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Cuspal Deflection in Premolar Teeth Restored Using Current Composite Resins With and Without Resin-modified Glass Ionomer Liner

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Clinical relevance

Using a recently introduced silorane-based composite resin, Filtek Silorane, and the placement of resin modified glass ionomer cement liner under the composite resin restorations resulted in reduced cuspal deflection.

SUMMARY

Aim: To evaluate the effects of four different types of composite resins and a resin modified glass ionomer cement (RMGIC) liner on the cuspal deflection of large MOD cavities in vitro. Materials & Methods: One hundred twenty-eight extracted human upper premolar teeth were used. After the teeth were divided into eight groups (n=16), standardized large MOD cavities were prepared. The distance between cusp tips was measured before and after the cavity preparations with a digital micrometer. Then the teeth were restored with different resin composites (Filtek Supreme XT, Filtek P60, Filtek Z250, Filtek Silorane - 3M ESPE, St Paul, MN, USA) with and without a RMGIC liner (Vitrebond, 3M ESPE, St Paul, MN, USA). Cuspal deflection was measured 5 min, 24 h, and 48 h after the completion of restorations. The data were statistically analyzed with Friedman and Kruskal Wallis tests. Results: A significant reduction in cuspal deflection was observed in Filtek Silorane restorations with and without RMGIC liner ($p<0.05$). In all restored teeth, the distance between cusps was reduced but they did not return to their original positions during the 48 h period. All teeth showed cuspal deflection,

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but placement of RMGIC liner reduced it. Conclusion: The use of silorane-based composites and the placement of RMGIC liner under the composite resin restorations resulted in significantly reduced cuspal deflection.

INTRODUCTION

The increasing demands for esthetic restorations and public concerns related to mercury in dental amalgams have produced increased interest in composite resin as an alternative posterior restorative. The mechanical performance, wear resistance, and esthetic potential of composite resins have significantly improved over the last few years. However, polymerization shrinkage of composite resins remains a challenge and still imposes limitations in the application of direct techniques.[1]

Polymerization shrinkage can produce two types of problems. When the filling material is weakly adhered to the dental tissues, detachment of the enamel margins can occur and/or gaps can form, resulting in marginal microleakage that allows the passage of bacteria, fluids, molecules, or ions between the cavity surface and the composite resin. In contrast, if the adhesive strength exceeds the contraction stress, there is no detachment but the restoration maintains an internal tension that pulls the cavity walls together, reducing the intercuspal distance (cuspal deflection). Cuspal deflection may cause changes in occlusion points, postoperative pain, and, in some cases, tooth fractures.[2]

To avoid these shortcomings and to make tooth-colored restorations not only esthetic but also functional, many techniques and new materials have been introduced. Recently, as the result of increasing demand for a universal restorative material indicated for all types of direct restorations, including posterior teeth, a new category of resin composite was developed, nanofilled composites. Nanocomposites show high translucency, high polish, and polish retention similar to those of microfilled composites while maintaining physical properties and wear resistance equivalent to those of several hybrid composites.[3]

During the late 1990s manufacturers introduced packable composites with high inorganic filler loading into the market as alternatives to amalgam. Packable composites use amalgam techniques for placement and produce acceptable interproximal contact. These allow these composites to be safely and successfully used in Class II restorations.[4]

To overcome the polymerization shrinkage problem, extensive efforts have been made over the years to develop low-shrinkage composite resins. Some modern developments in dental composite research have focused on the use of ring-opening systems like oxirane-based resins cured under visible light conditions. Weinmann and others[5] described the synthesis of a new monomer system, named silorane, obtained from the reaction of oxirane and siloxane molecules. The novel silorane-based resin was claimed to have combined the two key advantages of the individual components: low polymerization shrinkage due to the ring-opening oxirane monomer and increased hydrophobicity due to the presence of the siloxane species.

