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Comparative Assessment of Cuspal Deflection in Premolars Restored with Bulk-Fill and Conventional Composite Resins

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A B S T R A C T

Objectives: It has been reported that bulk-fill composites simplify tooth restoration with no adverse effect on the success rate. This study sought to assess the cuspal deflection of premolars with mesio-occluso-distal (MOD) cavities restored with bulk-fill and conventional posterior composite resins.

Materials and Methods: This in-vitro experimental study was conducted on 64 human maxillary premolars. MOD cavities were prepared on teeth and restored with Filtek P60 conventional composite and Filtek Bulk Fill flowable, X-tra fill, and X-tra base bulk-fill composites in four groups (n=16). Distance between the cusp tips was measured before, five minutes, 24 hours, 48 hours, and one week after restoration. The data were analyzed using repeated-measures analysis of variance (ANOVA) and Tukey's test ($\alpha=0.05$).

Results: The mean±standard deviation (SD) of cuspal deflection at five minutes after the restoration was 13.5±5.3, 12.2±3.5, 11.3±4.4, and 10.4±3.7 µm for Filtek P60, Filtek Bulk Fill, X-tra fill, and X-tra base, respectively. ANOVA showed that bulk-fill composites did not cause a significant reduction in cuspal deflection compared to P60 ($P>0.05$). Cuspal deflection in all groups significantly decreased with time ($P<0.05$).

Conclusion: Bulk-fill composites have no superiority over P60 in the reduction of cuspal deflection. The cuspal deflection was variable at different time points in all groups and decreased over time.

Keywords: Filtek Bulk Fill; Composite Resins; Polymerization; Bicuspid; Dental Restoration; Elasticity; Dental Cavity Preparation

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INTRODUCTION

Despite technological advances in the production of new composites, polymerization shrinkage has remained a challenge, limiting the clinical use of composite resins [1]. Polymerization shrinkage, if not controlled, can cause volumetric shrinkage and can create stress in bonded restorations, leading to eventual clinical failure [2]. Even if the composite bond to tooth structure remains intact, stresses transferred to tooth structures often result in cuspal deflection, enamel fracture or cuspal fracture [3,4]. Cuspal deflection can change the occlusal contact of the teeth and can cause postoperative tooth hypersensitivity or fracture in some cases [5]. Cuspal deflection occurs as the result of the interaction of polymerization shrinkage stress in composite and adaptation to cavity walls [6]. Since shrinkage stress cannot be directly and simply measured in restored cavities, its effect is often quantified by measuring the cuspal deflection of the restored tooth [7].

In recent years, bulk-fill composites have been introduced to the market with greater curing depth and less polymerization shrinkage compared to conventional composites. They are applied in the cavity in bulk increments (up to 4 mm) to overcome the limitations of the incremental technique [8-11]. The manufacturers claim that bulk-fill composites can be cured in 4mm-thick increments and have small polymerization shrinkage. Thus, the incremental application is not required, and the teeth can be restored faster [10]. Due to the advanced dynamics of the photoinitiators and greater translucency of bulk-fill composites [12], thick layers of bulk-fill composites allow greater penetration of light and deeper curing depth [13,14]. Moreover, bulk-fill composites have shown less polymerization stress and shrinkage than conventional hybrid and flowable composites [15]. However, due to the high modulus of elasticity of composites and plastic deformity due to polymerization shrinkage following the use of bulk-fill composites, it appears that stress accumulates at the tooth-composite interface. Thus, the prediction of the amount of cuspal deflection and the marginal gap is difficult [15]. This study aimed to assess cuspal deflection following bulk application of several commonly used bulk-fill composites in mesio-occluso-distal (MOD) cavities in comparison with incremental application of a conventional methacrylate composite (P60). The null hypothesis was that cuspal deflection would not be significantly different following the use of different types of bulk-fill and conventional composites.

