ORIGINAL ARTICLE

# The Effect of Endodontic Treatment and Thermocycling on Cuspal Deflection of Teeth Restored with Different Direct Resin Composites

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## Abstract

**Objective:** The purpose of this *in vitro* study was to assess the cuspal deflection of endodontically treated human premolars restored with different types of resin composites.

**Materials and methods:** Forty-eight intact human upper premolars were selected, and standardized mesio-occluso-distal cavities were prepared and randomly divided into four experimental groups according to different direct restorative materials as follows ($n = 12$): Group I: Filtek Bulk Fill; Group II: SureFil SDR Flow + Ceram X Mono; Group III: GCeverX posterior + G-aenial posterior; and Group IV: Tetric N-Ceram. After storage in distilled water for 24 h at 37°C, specimens were subjected to thermocycling (5–55°C, ×1000). The cuspal deflection measurements were performed in microns at "after preparation", "after endodontic treatment", "24 h after restoration", and "after thermocycling". Data were statistically analyzed using Friedman and Kruskal Wallis tests ($\alpha = 0.05$).

**Results:** There were no statistically significant differences between groups in terms of cuspal deflection either after 24 hours or after thermocycling measurements ($p > 0.05$). When comparing 24 hour and thermocycling cuspal deflection values within each restorative material group, none of the materials showed a significant difference ($p > 0.05$). While no significant difference was detected between "after endodontic treatment" and "24 h after restoration" for each group ($p > 0.05$), the difference between "after endodontic treatment" and "after thermocycling" cuspal deflection values increased statistically significantly for group II and group III ($p < 0.05$).

**Conclusion:** Endodontic treatment did not affect the cuspal movement of the upper premolars. Twenty-four hours after the restoration procedure and thermocycling procedure made no significant difference in the tested conventional/bulk-fill/bulk-fill flowable/fiber-reinforced resin composites' cuspal deflection.

**Keywords:** Bulk-fill composite, Cuspal deflection, Endodontically treated teeth, Fiber-reinforced composite.

*Conservative Dentistry and Endodontic Journal* (2021): 10.5005/jp-journals-10048-0105

## Introduction

Resin composites in the posterior region have been frequently used with the increase in the demand for esthetics. Recently, the abrasion resistance and mechanical and esthetic properties of composite resins have been greatly improved. However, polymerization shrinkage is still a problem and limits the application of direct techniques. According to the literature, resin-based composites show 1–3% reduction in volume during polymerization.[1,2] Polymerization shrinkage stresses can cause clinical difficulties such as microleakage, postoperative sensitivity, secondary caries, and pulp irritation at the composite–tooth interface.

A number of techniques and materials have been introduced to eliminate these problems. These are the modifications of the incremental technique, flowable composite application, and polymerization mechanisms.[3] The "incremental layering technique" is a method proposed by many researchers to reduce polymerization shrinkage stress and cuspal deflection, which is based on the fact that shrinkage can be less disadvantageous as the adaptation of the composite. Three main factors concur to reduce shrinkage stress: a lower cavity configuration factor, use of a small volume of material, and minimal contact with the opposing cavity walls during polymerization. Each increment is compensated by the next, and the consequence of polymerization shrinkage is less damaging since only the volume reduction of the last layer can damage the bond surface.[4]

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**How to cite this article:** Atalay C, Yazici AR, Horuztepe AS, *et al*. The Effect of Endodontic Treatment and Thermocycling on Cuspal Deflection of Teeth Restored with Different Direct Resin Composites. Cons Dent Endod J 2021;6(2):38–44.

**Ethics approval:** The Local Ethics Committee of Hacettepe University approved the study protocol and the approval code for this *in vitro* study was GO 17/117.

**Source of support:** This study was supported by Scientific Research Projects Coordination Unit of Hacettepe University (grant no. THD-2015-8632).

