Cuspal deflection in premolar teeth restored with a Silorane and a Dimethacrylate-resin based composite (A comparative study)

Ayad M. Mahmoud Al-Obaidi B.D.S. (1)
Inas I. Al-Rawi B.D.S. M.Sc. (2)

ABSTRACT
Background: This study was conducted to evaluate and compare the cuspal deflection between 2 low-shrinkage resin composites (Filtek™ Silorane) and (Tetric EvoCeram), and the effect of using light-cured GIC (Vivaglass® Liner) and storage in water on cuspal deflection at different periods.

Materials and methods: Forty extracted maxillary first premolars of approximately similar sizes were prepared with standardized MOD cavities. The sample teeth then divided into two main groups (20 specimens each) according to the restorative material (group A: Filtek™ Silorane and group B: Tetric B1: restored by Tetric EvoCeram with Vivaglass® Liner. Group B2: restored only by Tetric EvoCeram. All samples restored with oblique incremental technique. The intercuspal distance was measured before and after the restorative procedures and after 1, 2 and 4 weeks of water storage and the difference were recorded as cuspal deflection. Cuspal deflection was measured using digital micrometer. Data were analyzed statistically by ANOVA and least significant difference (LSD) test.

Results: Filtek™ Silorane significantly less cuspal deflection. Vivaglass® Liner significantly reduced cuspal deflection with Tetric EvoCeram. After four weeks water storage, cuspal deflection in all subgroups were highly significantly different with the two restoratives (P<0.01). While light-cured glass ionomer cement has a non significant effect on cuspal deflection after 4 weeks.

Conclusions: Silorane showed lower cuspal deflection and lower water uptake than Tetric EvoCeram. Polymerization shrinkage deformation was almost compensated by hygroscopic expansion within 4 weeks.

Key words: Cuspal deflection, Silorane, Tetric Evoceram, hygroscopic expansion. (J Bagh Coll Dentistry 2011;23(3):11-16)

INTRODUCTION
Interest in aesthetic dentistry has resulted in tooth colored restorations being increasingly used, not only as a replacement material for failed or unaesthetic amalgam, but as the first choice material to restore previously ‘virgin’ posterior teeth (1).

Polymerization shrinkage that occurs during light-curing of resin-based restorative materials inside a cavity may result in cuspal deflection, enamel crack propagation or debonding of the restoration (2).

Tooth deformation is indicative of a combination of stresses in the tooth, in the restoration or across the tooth-restoration interface. The size and configuration (C-factor) of the cavity influence the amount of cuspal deflection and the highest deflection values have been recorded for mesio-occluso-distal (MOD) cavities (3).

(1) Assistant lecturer, Conservative Department, College of Dentistry, University of Baghdad.
(2) Professor, Conservative Department, College of dentistry, University of Baghdad.

Post-operative sensitivity by fluid flow in exposed dentinal tubules has been associated with cuspal deflection due to the formation and/or propagation of enamel cracks or by gap formation at the interface between the tooth and the resin based composite restoration as a result of bending and/or insufficient bond strength. Cuspal deflection may compromise the synergism of the bond at the tooth restoration interface possibly leading to bacterial microleakage and ultimately to marginal discoloration, secondary caries and pulpal inflammation or necrosis (3).

Filtek™ Silorane low shrink resin based composites have been introduced, it is based on new Silorane chemistry comprised of ring-opening monomers that provide for low polymerization shrinkage aiming at reducing the polymerization shrinkage, therefore cuspal deflection and stress at the tooth–restoration interface will be reduced. Studies reported a decrease in total cusp deflection in MOD cavities restored with low shrink Silorane resin based composites. In addition incremental placement of composites is recommended by most manufacturers to maximize curing, to minimize polymerization shrinkage and to reduce gap formation and cuspal deflection (4).

Dimensional changes, both shrinkage and expansion, of a restorative material have a major impact on the clinical success of a restored tooth.
in a humid oral environment, polymerization shrinkage may be alleviated by hygroscopic expansion from water absorption.