MATERIALS AND METHODS

This in vitro experimental study was conducted on 64 human maxillary premolars extracted for orthodontic reasons. The teeth were visually inspected to ensure the absence of caries, defects or cracks. Calculi and soft tissue debris were removed using a manual scaler, and the teeth were immersed in 10% formalin and transferred to distilled water at room temperature (23±1°C) one week before the experiment. To match the bucco-palatal width (BPW) of the teeth in the study groups, first, the BPW of each tooth at the height of contour was measured using a digital micrometer gauge (Mitutoyo 230-293, Kawasaki, Japan) with one µm accuracy. The teeth were randomly divided into four groups of 16 each. All teeth were stored in distilled water at room temperature (23±1°C) during the experiment, except during measurements. The teeth were individually mounted in plastic molds measuring 2cm in diameter and 2cm in height, filled with auto-polymerizing acrylic resin (Acropars, Tehran, Iran) so that the resin level was 2mm below the cementoenamel junction. Reference points for measurement of the inter-cuspal distance were marked as follows: the buccal and palatal cusp tips of each tooth with an approximate diameter of 2 mm were etched with 32% phosphoric acid (Scotchbond Universal Etchant; 3M ESPE, St. Paul, MN, USA) for 30 seconds, rinsed for 20 seconds and air-dried. Single Bond 2 (3M ESPE, St. Paul, MN, USA) was applied on etched surfaces using a microbrush according to the manufacturer's instructions and light-cured for 10 seconds using Woodpecker light-emitting diode light-curing unit (Guilin Woodpecker Medical Instrument Co., Guilin, Guangxi, China). The light intensity was measured after five times of curing using a radiometer (DigiRate LM-100, Monitex Industrial Co., New Taipei, Taiwan) to be 750 mW/cm^2. Flowable composite (Filtek Flow; 3M ESPE, St. Paul, MN, USA) was applied in the form of a small ball with an approximate diameter of 1mm on the buccal and palatal cusp tips and cured for 20 seconds. After one week of storage in distilled water at room temperature, the distance between the reference balls on each tooth was measured with a digital micrometer and served as the baseline value (Fig. 1). Using a 010 fissure bur

(Tizkavan, Tehran, Iran) and a high-speed handpiece, large standard MOD cavities were prepared on teeth under water coolant. Mesial and distal boxes were prepared in teeth with a 4-mm depth. The width of the boxes measured two-thirds of the BPW of each tooth. Occlusal extension of the cavity had an isthmus width corresponding to half the BPW of each tooth with a 4-mm depth from the margins. Cavo-surface margins were 90°, and all internal line angles were beveled. Facial and lingual walls of the cavities were also paralleled as in previous studies [4,16]. The bur was changed after every five preparations.

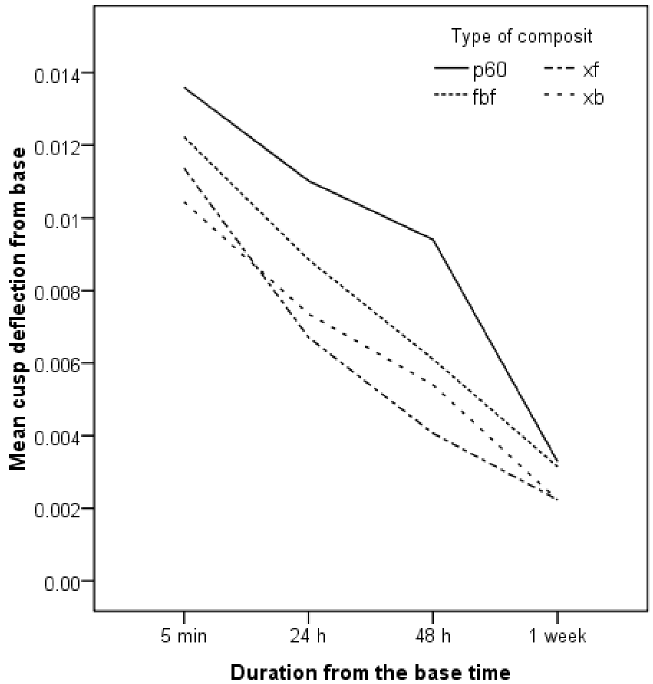

Fig. 1. Measurements related to the distance between cusp tips

For composite restoration of cavities, a transparent matrix band was used (Automatrix, Bioggio, Switzerland), which was removed after restoration. The cervical margin of the matrix at the site of proximal boxes was held by finger during the restoration procedure. All teeth were restored using Single Bond 2 and composite resins as recommended by the manufacturers. The materials used in this study are summarized in Table 1.

In group 1, enamel and dentin were etched with 32% phosphoric acid (3M ESPE, St. Paul, MN, USA) for 15 seconds and rinsed with water and air spray for 20 seconds. Using the wet bonding technique, excess water was removed from the tooth surface using absorbent paper. Two layers of Single Bond 2 were gently applied on the cavity walls for 15 seconds using a microbrush and thinned with gentle air spray for 5 seconds for the solvent to evaporate. Curing was then performed for 10 seconds. The A3 shade of Filtek P60 composite (3M ESPE, St. Paul, MN, USA) was applied in the cavity as bulk. The occlusal surface was formed using an anatomic burnisher, and curing was performed for 20 seconds according to the manufacturer's instructions. Composite restorations in groups 2, 3, and 4 were performed as in group 1 with the difference that the cavities were restored with Filtek Bulk-Fill (3M ESPE, St. Paul, MN, USA) with 40 seconds of curing time, X-tra fill Universal Shade (3M ESPE, St. Paul, MN, USA) with 20 seconds of curing time, and X-tra base Universal Shade (3M ESPE, St. Paul, MN, USA) with 10 seconds of curing time, respectively, as recommended by the manufacturers.