**Conflict of interest:** None

Advancements in mechanical and esthetic properties of posterior esthetic materials have brought up the expectation of ease of use. The bulk-fill technique and materials applied with this technique have become very popular recently. In addition

**Table 1:** The means and standard deviations (SDs) of the mean bucco-palatal width "BPW" and mesiodistal width "MDW" (in mm) of the teeth in each tested group

| Groups | *BPW* *Mean ± SD* | *p value* | *MDW* *Mean ± SD* | *p value* |
|---|---|---|---|---|
| I (Filtek Bulk Fill) | 7.25 ± 0.41 | >0.05 | 6.91 ± 0.21 | >0.05 |
| II (Surefil SDR + Ceram X Mono) | 7.28 ± 0.39 | | 6.83 ± 0.34 | |
| III (GCeverX posterior + G-aenial posterior) | 7.05 ± 0.55 | | 6.79 ± 0.28 | |
| IV (Tetric-N Ceram) | 7.35 ± 0.56 | | 6.87 ± 0.28 | |

Means are statistically insignificant at $p > 0.05$

to improved mechanical properties, bulk-fill materials have the advantages of easy manipulation and short application time with their contents that allow bulk increments up to 4–5 mm.[5] Some of these bulk-filled resin composites have a lower modulus of elasticity than nano-hybrid and micro-hybrid composites, which affects their performance under stress and increases their deformability.[6] Moreover, the increased polymerization depth of bulk-filled composites, as suggested by firms, can lead to superior marginal adaptation, if correct.

Another type of composite developed is fiber-reinforced composites. It is proposed that short fiber reinforced composites (SFRC) reduce polymerization shrinkage, increase stiffness and fracture resistance, and reinforce composite resin and tooth structure.[7] It has been observed that the properties of polyethylene fiber such as high elasticity and low bending modulus modify the stress developed at the adhesive interface. Results of mechanical tests showed that resin composites reinforced with short fiber fillers have higher fracture strength and load-bearing capacity compared to conventional particulate filler composites, and reduce marginal leakage by controlling polymerization shrinkage stress through fiber orientation.[8] The short fiber composite is designed as a substrate material that can be applied in a single layer and requires conventional resin composite application.[9]

Although there have been some studies in the literature about the performance of conventional, paste-like/flowable, and short fiber reinforced resin composites, there is no study evaluating these materials in endodontically treated teeth and subjecting them to thermocycling. Moreover, premolar teeth are naturally subjected to cuspal deflection under load application due to their structural design. This deflection tendency increases under chewing loads when MOD preparation and endodontic therapy are performed.[10] Various techniques have been reported in the literature to calculate cuspal deflection in large class II cavities with composite restorations. These techniques include digital micrometer, microscopy, flexible ribbons, strain gauges, trans-tooth illumination techniques, and two- and three-dimensional microcomputed tomography.[11,12]

The aim of this *in vitro* study was to investigate the effect of different composite resins applied on endodontically treated maxillary premolar teeth on cuspal movement. The null hypothesis was two-fold: (1) There would be no statistically significant difference in the cuspal deflection of endodontically treated teeth restored with different restorative resins either after 24 hours or after thermocycling; and (2) Endodontic treatment would have no influence on cuspal deflection of endodontically treated teeth.

# Materials and Methods

## Specimen Preparation

A total of 48 human upper premolar teeth were selected for this *in vitro* study. Teeth with caries, restorations, cracks, or defects were not included in the study. The soft tissue residues on the surface of the extracted teeth were removed with a hand scaler, and the teeth were stored in distilled water until the test was started. The enamel surfaces were cleaned with fluoride-free pumice. A digital micrometer (Series 480–505, resolution 1 µm, SHAN, Guilin, China) was used for the measurements of bucco-palatal and mesiodistal dimensions of the teeth, and the mean teeth sizes in each group were chosen to be close to each other (Table 1).