MATERIALS AND METHODS

Teeth selection

Forty sound first premolar teeth extracted for orthodontic purposes, collected from different health centers in Baghdad. The teeth had been stored in distilled water at room temperature until use. To minimize variables all teeth that were used in the investigation had regular occlusal anatomy and approximately similar crown size, sound and free from hypoplastic defects and cracks on visual examination and using light cure.

Any calculus deposits were carefully removed with Air scaler (Victor C9000) and teeth were polished with pumice (Alpha pro).

Each tooth was mounted vertically using a Cold cure acrylic powder and liquid, type 1 class (Dentsply) in a square plastic mould with dimensions of 23 x 12mm x 12mm. The resin should be extended to within 2 mm of the amelocemental junction (ACJ).

A 1.5 mm diameter glass ball was fixed to each cusps as reference points for intercuspal distance measurements using Adhesive techniques, using acid etch Alpha-Etch37% (37% phosphoric acid gel) (Lincolnwood, Illinois) for 30 seconds followed by application Tetric N bond (vivadent/ivoclar) and cured 20 second and then Tetric-N ceram (vivadent/ivoclar) light cure composite cured 20 seconds.

Cavity preparation

Each tooth was subjected to preparation of a large mesio-occlusal-distal (MOD) cavity, with the parallel walls using a Diamond flat-ended fissure bur (REF FG 108M010, Hahnenkratt) in a high speed handpiece (W&H) with water coolant (A new bur was used for every five preparations). The cavosurface margins were prepared at 90° and axiopulpal and axiogingival line angle were rounded with small round bur.

The cavity depth at the occlusal isthmus was standardized (3.0 mm) and all gingival walls were located above the amelocemental junction (ACJ) at the cervical aspect of the proximal boxes. The width of the floor and the width of the gingival floor were 3 mm; the axial gingival depth and axial height were 1 mm for each. The cavity depth and width were checked by a graduated periodontal probe.

Sample distribution

The experimental teeth were divided into two groups; twenty teeth each, according to the restorative material and each group is subdivided into two subgroups ten teeth each according to the restorative technique:

Group A: Twenty teeth where restored by Silorane low shrinkage dental composite shade A3 (3M ESPE) in (MOD) cavities. This group subdivided according to the restorative technique into:
- Group A2: Ten teeth restored by Silorane (3M ESPE) in (MOD) cavities without placement of Vivaglass liner (vivadent/ivoclar).

Group B: Twenty teeth where restored by low-shrinkage Tetric EvoCeram (vivadent/ivoclar) in (MOD) cavities. This group subdivided according to the restorative technique into:
- Group B1: Ten teeth restored by Tetric-EvoCeram (vivadent/ivoclar) in (MOD) cavities with placement of Vivaglass liner (vivadent/ivoclar).

Tooth restoration

Four different restorative techniques were used in the investigation:
- Group A1: After complete cavity preparation, a light-cured glass ionomer cement Vivaglass liner (vivadent/ivoclar) was applied on the pulpal floor and axial walls according to manufacturer’s instruction, the cavity cleaned and dried in the customary manner. The standard powder/liquid ratio of 1.4 g/1.0 g can be achieved with a level Vivaglass measuring spoon of powder and one drop of liquid. The required amount of powder and liquid dispensed onto the mixing pad, the powder divided into two equal parts, the first half mixed with the liquid for approx. 5–10 seconds, the second half of the powder added for another 5–10 seconds. Total mixing time should not exceed 20 seconds, then the Vivaglass Liner adapted into axial and pulpal floor in a thickness of about 0.5 mm, then the material cured for 30 seconds with a Light cure device, after that Silorane System Adhesive (3M ESPE) was applied according to the manufacturer’s instruction, the Silorane System Adhesive primer placed to the entire cavity for 15 seconds then dispersed with a stream of air and light-cured the primer for 10 seconds then Silorane System Adhesive bond (3M ESPE) rubbed and light-cured for 10 seconds. Silorane composite shade A3 (3M ESPE) was placed into the cavity using CompoRoller™ (KERR) instrument which is an innovative composite moulding instrument that is...
designed to provide complete control in layering and contours of direct composite restoration to its final form. The composite resin was placed in wedge-shaped incremental insertion technique. The first increment was placed against the palatal wall and gingival seat of the proximal boxes and polymerized. Then, composite resin was placed against the facial wall and polymerized. This procedure was repeated for the occlusal portion of the preparation and the number of total increment was 4 increments for each tooth. The restoration was progressively built up with increment not exceed 2 mm. Each increment was light-cured for 40 seconds using a visible-Light cure device (Type: Halogen light), (Light intensity: 400mW/cm²) (Dentsply) only from the occlusal surface.