The teeth were then immersed in distilled water

Table 1: List of all materials used in this study

Material	Type/Color	Manufacturer	Composition
Filtek P60	High-viscosity, packable composite resin Shade: A3	3M ESPE, St. Paul, MN, USA	Inorganic fillers (61 vol%), Bis-GMA, UDMA, Bis-EMA, zirconia/silica nanofillers (0.01-3.5 μm)
Filtek Bulk-Fill Flowable	Low viscosity, flowable resin composite for bulk fill Shade: A3	3M ESPE, St. Paul, MN, USA	Bis-GMA, UDMA, Bis-EMA(6), Procrylat resins, zirconia/silica (particle size 0.01-3.5 μm), YbF3 (particle size 0.1-5 μm) Fillers, Inorganic filler loading: approximately 64.5% by weight (42.5% by volume)
X-tra fill	High-viscosity, packable resin composite for bulk fill Shade: Universal	Voco, Cuxhaven, Germany	Matrix: Bis-GMA, UDMA, TEGDMA Filler load: 70.1 vol%, 86 wt%
X-tra base	Low-viscosity, flowable resin composite for bulk fill Shade: Universal	Voco, Cuxhaven, Germany	Methacrylates, Bis-EMA Inorganic fillers (75 wt%, 58 vol% silica)
Adper Single Bond 2	Etch and rinse adhesive	3M ESPE, St. Paul, MN, USA	HEMA, Bis-GMA, dimethacrylate, polyacrylic and polyitaconic acids, water, ethanol
Scotchbond Universal Etchant	Etching gel	3M ESPE, St. Paul, MN, USA	32% phosphoric acid

Bis-GMA: Bisphenol A-glycidyl methacrylate; UDMA: Urethane dimethacrylate; Bis-EMA: Ethoxylatedbisphenol-A-dimethacrylate; TEGDMA: Triethylene glycol dimethacrylate; HEMA: 2-Hydroxyethyl methacrylate

at room temperature (23±1°C) until measuring the amount of cuspal deflection. The distance between the reference balls was measured at five minutes, 24 hours, 48 hours, and seven days after the completion of restoration using a digital micrometer [17]. One operator made all measurements. Each measurement was repeated three times, and three values were recorded. The mean of the three values for each measurement was calculated and used for statistical analyses. The amount of cuspal deflection at each time point was calculated as the difference between the final value at each time point and the baseline value of each distance and was separately reported for each time point. The data were analyzed using SPSS version 16 (SPSS Inc., Chicago, IL, USA). Since the time points were repeated for the samples, a comparison of the groups was made using repeated-measures analysis of variance (ANOVA).

The data were then subjected to Tukey's post-hoc test for pairwise comparisons and evaluation of changes in cuspal deflection in each group over time. The level of significance was set at $P<0.05$.

RESULTS

The mean and standard deviation (SD) of cuspal deflection in each group are presented in Table 2.

Table 2: Comparison of the mean and standard deviation (μm) of cuspal deflection of composite groups at different time points

Group	5min	24h	48h	1w
P60	13.5±5.3	11±4.3	9.4±4.1	3.2±1.7
FBF	12.2±3.5	8.8±3.1	6.1±1.8	3.1±1.1
XF	11.3±4.4	6.7±2.6	4.0±2.1	2.2±1.4
XB	10.4±3.7	7.3±3.5	5.4±2.8	2.2±1.5
P-value	0.213	0.004	<0.001	0.073

FBF: Filtek Bulk-Fill; XF: X-tra fill;, XB: X-tra base

At five minutes after the restoration of MOD cavities, the maximum amount of cuspal deflection was noted in the group restored with P60 composite (13.5 μm) while the minimum amount was found in the group restored with X-tra base composite (10.4 μm).

The inter-cuspal distance in all groups increased over time (after 24 and 48 hours and one week) but the final values did not return to the baseline in any group after one week of water storage (Fig. 2). Two-way repeated-measures ANOVA revealed that the mean cuspal deflection was significantly different among the composite groups (P=0.006). Also, the mean cuspal deflection was significantly different within each group at different time points (P<0.001).