The use of resin-modified glass ionomer (RMGIC) liners to decrease the amount of polymerization shrinkage of large composite restorations and cuspal deflection is a controversial issue in dentistry. Cara and others[6] suggested that using RMGIC liners reduces cuspal deflection, while Taha and others[7] reported similar cuspal deflection regardless of whether a RMGIC liner was placed. As a result, the current study aimed to assess cuspal deflection with and without a RMGIC liner for the restoration of large mesio-occlusal-distal MOD cavities with four different composite resins. The research hypothesis of the study was that using silorane-based composites and the placement of RMGIC liner under the composite resin restorations would result in reduced cuspal deflection.

MATERIALS AND METHODS

Selection of Teeth

One hundred twenty-eight upper premolar teeth, extracted for orthodontic purposes, that on visual examination were free from caries, hypoplastic defects, and cracks were selected. Calculus deposits were carefully removed using a hand scaler. The teeth had been stored in distilled water for a maximum of three months prior to use. The maximum bucco-palatal width (BPW) of each tooth was measured with a digital micrometer gauge (Series 480–505, resolution 1 μm, SHAN™; Precision Measuring Instruments, Guilin, China). The BPW dimensions were used to divide the teeth into eight groups of 16 teeth, and the mean BPW of the teeth between groups varied by no more than 5% according to one-way analysis of variance and a paired Tukey test comparison (Table 1). The teeth were stored in water at room temperature (23°C±1°C) except when aspects of the experimental procedure required isolation from moisture.

Table 1: *Bucco-palatal Width (BPW) Dimensions of Teeth (μm) Highlighting No Statistical Differences Between Groups (n=16)*

Groups	Mean	Standard Deviation
1 (Filtek Supreme XT)	9.85	0.41
2 (Filtek P60)	9.88	0.37
3 (Filtek Z250)	9.90	0.35
4 (Filtek Silorane)	9.87	0.42
5 (Vitrebond + Filtek Supreme XT)	9.82	0.35
6 (Vitrebond + Filtek P60)	9.92	0.35
7(Vitrebond + Filtek Z250)	9.85	0.35
8 (Vitrebond + Filtek Silorane)	9.94	0.35

Cavity Preparation

The teeth were embedded with crown uppermost and long axis vertical so that the resin extended to within 2 mm of the cementoenamel junction (CEJ) in a plastic ring with acrylic resin (Ortocryl EQ, Dentaurum, Germany). Buccal and palatal cusp tips of each tooth were acid etched for 30 seconds, washed for 20 seconds, and dried. Adper Single Bond 2 was applied according to the manufacturer's recommendations and light-cured with light-emitting diode (Radi Plus, SDI, Victoria, Australia) for 10 seconds. The curing light intensity was measured with a radiometer (Curing Radiometer Model 100; Demetron Research Corp, Danbury, CT, USA). Then flowable composite (Filtek Flow, 3M ESPE, St Paul, MN, USA) was applied to the buccal and palatal cusp tips as reference balls for intercuspal distance measurements, followed by light-curing for 20 seconds (Figure 1). After one week, the distance between reference balls of each tooth was measured using a digital micrometer and recorded as "initial distance" (Figure 2).

Standardized large MOD cavities were prepared with boxes two-thirds the BPW of the tooth, and the occlusal isthmus was prepared to half of the BPW. The cavity depth at the occlusal isthmus was also standardized to 3.5 mm from the tip of the palatal cusp and 1 mm above the CEJ at the cervical aspect of the proximal boxes (Figure 3). The cavosurface margins were prepared at 90°, and all internal line angles were rounded. The facial and lingual walls of the cavity were also prepared parallel to each other in accordance with a previously reported procedure.[6,8] Diamond fissure burs (DIATECH, Swiss Dental, Heerbrugg, Switzerland) were used in a high-speed handpiece with water coolant and changed for every five cavity preparations.

Figure 1. *Specimen with reference points for intercuspal distance measurements.*

Restorative Procedures

The materials used in this study are listed in Table 2. All of the teeth were restored with the same manufacturer's composite resin and its associated bonding system in accordance with the manufacturer's instructions.