Group A2: Silorane System Adhesive and low shrinkage Silorane (3M ESPE) was applied as in subgroup A1.

Group B1: Light-cured glass ionomer cement Vivaglass liner (vivadent/ivoclar) was applied on as in subgroup A1, then AdheSE self etching adhesive (vivadent/ivoclar) was applied, first AdheSE Primer (vivadent/ivoclar) was applied for 30 seconds, primer dispersed with stream of air, and AdheSE Bond (vivadent/ivoclar) rubbed in and light-cured for 10 seconds.

Tetric Evoceram (vivadent/ivoclar) was placed into the cavity as in group A.

Group B2: AdheSE self etching adhesive and low shrinkage Tetric Evoceram (vivadent/ivoclar) composite was applied as in group B1.

In all cases, the matrix band was placed without using a retainer in order to avoid any tension on the cusps

**Sample measurement**

All measurements were performed by the same operator and ten consecutive measurements were recorded for each sample and the mean was used for the subsequent statistical analysis.

The intercuspal distance of unaltered tooth (ID) was measured before any restorative procedures. The intercuspal distance between reference balls was measured with a digital micrometer (CT Brand, 200-521, Wah Luen electronics). The mean values of the ten consecutive measurements of intercuspal distance after cavity preparation for each tooth recorded as ‘initial distance’.

The samples were stored in distilled water in plastic tube 15 minutes after the polymerization of the last increment of composite, the distance between the glass balls (intercuspal distance 15 min. after tooth restoration) measured and the mean value of the ten consecutive measurements for each tooth recorded as ‘final distance’.

The cuspal deflection (CD2) was obtained by calculating the difference between ‘final’ and ‘initial’ measurements.

After that the teeth were stored in deionized distilled water (Al-Mansur factory) in plastic tubes and placed in the Incubator (Binder) in 37°C in Al-Yarmouk Teaching Hospital for one, two and four weeks, cuspal deflection were measured after each period.

The effect of water storage on cuspal deflection following placement of MOD composite restorations after one, two and four weeks of water storage measured by subtracting the intercuspal distance after water storage in different periods from intercuspal distance 15 min. after tooth restoration (Final distance).

**RESULTS**

1. Shrinkage pulls cusps together, recording negative cuspal deflection values on the buccal and palatal surfaces. Cuspal deflection 15 min. after tooth restoration the statistical analysis of data by one-way ANOVA showed a highly significant difference (P < 0.01) between the two restoratives as shown in Table 1. Further analysis of all data is needed to examine the difference between subgroups and explore the effect of Vivaglass liner on the cuspal deflection, so least significant difference (LSD) of cuspal deflection 15 min. after tooth restoration shown in Table 3. The cuspal deflection 15 min. after tooth restoration showed highly significant difference (P<0.01) between all subgroups except between subgroup (A1&A2) there is a non significant difference (P>0.05).