Before starting the procedures, reference points were created on the tops of all teeth in order to measure the distance between the cusp tips. Following the etching procedure with 37% phosphoric acid, Single Bond Universal (3M ESPE) was applied in accordance with the recommendations of the manufacturer and was polymerized with an LED device (Cromalux 1200, Mega- Physik, Rastatt, Germany; 1400 mW/cm$^2$) for 10 s. The resin composite spheres (Filtek Flow, 3M ESPE, USA) were applied to the buccal and palatal cusp tips and light-cured. A radiometer (Curing Radiometer Model 100; Demetron Research Corp, Danbury, CT, USA) was used for checking the curing light intensity.

## Preparation Procedures

Standardized MOD preparations were performed with diamond burs (Diatech, Heerbrugg, Germany), and the burs were renewed after every four cavities. Adhering to the class II preparation rules; the width of the isthmus was 1/3 of the distance between the cusps, while the width of the approximal box was 2/3 of the bucco-palatal width. The position of the gingival floor in the approximal box was adjusted to be 1 mm above the cementoenamel junction. The cavosurface margins were prepared at 90°. The dimensions of the preparations were controlled by means of a periodontal probe.

## Endodontic Treatment

Following standard endodontic access cavity preparation, a #2 diamond round bur (Dentsply, Tulsa, OK, USA) and a tapering cylinder bur were used for wall overhangs. Root canals were instrumented to length with Protaper nickel-titanium rotary instruments (Dentsply-Maillefer, Ballaigues, Switzerland) in conjunction with 2 mL of 5.25% sodium hypochlorite irrigation between each file. About 17% EDTA solution was used for the final irrigation. After drying with paper points, root canals were filled with ProTaper F3 gutta-percha and a resin-based endodontic sealer (AH Plus; Dentsply De Trey, Konstanz, Germany). After endodontic treatment, teeth were stored in 100% humidity for 7 days, and a resin-modified glass ionomer liner (WP-Glassliner, Germany) was used as a root canal sealer. All endodontic procedures were performed by a specialist in endodontics.

## Restorative Procedures

Before restorative procedures, each tooth was surrounded by a universal metal matrix band/retainer (Tofflemire) and was adapted. The teeth were randomly assigned into four groups,

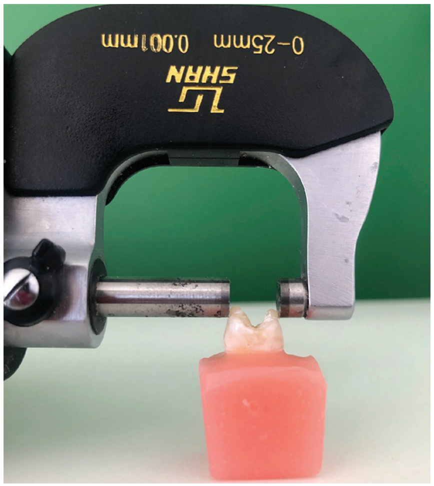

**Fig. 1:** Recording baseline measurement before the cavity preparation

each containing 12 teeth. The four different restorative procedures evaluated were as follows: Group I: Filtek Bulk Fill (3M ESPE, St. Paul, MN, USA); Group II: SureFil SDR Flow + Ceram X Mono (Dentsply Caulk, Milford, DE, USA); Group III: GCeverX posterior + G-aenial posterior (GC Co., Milford, DE, USA); and Group IV: Tetric N-Ceram (Ivoclar Vivadent, Schaan, Liechtenstein). All restorative materials were used with their respective adhesive system, and curing was performed with an LED device. The materials and applications for the restorative procedures are listed in Table 2. Diamond finishing burs (Diatech Dental AC), Soflex Polishing Discs (3M ESPE), and rubber points were used for finishing and polishing procedures. All restorative procedures were performed by the same restorative specialist.

