphaticdimethacrylate, catalyst</td>
<td>Voco, Germany</td>
<td>1216598</td>
</tr>
</tbody>
</table>

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Group 2: OptiBond All-in-One was applied to the enamel and dentin according to the manufacturer’s instructions. After the matrix application, Clearfil Majesty Esthetic was applied toward the metallic matrix on both mesial and distal margins and cured for 40 s as described above. The bulk-fill flowable composite (Venus Bulk Fill, Heraeus Kulzer, Germany) was applied at a 2 mm thickness horizontally to the resulting class I cavity and cured for 20 s. After the flowable composite application, the remaining cavity was restored with Clearfil Majesty Esthetic, as mentioned above.

Group 3 (control): After the application of OptiBond All-in-One, the cavities were restored with Clearfil Majesty Esthetic by using a centripetal technique. In this technique after polymerization of mesial and distal margins, Clearfil Majesty Esthetic was inserted to the created class I cavity as four oblique layers.

Group 4: Self-adhering flowable composite (Vertise Flow, Kerr Corporation, Orange, CA, USA) was dispensed in the cavity, brushed onto all cavity walls and the beveled area with moderate pressure for 15–20 s, and light cured for 20 s. After the restorations of the marginal ridges with Clearfil Majesty Esthetic using a centripetal technique, Vertise Flow was applied at a 2 mm thickness horizontally and cured for 20 s. After the flowable composite application, the remaining cavity was restored with Clearfil Majesty Esthetic, as mentioned for Groups 1 and 2.

Group 5: After the restorations of the mesial and distal marginal ridges with Clearfil Majesty Esthetic, a bulk-fill flowable composite (SDR, Dentsply, Germany) was applied at a 2 mm thickness horizontally to the resulting class I cavity and cured for 20 s. The remaining cavity was restored as described in Groups 1, 2, and 4.

Group 6: After the restorations of the mesial and distal marginal ridges with Clearfil Majesty Esthetic, bulk-fill flowable composite (x-trabase, Voco, Germany) was applied at a 2 mm thickness horizontally, and the remaining cavity was restored as described in all groups except Group 3.

2.5. Fracture testing

One dental operator made all the preparations and restorations. After the cuspal deflection measurements, the teeth were then subjected to 500 thermal cycles, each with a dwell time of 20 s at 5 and 55 °C and handled in moist gauze to prevent dehydration. A thin coat of wax (0.3 mm) was applied on the external root surface of all teeth. The teeth were vertically mounted to a level of 1.0 mm apical to the CEJ, with the long axis of the tooth parallel to that of the acrylic resin molds. The wax on the root surfaces was purified with boiling water, and this space was filled with silicone paste (Oranwash vl, Zhermark, Germany) 1 mm apical to the CEJ to simulate periodontal ligament. The specimens were stored in 100% humidity for 24 h before fracture testing. The specimens were placed in a universal testing machine (Autograph AG-IS, Shimadzu Co, Kyoto, Japan) with the long axis of the roots parallel to the load direction after storing. A stainless steel ball (4 mm diameter) was used to load the specimens until fracture, with a crosshead speed of 1 mm/min. The loading site was the central fissure and the ball was contacted to occlusal surface of the restorations and the buccal and palatinal cusps of the teeth, while the mean loads were recorded in Newtons. The failure modes (adhesive, cohesive, or mixed) were evaluated and assessed using standard criteria [23] at a magnification of 20×. Fractures were characterized as ‘restorable’ if they were limited to the coronal portion and included retention failures and ‘not restorable’ if the fractures reached the root.
2.6. **Statistical analysis**

The fracture load and cuspal deflection data were expressed as median, minimum, and maximum values. Since the data had a non-normal distribution, the difference among groups was statistically analyzed using a non-parametric one-way ANOVA (Kruskal–Wallis) test at a 5% significance level. All data were analyzed using SPSS 11.5 for Windows software (SPSS Inc., Chicago, IL, USA).