Group 1—Etching of enamel and dentin was performed with 35% phosphoric acid for 30 seconds, followed by rinsing with air-water spray for 20 seconds. Enamel surfaces of the cavity were dried with compressed air and dentin surfaces were dried with cotton pledgets. Two consecutive coats of Adper

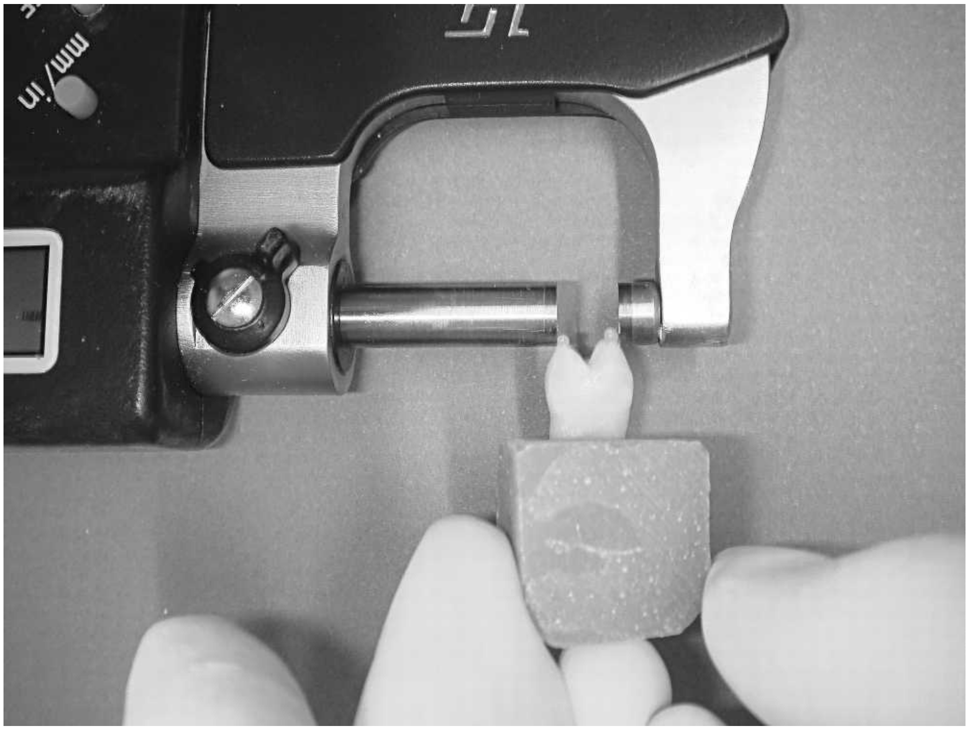

Figure 2. *Measuring the distance between cusp tips.*

Single Bond 2 were applied using a microbrush for 15 seconds, followed by gentle air-drying and then light-curing for 10 seconds. Filtek Supreme XT (Shade A3B) was placed and light-cured for 20 seconds.

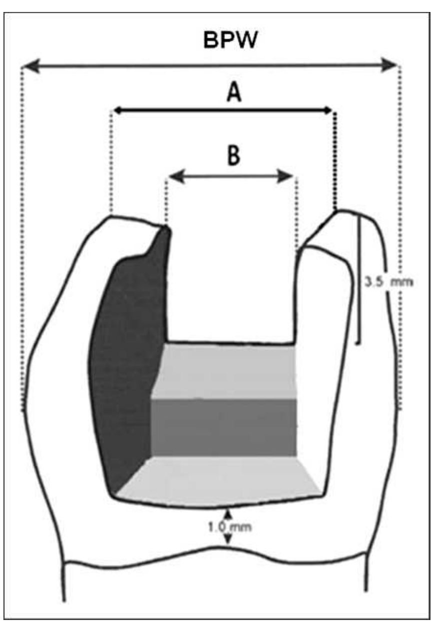

Figure 3. *Schematic view of MOD cavities.*

Group 2—Teeth were restored with Filtek P60 (Shade A3) as previously described.

Group 3—Teeth were restored with Filtek Z250 (Shade A3) as previously described.