2. Expansion pushed the buccal and palatal surfaces outwards, resulting in positive deformation values, the Positive Cuspal Deflection (CD3) which represent hygroscopic expansion in Silorane group A has lower mean value (+ 5.3350 and + 5.6360) compared with Tetric EvoCeram group B (+ 9.7290 and + 9.7700) and the difference is highly significant Table2. The same behavior of the shrinkage deformation reduction continued after two weeks water storage and the hygroscopic expansion (Positive Cuspal Deflection) (CD4) between the two restoratives was a highly significant difference. The gradual reduction continued after four weeks water storage, but in much less degree than at one and two weeks water storage, the hygroscopic expansion (Positive Cuspal Deflection) after four weeks water storage (CD5) between the two restoratives was statistically highly significant difference as shown in Table 2.
storage periods, the total amount of hygroscopic expansion (Positive cuspal deflection) after four weeks water storage Table 3 for (A1 &B1) was slightly higher than that in the cavity restored with Silorane or Tetric EvoCeram only (A2&B2) statically there is a non significant difference in all water storage periods as shown in Table 3.

The percentage of natural tooth dimensional recovery after four weeks water storage showed that according to the data presented in the results, following hygroscopic expansion, was 99.99277 % for subgroup A1 restored with Silorane, 99.98792 % for Silorane subgroup A2, 99.99845 % for subgroup B1 restored with Tetric EvoCeram with RMGIC liner and 99.98845 % for subgroup B2.

Table 1: Mean, standard deviation and ANOVA test of negative cuspal deflection 15 min. (CD2) after tooth restoration mean values for all sub groups.

<table>
<thead>
<tr>
<th>Subgroups</th>
<th>Mean ±SD</th>
<th>ANOVA test (d.f.=39)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>-4.1603</td>
<td>0.72026</td>
</tr>
<tr>
<td>A2</td>
<td>-4.9773</td>
<td>1.36569</td>
</tr>
<tr>
<td>B1</td>
<td>-9.087</td>
<td>1.33061</td>
</tr>
<tr>
<td>B2</td>
<td>-10.8337</td>
<td>0.93796</td>
</tr>
</tbody>
</table>

Table 2: Mean, standard deviation and ANOVA test of positive cuspal deflection (CD3),(CD4), (CD5) after water storage mean values for all sub groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sub-group</th>
<th>MD</th>
<th>P-value</th>
<th>SIG</th>
</tr>
</thead>
<tbody>
<tr>
<td>CD 15 min. after tooth restoration</td>
<td>A1 &amp; A2</td>
<td>-0.817</td>
<td>0.112</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>A1 &amp; B1</td>
<td>-4.9267</td>
<td>0.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>A2 &amp; B2</td>
<td>-5.8564</td>
<td>0.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>B1 &amp; B2</td>
<td>-1.7467</td>
<td>0.001</td>
<td>HS</td>
</tr>
<tr>
<td>Positive CD after 1W water storage</td>
<td>A1 &amp; A2</td>
<td>0.301</td>
<td>0.657</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>A1 &amp; B1</td>
<td>-4.093</td>
<td>0.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>A2 &amp; B2</td>
<td>-4.435</td>
<td>0.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>B1 &amp; B2</td>
<td>-0.041</td>
<td>0.952</td>
<td>NS</td>
</tr>
<tr>
<td>Positive CD after 2W water storage</td>
<td>A1 &amp; A2</td>
<td>0.3914</td>
<td>0.805</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>A1 &amp; B1</td>
<td>-5.6336</td>
<td>0.001</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>A2 &amp; B2</td>
<td>-6.1536</td>
<td>0.000</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>B1 &amp; B2</td>
<td>-0.12836</td>
<td>0.935</td>
<td>NS</td>
</tr>
<tr>
<td>Positive CD after 4W water storage</td>
<td>A1 &amp; A2</td>
<td>0.2884</td>
<td>0.888</td>
<td>NS</td>
</tr>
<tr>
<td></td>
<td>A1 &amp; B1</td>
<td>-5.5176</td>
<td>0.01</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>A2 &amp; B2</td>
<td>-6.4227</td>
<td>0.003</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td>B1 &amp; B2</td>
<td>-0.6167</td>
<td>0.763</td>
<td>NS</td>
</tr>
</tbody>
</table>