### Cuspal Deflection Measurements

Care was taken to keep the teeth in distilled water at 37°C between measurements. The distance between reference points was measured with a digital micrometer, and the first measurement was recorded as "baseline measurement" Figure 1. Following the baseline measurement, the distance between reference points was measured at "after preparation", "after endodontic treatment", "24 h after restoration", and "after thermocycling". The cuspal deflection values were obtained by calculating the difference between the measurement at "after endodontic treatment" and the other measurements. Measurements were repeated three times for each tooth, and all measurements were performed by the same operator. The average of these measurements was used for the subsequent statistical analysis.

### Statistical Analyses

Statistical analysis was performed with IBM SPSS statistics version 20.0 (SPSS Inc., Chicago, IL, USA) for Windows. Descriptive statistics were calculated for the values of BPW and MDW of the teeth. Friedman test was performed for comparison between the mean cuspal deflection values of the tested groups. In cases where the Friedman test showed significant differences, Kruskal–Wallis test was used for pair-wise comparison between means. All tests employed $\alpha = 0.05$ significance level.

## Results

When the mean cuspal deflection of the teeth was compared after cavity preparation and endodontic treatment, no significant difference was detected between the groups ($p = 0.441$, $p = 0.479$; respectively). The means and standard deviations of cuspal movement at 24 hours (difference between the intercuspal distance after endodontic therapy and the intercuspal distance 24 hours after restoration placement) and after thermocycling (difference between the intercuspal distance after endodontic therapy and the intercuspal distance after thermocycling) are displayed in Table 3. There were no statistically significant differences between groups in terms of cuspal deflection either after 24 hours or after thermocycling measurements ($p > 0.05$).

When comparing 24 hour and thermocycling cuspal deflection values within each restorative material group, none of the materials showed a significant difference ($p > 0.05$). There was also no statistically significant difference when comparing after endodontic treatment vs 24 hours values within each group ($p > 0.05$). In terms of comparing after endodontic treatment vs after thermocycling measurements, group II (bulk-fill flowable resin composite + nanoceramic composite) and group III (fiber-reinforced composite + posterior resin composite) showed statistically significant differences (respectively, $p = 0.037$, $p = 0.010$). After thermocycling, significant increases were observed in cuspal deflection values of these groups ($p < 0.05$).

## Discussion

As endodontic treatment weakens the tooth structure, the teeth become more prone to fracture or failure. Therefore, it is important to find the most appropriate material to restore if it is needed to be restored directly. This study investigated the cuspal deflection of endodontically treated teeth restored with different direct restorative procedures and the tested materials did not make a significant difference in terms of cusp movements. Thus, the first null hypothesis that there would be no differences in cuspal deflection between the tested resin restorations was accepted. Moreover, endodontic treatment after MOD preparations did not affect cuspal movement significantly according to our results, so that our second null hypothesis was also accepted.

da Rocha and others[13] investigated the restorative technique's effect on the mechanical behaviors such as cusp deflection of endodontically treated premolars with MOD cavities. They reported that restoring these premolars with resin composite materials combined with the base material-glass ionomer cement yielded better results than methods such as applying metallic/fiberglass posts. We also found it appropriate to test the procedure that restoring teeth with direct composite resins instead of time-consuming and risky clinical applications such as post restorations.

In the present study, when comparing cuspal deflection values within each restorative material, bulk-fill flowable resin composite + nanoceramic and fiber-reinforced composite + posterior resin composite groups showed statistically significant differences when comparing after endodontic treatment vs thermocycling measurements. Flowable composite resins are widely used for an intermediate layer to reduce shrinkage stresses. On the other hand, Cadenaro and others[14] reported that flowable composites did not significantly reduce polymerization stresses and even increased the risk of deterioration at the interface. Although flowable composites are known to shrink more than conventional resin composites,[15] bulk-fill flowables have been suggested to have lower shrinkage stress. The manufacturers emphasize the stress-breaking feature of "SDR" and claim to have polymerization ability up to 4 mm, thanks to its improved transparency.