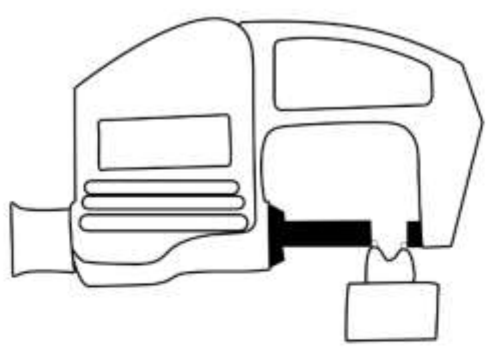

Fig. 2. The mean cuspal deflection (μm) of the composite groups at different time points

The interaction effect of time and type of composite on cuspal deflection was also significant (P=0.001). Thus, one-way repeated-measures ANOVA was used for each time point according to the type of composite. Cuspal deflection at five minutes and one week after the restoration was not significantly different among the study groups (P=0.213 for five minutes and P=0.073 for one week). Bulk-fill composites did not cause a significant reduction in cuspal deflection compared to P60 highly filled composite (P>0.05). However, at 24 and 48 hours after the restoration, the cuspal deflection was significantly different among the composites (P=0.004 and <0.001, respectively; Table 2).

Tukey's post-hoc test was used for pairwise comparisons of composites in terms of cuspal deflection at different time points (Table 3).

Table 3: Pairwise comparisons of cuspal deflection between composite groups at different time points

Group	P-value*			
	5min	24h	48h	1w
P60 vs FBF	0.809	0.302	0.011	0.992
P60 vs XF	0.470	0.005	<0.001	0.189
P60 vs XB	0.176	0.021	0.001	0.181
FBF vs XF	0.942	0.312	0.202	0.307
FBF vs XB	0.646	0.621	0.901	0.295
XF vs XB	0.929	0.952	0.564	1.000

* Tukey test, FBF: Filtek Bulk-Fill; XF: X-tra fill; XB: X-tra base

At 24 and 48 hours, the difference in cuspal deflection between X-tra fill and P60 was statistically significant (P=0.005 and <0.001, respectively). Also, at 24 and 48 hours, the cuspal deflection of X-tra base was significantly different from that of P60 (P=0.021 and 0.001, respectively). At 48 hours, the difference in cuspal deflection between Filtek Bulk-Fill and P60 was statistically significant (P=0.011).

DISCUSSION

Cuspal deflection depends on several factors, such as the type of tooth (molars or premolars) [18], the size and shape of the cavity, properties of the restorative material, the bonding system [3,4], and the technique of application of the restorative material (bulk or incremental) [19-24]. In the current study, one clinician prepared large MOD cavities, and the dimensions of the cavities were dictated by the BPW of each tooth. Thus, the ratio of the remaining tooth structure after cavity preparation was almost the same in all teeth, and the size of the cavity was standardized as such. Prepared cavities with such dimensions have a high C factor and better simulate the clinical setting [25]. Several methods are available for measurement of the amount of cuspal deflection, including microscopy [26], strain gauge [27], direct current differential transformers [19], linear variable differential transformers [28], and digital

micrometer [5,17,29].
In the current study, polymerization shrinkage of composites caused cuspal deflection in all groups, which was in line with the findings of previous studies [19,26,30]. The results of this study showed that the cuspal deflection of bulk-fill composites was not significantly different from that of conventional P60 composite (P>0.05). Composite shrinkage is the consequence of polymerization [20]. Low rate of polymerization [31] and the flowability of composites during polymerization [32] decrease the shrinkage stress of bulk-fill composites. Pairwise comparisons of composites at five minutes after the restoration in the current study showed that the cuspal deflection of X-tra base and then X-tra fill composites was lower than that of other groups although these differences were not statistically significant (P>0.05). The current results also showed that time significantly affected the cuspal deflection of composites (P<0.05), and a reduction in cuspal deflection of restored teeth occurred over time (after curing), which depended on the duration of water storage. Several previous studies have also confirmed this finding [23,25,30]. It has been reported that the return of deflected cusps (following composite restoration) to their baseline position is strongly influenced by the hydrophilicity of composites and their ingredients as well as the cavity size. Some studies [23,30] have discussed that complete or relatively complete return of the inter-cuspal distance to the baseline value is a gradual process, which does not occur in moderate or large size cavities (never returns to the exact baseline value). Comparison of cuspal deflection at five minutes, 24 and 48 hours, and one week revealed that all restored teeth tended to return to their baseline state. At 24 and 48 hours, the faster return of the cuspal deflection of X-tra fill compared to X-tra base composite was noted, which may be attributed to the composition of the polymer and the presence of hydroxyl (OH) groups in the resin matrix and consequently higher hydrophilicity of X-tra fill. Further studies employing more advanced technologies, such as optical coherence tomography, during the process of polymerization of bulk-fill composites are recommended to better understand the performance and mechanism of action of bulk-fill composites in the clinical setting.

CONCLUSION

Based on the results, bulk-fill composites were not significantly different from P60 conventional composite in decreasing cuspal deflection. The amount of cuspal deflection was variable at different time points in all composites and significantly decreased over time in all groups. The inter-cuspal distance approximated the baseline value after one week.

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CONFLICT OF INTEREST STATEMENT

None declared.

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