3. **Results**

The mean buccal–palatal width of the maxillary premolar teeth did not vary significantly between the specimen groups \((p > 0.05)\). The forces (N) required to fracture the teeth in each group are displayed in Figure 1 and Table 2. The Kruskal–Wallis test demonstrated no significant differences \((p = 0.18)\) with respect to fracture resistance among all groups. The influence of using bulk-fill flowables on the cuspal movement was not statistically significant \((p = 0.63)\) for all groups. The cuspal deflection values for the experimental groups are shown in Figure 2 and Table 3. Table 4 shows the failure mode results of all the experimental groups in the study. It was observed that the fractures were generally not restorable.

![Fracture resistance values](image)

**Figure 1.** Fracture resistance values.

**Table 2.** The minimum, maximum, and median forces of experimental groups (N).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (Clearfil Majesty Flow)</td>
<td>653.59</td>
<td>486.72</td>
<td>886.09</td>
</tr>
<tr>
<td>Group 2 (Venus Bulk Fill)</td>
<td>642.81</td>
<td>523.75</td>
<td>919.84</td>
</tr>
<tr>
<td>Group 3 (Clearfil Majesty Posterior)</td>
<td>782.97</td>
<td>534.06</td>
<td>998.13</td>
</tr>
<tr>
<td>Group 4 (Vertise Flow)</td>
<td>830.00</td>
<td>623.59</td>
<td>948.13</td>
</tr>
<tr>
<td>Group 5 (SDR)</td>
<td>692.97</td>
<td>426.09</td>
<td>806.09</td>
</tr>
<tr>
<td>Group 6 (x-trabase)</td>
<td>691.17</td>
<td>503.13</td>
<td>749.06</td>
</tr>
</tbody>
</table>
4. Discussion

Maxillary premolar restorations may undergo palatal and buccal strains, as a result of occlusal chewing loads which is related with high stress inside the tooth–restoration structure. However, if the strain is higher from the maximum resistance of the tooth, gap formation, nanoleakage, crack, or fracture may be occurred and also the restoration may have failed.[24] Thus, in this study, maxillary premolars were used to compare the fracture resistance of different restorative materials regard to mechanical occlusal loading.

Numerous investigations have been carried out to decide out the ideal way to restore endodontically treated teeth. In a literature, it was mentioned that tooth fracture decreased when MOD cavities were restored with direct composite restoratives.[25] According to Reeh and Messer,[26] the access of endodontic treatment within intact teeth reduces fracture resistance and when it was combined with an MOD cavity preparation, the resistance is reduced more. Mondelli et al. [27] reported that maxillary premolars (no endodontic treatment) with MOD cavity preparations close to 2.5 mm deep presented only 36% of the fracture resistance recorded for that of sound premolars. They related the difference to the smaller remaining tooth structure following MOD cavity preparations, similar to the study of Burke.[28] Adhesive restorations have also been suggested for larger cavities of endodontically treated teeth.[29] Large MOD cavities were prepared in maxillary premolars with endodontic access in our study according to the knowledge of these restorations with low fracture toughness.

Table 3. The minimum, maximum and median values of cuspal deflection (µm).

<table>
<thead>
<tr>
<th>Groups</th>
<th>Median</th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (Clearfil Majesty Flow)</td>
<td>11.30</td>
<td>8.77</td>
<td>13.00</td>
</tr>
<tr>
<td>Group 2 (Venus Bulk Fill)</td>
<td>11.77</td>
<td>5.81</td>
<td>15.20</td>
</tr>
<tr>
<td>Group 3 (Clearfil Majesty Posterior)</td>
<td>11.30</td>
<td>7.40</td>
<td>13.97</td>
</tr>
<tr>
<td>Group 4 (Vertise Flow)</td>
<td>9.90</td>
<td>9.40</td>
<td>14.03</td>
</tr>
<tr>
<td>Group 5 (SDR)</td>
<td>10.00</td>
<td>8.60</td>
<td>12.30</td>
</tr>
<tr>
<td>Group 6 (x-trabase)</td>
<td>8.27</td>
<td>7.60</td>
<td>13.03</td>
</tr>
</tbody>
</table>