**Table 2:** Materials used in the study and their compositions and application procedures

| *Groups* | *Product Name/Manufacturer* | *Composition* | *Application* |
|---|---|---|---|
| I | Single Bond Universal<br>3M ESPE, St Paul, MN, USA 52768 | MDP phosphate monomers, dimethacrylate resins, HEMA, methacrylate-modified polyalkenoic acid copolymer, fillers, ethanol, water, initiators, and silane | After etching, the adhesive was applied for 20 seconds; the solvent was air-dried for 5 seconds, and then light-cured for 10 seconds by LED. |
| | Filtek Bulk Fill<br>N604746 | Silica filler, zirconia filler, zirconia/silica cluster filler, ytterbium trifluoride filler, AUDMA, UDMA, and 1, 12-dodecane-DMA | Each layer was approximately 5 mm thick and was cured for 40 seconds. |
| II | Prime&Bond NT<br>Dentsply Caulk, Milford, DE, USA<br>1306000189 | Di- and trimethacrylate resins, PENTA, nanofillers-amorphous silicon dioxide, photoinitiators, stabilizers, cetylamine hydrofluoride, and acetone | After etching, the adhesive was applied and remained fully wet for 20 seconds; teeth were then gently air-dried for 5 seconds and light-cured for 10 seconds. |
| | SureFil SDR-Flow<br>1207205 | Barium and strontium alumino-fluoro-silicate glass, modified UDMA, EBPADMA, TEGDMA, camphorquinone photoinitiator, photoaccelerator, butylated hydroxyl toluene, UV stabilizer, titanium dioxide, iron oxide pigments, and fluorescing agent | The composite (SureFil SDR Flow, Dentsply) at up to 4 mm in thickness and were then cured for 40 seconds. |
| | Ceram-X Mono<br>1203000406 | Methacrylate-modified polysiloxane, dimethacrylate resin, barium-aluminum-borosilicate glass, methacrylate functionalized silicon dioxide nanofillers | The remaining parts of the cavities were restored with increments at a maximum of 2 mm in thickness and were light-cured for 40 seconds. |
| III | G-aenial Bond<br>GC Co., Milford, DE, USA<br>1401271 | Phosphoric ester monomers, 4-MET, a hydrophilic methacrylate monomer, water, acetone, photoinitiator, nano-silica | The adhesive was applied, remaining undisturbed for 10 seconds, and teeth were then dried for 5 seconds under maximum air pressure and light-cured for 10 seconds. |
| | EverX Posterior<br>1309121 | Bis-GMA, TEGDMA, PMMA, short E-glass fiber filler, barium borosilicate glass filler | The composite measuring approximately 4 mm in thickness was placed, and enough space was left for the overlaying composite on all surfaces of the restoration and was cured for 40 seconds. |
| | G-aenial Posterior<br>1211192 | Methacrylate monomers, UDMA, dimethacrylate comonomers, prepolymerized fillers, camphorquinone and amine, fluoroaluminosilicate, fumed silica | The remaining parts of the cavities were restored with increments at a maximum of 2 mm in thickness and were light-cured for 40 seconds. |
| IV | Excite F<br>Ivoclar Vivadent, Schaan, Liechtenstein<br>P56445 | Phosphonic acid acrylate, HEMA, dimethacrylate, highly dispersed silicone dioxide, initiators, stabilizers and potassium fluoride in an alcohol solution | After etching, was applied, agitated for 10 seconds, gently air-dried, and light-cured for 10 seconds. |
| | Tetric N-Ceram<br>S37370 | Dimethacrylates, barium glass, ytterbium trifluoride, mixed oxide, copolymers, additives, catalysts, stabilizers, and pigments | The composite was applied incrementally. Each layer was 2 mm thick and was light-cured for 40 seconds. |
| I, II, and IV (Etching) | Scotchbond Universal Etchant<br>3M Deutschland GmbH, Neuss, Germany 524441 | 32% phosphoric acid, synthetic amorphous silica (fumed), polyethylene glycol, aluminum oxide, and water | The cavities were etched for 30 seconds on enamel and for 15 seconds on dentin, then rinsed for 15 seconds, and gently air-dried, leaving the tooth moist. |