Group 4—Silorane Adhesive System primer was applied using a microbrush for 15 seconds, followed by gentle air-drying and then light-curing for 10 seconds. After that the Silorane Adhesive System bond was applied, followed by a gentle stream of air, and light-cured for 10 seconds. Filtek Silorane (Shade A3) was placed and light-cured for 20 seconds.

Group 5—Teeth were lined with a thin layer of Vitrebond on the pulpal and axial walls with approximately 1-mm thickness and light-cured for 30 seconds. Then the teeth were restored with Filtek Supreme XT (Shade A3B) using the same method as for group 1.

Group 6—Teeth were restored with Filtek P60 (Shade A3) using the same method as for group 5.

Group 7—Teeth were restored with Filtek Z250 (Shade A3) using the same method as for group 5.

Group 8—Vitrebond was applied as previously described and teeth were restored with Filtek Silorane (Shade A3) using the same method as for group 4.

Table 2: *Materials Used in the Current Study(3M ESPE is manufacturer for all materials)*

Product (Batch No.)	Material	Ingredient
Filtek Supreme XT (20080117)	Nanofilled composite resin	Inorganic fillers (59.5%), Bis-GMA, UDMA, Bis-EMA, TEGDMA, silica nanofillers (5–7 nm) zirconia/silica nanoclusters (0.6-1.4 μm)
Filtek P60 (20081004)	Packable composite resin	Inorganic fillers (61%), Bis-GMA, UDMA, Bis-EMA, zirconia/silica nanofillers (0.01–3.5 μm)
Filtek Z250 (20090406)	Universal hybrid composite resin	Inorganic fillers (60%), Bis-GMA, UDMA, Bis-EMA, zirconia/silica nanofillers (0.01–3.5 μm)
Filtek Silorane (N105399)	Low shrink composite resin	Inorganic fillers (55%), hydrophobic resin matrix
Scotchbond (20071207)	Acid	Aqueous solution of 35% phosphoric acid
Adper Single Bond 2 (7MX)	Etch & rinse adhesive	HEMA, Bis-GMA, dimethacrylate, polyacrylic and polyitaconic acids, water, ethanol
Silorane System Adhesive (20081117)	Primer	HEMA, Bis-GMA, water, ethanol, phosphoric acid–methacryloxy-hexyl ester, 1,6-hexanediol dimethacrylate, acrylic and itaconic acid copolymer, (dimethylamino) ethyl methacrylate, DL-camphorquinone, phosphine oxide
Silorane System Adhesive (20081117)	Bonding agent	Substitute dimethacrylate, TEGDMA, phosphoric acid–methacryloxy-hexyl ester, DL-camphorquinone, hexanediol dimethacrylate
Vitrebond (20090521)	Resin-modified glass ionomer	Fluoramino silicate glass, polyalkenoic acid

Abbreviations: Bis-GMA, bisphenol A diglycidyl ether dimethacrylate; UDMA, urethane dimethacrylate; Bis-EMA, bisphenol A ethoxylated methacrylate; TEGDMA, triethylene glycol dimethacrylate; HEMA, 2-hydroxyethyl methacrylate

Eight nominally triangular increments of approximately 2-mm thickness were used to restore the teeth, three for each proximal box and two for the occlusal surface.[6,8,9] Each increment was cured for 20 seconds, per the manufacturer's instructions. The occlusal aspect of the restorations was carved to approximate the normal occlusal anatomy of an upper premolar tooth. Each tooth was restored by placing a transparent matrix (Auto matrix II, combination matrix intro-kit, Dentsply, Petrópolis, Brazil), which was removed after the restorations were completed. Between measurements on subsequent days teeth were stored under the same wet conditions (distilled water) at room temperature (23°C±1°C).

The distance between reference points was measured with a digital micrometer[2,10–12] five minutes, 24 hours, and 48 hours after restorations were completed to determine the stress relaxation in the cusps.[11,13] All measurements were made by the same operator and three measurements were recorded for each tooth, and the mean was used for the subsequent statistical analysis. The cuspal deflection was obtained by calculating the difference between "initial" and the other measurements at five minutes, 24 hours, and 48 hours.