Figure 2. Cuspal deflection values.
It is believed that the clinical performance of endodontically treated teeth depends on both root canal treatment and the restorative technique. Deciding the best technique and material according to functional demands and lost tooth structure are the key factors for clinical success.[30,31] Direct adhesive restorations are able to resist functional stresses and reinforce the weakened tooth structure.[32,33] The low elastic modulus of resin composites may explain the energy transmitted to the tooth structure.[32,34] Today’s nano technology made small modifications on resin composites to have superior mechanical properties like increased elastic modulus and easy adaptation techniques.[35] Here in this study, we decided to use direct adhesive restorative materials, which were developed with nanotechnology to present superior properties.

Although it was known that flowable composites shrink more than traditional resin composites,[36] bulk-fill flowables have lower shrinkage stress. The stress-relieving flowability is potentially claimed by the manufacturer (Dentsply) as “SDR” resin monomer[20]; SDR’s enhanced translucency promotes light transmittance and better polymerization kinetic up to 4 mm. Several new materials are also claimed bulk-fill polymerization up to 4 mm (Tetric EvoCeram Bulk Fill, Ivoclar-Vivadent, Schaan, Liechtenstein) and 5 mm (SonicFILL, Kerr, Orange, CA, USA). Bulk-fill restoratives with enhanced polymerization and controlled shrinkage[35–37] reduce chairside time of restorative treatments.[21]

Van Meerbeek et al. [15] observed that the use of a low modulus flowable composite may increase the flexibility by allowing it to act as a stress breaker. Alshali et al. [38] reported that the bulk-fill composites’ (SDR and Venus Bulk Fill) shrinkage were generally comparable to those of the conventional composites that they tested. However, in other studies,[20] it was reported that SDR showed 60–70% less polymerization shrinkage stress than that of the conventional resin composites. In our study, the fracture resistance of four different bulk-fill flowable composites was not statistically different. The use of flowable composite resin material is believed to relieve stress, promote adaptation, and work against fractures; however, it did not support the findings (the differences were not statistically significant) of our study. The median fracture forces were observed as 653.59 in Group 1, 642.85 in Group 2, 782.97 in Group 3, 830 in Group 4, 692.97 in Group 5, and 691.17 in Group 6. This similarity would be related to the bulk application technique limited with 2 mm thickness. The manufacturers also

<table>
<thead>
<tr>
<th>Groups</th>
<th>Restorable</th>
<th>Unrestorable</th>
<th>Adhesive</th>
<th>Cohesive</th>
<th>Mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group 1 (Clearfil Majesty Flow)</td>
<td>1 (14.28%)</td>
<td>6 (85.72%)</td>
<td>1 (14.28%)</td>
<td>0 (0%)</td>
<td>6 (85.72%)</td>
</tr>
<tr>
<td>Group 2 (Venus Bulk Fill)</td>
<td>2 (28.57%)</td>
<td>5 (71.43%)</td>
<td>3 (42.85%)</td>
<td>0 (0%)</td>
<td>4 (57.14%)</td>
</tr>
<tr>
<td>Group 3 (Clearfil Majesty Posterior)</td>
<td>1 (14.28%)</td>
<td>6 (85.72%)</td>
<td>7 (100%)</td>
<td>0 (0%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Group 4 (Vertise Flow)</td>
<td>4 (57.14%)</td>
<td>3 (42.86%)</td>
<td>5 (71.43%)</td>
<td>0 (0%)</td>
<td>2 (28.57%)</td>
</tr>
<tr>
<td>Group 5 (SDR)</td>
<td>3 (42.85%)</td>
<td>4 (57.14%)</td>
<td>4 (14.28%)</td>
<td>1 (14.28%)</td>
<td>2 (28.57%)</td>
</tr>
<tr>
<td>Group 6 (x-trabase)</td>
<td>2 (28.57%)</td>
<td>5 (71.43%)</td>
<td>3 (42.86%)</td>
<td>0 (0%)</td>
<td>4 (57.14%)</td>
</tr>
</tbody>
</table>
mentioned that bulk-fill flowables could be applied in bulk with a single layer of up to 4 mm thickness; perhaps this thickness would change the polymerization shrinkage stress as well as fracture resistance.