4-MET, 4-methacryloxyethyl trimellitic acid; AUDMA, aromatic urethane dimethacrylate; bis-GMA, bisphenol-A diglycidyl ether dimethacrylate; DMA, dimethacrylate; EBPADMA, ethoxylated bisphenol A dimethacrylate; HEMA, hydroxyethyl methacrylate; PENTA, dipentaerythritol penta acrylate monophosphate; PMMA, polymethyl methacrylate; TEGDMA, triethylene glycol dimethacrylate; UDMA, urethane dimethacrylate

**Table 3:** The means and standard deviations (SDs) of cuspal deflection of tested groups in microns

| Groups | *24 h after restoration* Mean ± SD | *After endodontic treatment vs 24 h after restoration* p | *After thermocycling* Mean ± SD | *After endodontic treatment vs After thermocycling* p | *24 h after restoration vs After thermocycling* p |
|---|---|---|---|---|---|
| I (Filtek Bulk Fill) | 3.8 ± 0.4 | 0.348 | 1.2 ± 0.1 | 1.000 | 1.000 |
| II (Surefil SDR + CeramX Mono) | 3.9 ± 0.4 | 0.301 | 4.2 ± 0.5 | 0.037* | 1.000 |
| III (GCeverX posterior + G-aenial posterior) | 2.2 ± 0.1 | 1.000 | 4.8 ± 0.6 | 0.010* | 1.000 |
| IV (Tetric-N Ceram) | 1.8 ± 0.2 | 1.000 | 2.9 ± 0.3 | 0.422 | 0.347 |
| *p* | 0.391 | | 0.401 | | |

*Indicates statistical significance ($p < 0.05$)

Ilie et al.[16] reported that the flowability of "SDR" reduced polymerization shrinkage by 60–70% compared to conventional composites. In the present study, bulk-fill flowable resin composite+nanoceramic composite shrinkage values did not significantly differ from others, but the thermocycling process affected the intragroup results, in a direction to increase cuspal deflection. The polymerization shrinkage of SDR is 3.5%, but in our study, this material was not used alone because of its low physical properties, and the occlusal surface was covered with Ceram X mono with a 2.3% polymerization shrinkage. This nanohybrid resin composite has nanostructures for properties such as high wear resistance and low shrinkage. Moreover, filler loading is 76% by weight and 57% by volume.[17] Unlike the present study, low polymerization values obtained by SDR[18] might be related to the use of this material alone.

A number of studies are in agreement with our findings that cuspal movement was observed in all cavities restored with composite resin, which shows an adhesion at the tooth-composite interface.[19–21] Prager et al.[22] compared the cuspal deflection and volumetric shrinkage of a hybrid composite, two high-viscosity bulk-fill, and three bulk-fill flowable composites with their respective adhesives. They suggested that the filler rates of resin composites may have an effect on cuspal deflection and a direct proportional relationship was observed between the increase of filler content and the increase of cuspal deflection. However, we cannot directly compare our results with that study due to the cavity configurations and materials tested.

For a safe polymerization, incremental technique in resin composite application has been used for many years.[23,24] However, there are some studies suggesting that incremental technique was not superior than bulk-fill materials that can be applied up to 4–5 mm thickness.[25,26] In the present study, no significant difference was observed between after endodontic treatment values and 24 hours or thermocycling values of group I (conventional composite) and group IV (bulk-fill composite). Elsharkasi et al.[27] compared the cuspal deflection of teeth restored with three high-viscosity bulk-fill resin-based composites with an incrementally placed universal resin composite. They reported that conventional composite had significantly more cuspal deflection than did the bulk-fill materials for all tested times which were after 5 minutes and after 24 and 48 hours.