Statistical Analysis

Since the data did not show a homogeneous distribution, the global comparison among the study groups for the different measurements was carried out using the Kruskal-Wallis test. The data were subjected to Friedman test to determine significant changes in cuspal deflection of each group with time. Statistical significance was set in advance at the 0.05 confidence level. All data were analyzed using SPSS 11.5 for Windows software (SPSS Inc, Chicago, IL, USA).

Table 3: *Mean Cuspal Deflection Measurements and Standard Deviations (SDs) for Each Group Examined in the Current Study (n=16)*[a]

Groups	5 Minutes	24 Hours	48 Hours
1 (Filtek Supreme XT)	21.7 ± 12.6 A^{1}	17.5 ± 17 A^{1}	9.8 ± 8.2 A^{2}
2 (Filtek P60)	30.5 ± 22.8 A^{1}	20.5 ± 23.3 A^{2}	17.3 ± 14 A^{2}
3 (Filtek Z250)	14.9 ± 3.6 B^{1}	11 ± 7.6 B^{1}	9 ± 4.1 B^{1}
4 (Filtek Silorane)	0.2 ± 0.5 C^{1}	0.3 ± 0.6 C^{1}	0.3 ± 0.6 C^{1}
5 (Vitrebond + Filtek Supreme XT)	14.2 ± 5.9 B,D^{1}	11 ± 6.9 B,D^{1}	8.8 ± 7.4 B,D^{1}
6 (Vitrebond + Filtek P60)	13.3 ± 6.5 B,D^{1}	11.3 ± 7.1 B,D^{1}	10 ± 15.4 B,D^{1}
7 (Vitrebond + Filtek Z250)	9.5 ± 5.5 D^{1}	9.3 ± 5.3 D^{1}	8.4 ± 7.3 D^{1}
8 (Vitrebond + Filtek Silorane)	0.1 ± 0.4 C^{1}	0.1 ± 0.4 C^{1}	0.1 ± 0.4 C^{1}

[a] *Mean values exhibiting different letters (within columns) and different superscripted numbers (within rows) are significantly different.*

RESULTS

No significant differences were identified between the groups when the mean cuspal deflection after cavity preparation of the teeth was compared (p=0.807). Cavity preparation produced approximately 9.68 μm of cuspal deflection in all groups.

The mean cuspal deflection and standard deviations for each group are shown in Table 3. The cuspal deflection was greatest in the group restored with Filtek P60 without Vitrebond (group 2) and least in the group restored with Filtek Silorane and Vitrebond (group 8) at all measurements after restorations were completed.

At five-minute measurements, differences between cuspal deflection were statistically significant for all groups except groups 1 and 2; groups 3, 5, and 6; groups 4 and 8; and group 6 and 3, 5, and 7 ($p<0.05$). RMGIC (Vitrebond) liner usage produced a statistically significant reduction in cuspal deflection for the groups restored with the same composite resins (groups 1–5, groups 2–6, groups 3–7), except for the groups restored with Filtek Silorane (groups 4–8) ($p<0.001$).

At 24-hour and 48-hour measurements, groups restored with Filtek Silorane showed less cuspal deflection than did the other groups, and the differences were statistically significant ($p<0.001$). Using Vitrebond with composite resins influenced cuspal deflection; greater mean cuspal deflection was detected for all groups restored without Vitrebond, although no significant difference was revealed except for the 48-hour measurement of groups restored with Filtek P60 (groups 2–6).

The intercuspal distance increased in all experimental groups during the 48 hours, but the cusps did not fully achieve their original dimensions in any of the groups.

DISCUSSION

The magnitude of cuspal deflection depends on many factors, including the size and configuration of the cavity and the properties of the restorative material and the bonding system.[8,14] Consequently, in addition to the standardization of cavity sizes, the incremental packing of the composite resins and the application of the associated adhesive systems were carefully performed by one operator in each cavity in the current study.