Regarding fracture mode, majority of the specimens in the groups exhibited non-restorable failures, except in the group restored with Venus fill. However, the difference was not statistically different. Failures typically occurred by adhesive breakdown at the buccal or palatal interface, with a cuspal fracture obliquely extending from the lower part of the buccal or palatal line angle. Fracture patterns generally varied related to loading conditions for example with vertical loading, the fracture was occurred vertically through the restoration extending into the root and cause marginal failure where the cuspal fracture was also seen.[2,23]

The cuspal deflection occurred during restorative treatment is related to many factors, such as size and configuration of preparations or the adhesive materials used.[7] Although the incremental technique is preferred, it is not clear that this technique can reduce the deflection compared to the bulk-fill restorations. Some studies also reported that cuspal deflection was reduced with incremental technique,[6,39] whereas others mentioned that this technique was not better than bulk-fill restorations.[40,41] It was also reported that the cuspal deflection with bulk-fill application technique was observed significantly lower compared with incremental cure due to the incomplete polymerization of resin composite applied as bulk.[40] However, this fact cannot be expected for bulk-fill flowables applied as up to 4–5 mm thickness due to the better controlled polymerization kinetics of these materials. To standardize the materials curing depths, the cavities were restored with centripetal technique, and the thickness of all flowables including bulk fills applied in bulk and 2 mm thick in our study. It was subjected that flowable composites shrink more[20]; thus, we could except that cuspal deflection values must be higher for Groups 1 and 4; and through the knowledge of the effect of incremental technique on shrinkage stress decrease,[6,39] it could be excepted that cuspal deflection values must be lower for Group 3. However, the cuspal deflection values did not vary among the groups. This finding could be related to the lower polymerization shrinkage of bulk-fill flowable composites.

Taha et al. [7] observed the mean cuspal deflections as 6 μm for low shrink composites and 10–40 μm reported for high shrink composites similar to some other literature.[10,42,43] In our study, the cuspal deflection values we observed were 11.30 (Group 1), 11.17 (Group 2), 11.30 (Group 3), 9.9 (Group 4), 10.00 (Group 5), and 8.27 (Group 6), respectively, like high shrink composites. It is important to determine whether the lower cuspal deflection in bulk cure is because of an incomplete cure or another reason, as Versluis et al. [44] indicated. If it is occurred due to an incomplete polymerization, it would have different results when curing time or density was extended.

On fracture mode, adhesive failure was observed on all specimens of Group 3. This situation could be explained with better mechanical properties of traditional resin composites when compared to flowable ones. However, it can be thought that due to the higher elastic modulus of these conventional resins, 85.72% of the fractures observed in Group 3 specimens were unrestorable failures. In addition to this, more restorable fractures were observed in the Groups 4 and 5 but these differences were not statistically significant. Further studies with larger specimen numbers and with different restorative groups are needed to find out the differences between the flowable and conventional resin composites.
Consequently, the null hypothesis tested, which stated that bulk-fill flowable composites would not have an effect on the cuspal deflection and fracture resistance of direct restorations of endodontically treated teeth, was accepted.

5. Conclusion
Within the limitations of this study, it can be concluded that using bulk-fill flowables did not change the cuspal deflection or fracture resistance of endodontically treated premolars. The findings would be different if the restorations were done only in bulk and not by using a centripetal technique or if the thickness of bulk-fill composite were 4 mm or more.

Disclosure statement
No potential conflict of interest was reported by the authors.

References


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