In most studies, the cuspal deflection was evaluated after 5 minutes and after 24–48 hours. However, taken into account that resin materials undergo hygroscopic expansion, we repeated the measurements after thermocycling procedure in order to simulate oral conditions. One of the reasons for the discrepancy between our results and previous ones could be related to this factor. Even after 10,000 cyclings, no difference existed between paste-like/flowable bulk resins with conventional hybrid resins. On the other side, except for Filtek Bulk Fill and Tetric-N Ceram, the rest of the tested materials showed a difference between them after endodontic treatment values. Moreover, among other materials, only Filtek Bulk Fill showed a decreasing tendency for cuspal deflection following thermocycling. This could be related to the water sorption capacity of the resin material. It has been claimed that hygroscopic expansion of the materials generally leads to relaxation of the cusps and thereby returns their original position. The polymerization shrinkage of the bulk-fill resin composite used in this study was 1.39%, while 2% of the conventional composite. On the other hand, filler contents, which are important factors in cuspal deflection, are 64.5% and 63.5% by weight, respectively. The manufacturers claimed that by including stress relievers in bulk-fill composite's content, they reduce polymerization stresses and change the dynamics of polymerization shrinkage. Although it was not statistically significant, this might be the other reason for the decrease in the cuspal deflection values of this material, unlike the others.

The manufacturers claim that every X posterior's short fiber structure results in a degree of toughness very close to dentin if covered with a universal layer of restorative composite.[9] In addition, they put forward that the product shrinks minimally so that the formation of fractures can be prevented. In a study conducted by Ozsevik and others,[28] the effect of fiber-reinforced composite on the fracture resistance of root-filled teeth was evaluated, and they found that using fiber-reinforced composites under conventional resin composite materials resulted in fracture resistance similar to that of untouched teeth. Yasa et al.[29] compared SRFC and conventional composite in the restoration of endodontically treated molar teeth and found the highest fracture loads for teeth restored with SRFC compared to conventional composite. There are only few studies related to SRFC resin in the literature, one of which was another study that performed these restorative procedures and evaluated their fracture resistance on endodontically treated upper premolars.[30] The authors also reported that the restorative procedures tested did not differ significantly in terms of fracture resistance.

Evaluation of cuspal deflection can be performed with different methodologies, and there are actually many different factors that must be taken into account. Cuspal deflection evaluation with a digital micrometer is a reliable and highly accurate method and is much simpler to implement than other methods. As the most important benefit of this method is that it allows the teeth to remain moist, the usage of this method was preferred.[12] In addition, this *in vitro* study has some limitations such as a lack of measurements at 5 s and 48 h after restoration, and further studies based on restorations of endodontically treated teeth should be performed.

## Conclusion

Within the limitations of this study, endodontic treatment did not affect the cuspal deflection of upper premolars. Following endodontic treatment, the utility of different direct restorative materials made no significant difference in the cuspal deflection. Although the thermocycling procedure which corresponds to 12-month *in vivo* functioning, did not result in a significant difference between cuspal deflection values of tested materials, increased the cuspal deflection of bulk-fill flowable resin composite + nanoceramic composite, and fiber-reinforced composite + posterior resin composite.

## Authors' Contributions

CA contributed to the study design, performed restorative procedures, data analysis and interpretation, drafted and revised the manuscript; ARY contributed to data acquisition and interpretation and revised the manuscript; ASH contributed to study design, data analysis and data interpretation, and revised the manuscript; and EN contributed to design, performed endodontic treatments, and revised the manuscript. All authors gave final approval of the work.

## Acknowledgments

All statistical analyses of the study were carried out with the service purchase from Hacettepe University, Department of Biostatistics. The statistical consultant was Dr Sevilay Karahan.

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