The preparations in the current study were large MOD cavities, and the geometry of the cavity preparations resulted in a high C-factor. The preparations were designed to weaken the remaining tooth structure, in order to maximize possible cuspal movement during restoration, and to provide a realistic *in vitro* simulation of the clinical situation. However, these cavities could be considered typical of large amalgam replacement cavities, and the number of such restorations currently placed in clinical practice is increasing since improved matrix and bonding systems have made the use of composite resin restorations more viable.[15]

Many methods have been used to measure cuspal deflection, including microscopy,[13] strain gauges,[16] direct current differential transformers,[9] linear variable differential transformers,[17] and digital micrometers.[2,11,12] In the current study a digital micrometer was used for cuspal deflection measurements.

Polymerization shrinkage of composite resins resulted in an inward deflection of cusps for all experimental groups evaluated, in agreement with the findings of previous reports.[9,13,18] Nevertheless, values of cuspal deflection in the present study were different than other reported values, probably because of differences in experimental design. The methods utilized in the current study during placement of the composite resins replicated those commonly used in clinical practice.

The results of our study showed that cuspal deflection was lower in the teeth restored with silorane-based composite resin than in the teeth restored with methacrylate-based composite resins. In agreement with this, Laughlin and Sakaguchi[19] found significantly lower cuspal deflection when the teeth were restored with experimental silorane-based composite resin compared to those restored with Filtek Z250 (methacrylate-based composite resin). The results of our study also agree with those reported by Palin and others,[8] who found that the use of oxirane- and silorane-based composite resins reduced cuspal deflection. The increase in cuspal deflection of cavities restored with methacrylate-based composite resins may have been expected as a result of the differences in polymerization reaction between the free-radical and cationic species, respectively.

The difference between cuspal deflection measurements of methacrylate-based composite resins applied without RMGIC liner were statistically similar, except for the measurement five minutes after the restorations were finished. This result can be explained by the similar filler loading and resin constituents of the composites used in the study (Table 2).

The cuspal deflection generated by Filtek P60 was greatest at all measurement times. Fleming and others[20] and Cara and others[6] have also reported that Filtek P60 caused higher cuspal deflection than Filtek Z250 and Filtek Supreme, respectively.

In this study the placement of RMGIC liner reduced the amount of cuspal deflection, which is in accordance with the findings reported by Alomari and others[13] and McCullock and Smith.[21] The RMGIC used in this study (Vitrebond) had a modulus of elasticity of 1.1 GPa and a volumetric polymerization shrinkage of 2.3 vol%.[22] The volumetric polymerization shrinkage and the elastic modulus have opposite effects on the total stress on the tooth structure and eventually on cusp deflection. A material with low elastic modulus, particularly when placed in posterior regions, will result in a higher deformation under masticatory stresses, potentially resulting in more catastrophic failures as a consequence.[23] Low cuspal deflection with RMGIC usage can be explained in this way.

Comparisons among the measurements of cuspal deflection at five minutes, 24 hours, and 48 hours showed that all restored teeth tended to recover their original position, although none of them fully recovered during the 48-hour period. It has been reported that cusps recover their original position after inward deflection because of shrinkage of composite restorations and that this recovery is strongly influenced by tooth hydration conditions and cavity size. However, some studies[18,24] have shown that the total and near-total recovery of the initial intercuspal distance is a slow process that may last up to two weeks and is never complete in medium-sized and large restorations. Teeth restored with methacrylate-based composites had greater recovery than those restored with silorane-based composites. This may be due to the differences between the water sorption properties, saturation time, and capacity of the composite resins used in this study. Palin and others[25] reported that water sorption of silorane-based composite resins is lower than that of methacrylate-based composite resins.

CONCLUSION

Within the limitations of this *in vitro* study the research hypothesis was accepted: the use of silorane-based composites and the placement of RMGIC liner under the composite resin restorations resulted in significantly reduced cuspal deflection.

Conflict of Interest

The authors of this manuscript 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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