Table 3: LSD test at different periods of restorative procedures for all sub groups.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Sub-group</th>
<th>Mean ±SD</th>
<th>ANOVA test F- test</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive CD after 1W water storage</td>
<td>A1</td>
<td>5.636</td>
<td>1.3375</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>5.335</td>
<td>1.2595</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>9.729</td>
<td>0.2201</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>9.777</td>
<td>2.3741</td>
<td></td>
</tr>
<tr>
<td>Positive CD after 2W water storage</td>
<td>A1</td>
<td>7.423</td>
<td>2.3582</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>7.032</td>
<td>1.9312</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>13.06</td>
<td>4.3996</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>13.19</td>
<td>4.6462</td>
<td></td>
</tr>
<tr>
<td>Positive CD after 4W water storage</td>
<td>A1</td>
<td>7.969</td>
<td>2.553</td>
<td></td>
</tr>
<tr>
<td></td>
<td>A2</td>
<td>7.862</td>
<td>2.0354</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B1</td>
<td>13.48</td>
<td>8.1131</td>
<td></td>
</tr>
<tr>
<td></td>
<td>B2</td>
<td>14.1</td>
<td>2.565</td>
<td></td>
</tr>
</tbody>
</table>

**DISCUSSION**

Cuspal deflection regarded as a topic of interest as it indicates residual (internal) stresses in the tooth structure that may cause failure during composite curing or act as a preloading, facilitating tooth fracture under occlusal loads.

Large MOD cavities were prepared in the present study because its favors potential cuspal deflection, the larger the cavity size, the greater was the cusp deflection. Two points can explain this: First, there was less tooth structure left in large cavities, which meant more flexibility of the cusps and more compliance with composite shrinkage. As the cavity preparation becomes wider and deeper, the strength of the prepared tooth is considerably reduced and the tooth becomes more flexible. Second, the greater total volume of composite needed for restoration of large cavities results in a higher shrinkage force.

In this study, the matrix band was placed without using a retainer in order to avoid any tension on the cusps also its placement may interfere with the presence glass balls in the samples.

Oblique incremental technique was used in order to avoid or delay the bonding of opposing cusps together, thus reducing the stress within the restoration. Wedge-shaped composite increments are placed to prevent distortion of cavity walls and reduce the C-factor. The oblique incremental technique of resin composite has been proposed to reduce the composite mass to be polymerized and the resulting shrinkage stress. Restoring large cavities in several increments has been shown to distribute the contraction strain among the
increments, reduce the stress on the cusps, and result in less cuspal deflection (7,14,17,18).

Intercuspal distances were measured 15 min after polymerization, because the majority of cuspal deflection is reported to occur within this period and the teeth were fully hydrated (7,14).

All experimental subgroups showed a reduction in intercuspal distance after the restorative procedure. The Polymerization shrinkage of composite restorations resulted in an inward deflection of the cusps for all the experimental subgroups evaluated 1,5,8,9,13-16,18).

The Silorane-based resin composite caused less cuspal deflection compared to the Dimethacrylate-based resin composite (3,12,13,15,19,20,21). The statistical analysis of data showed a highly significant difference between Silorane Group A and Tetric EvoCeram Group B of means value Table 1, the main explanation is based on the different polymerization process of the two low shrinkage composites, Silorane based on a new chemical composition for the matrix system. The Silorane monomer was developed with a primary target of overcoming some drawbacks pertaining to the polymerization of dimethacrylate-based resin composites, like radical oxygen inhibition, polymerization shrinkage, polymerization stress, and water sorption, the cationic ring-opening polymerization process of the Silorane-based composite due to the presence of oxirane species yielding a reduced volumetric shrinkage in comparison to the free-radical addition reaction of the double bonds of the dimethacrylate-based composite. Siloranes have a polymerization reaction with a slow onset as the cation formation needs more time than a free radical formation mechanism, allowing time for flow of material and stress relaxation, resulting in less cuspal deflection (15,22,23).

Regarding to the effect of Vivaglass liner, in group A Silorane, the negative cuspal deflection mean value for subgroup A1 was (-4.1603) and has lower mean value than subgroup A2 (-4.9773), but the difference is not statically significant Table 3, there is no study to compare with it and that might due to the low shrinkage behavior of Silorane. In Group B Tetric-EvoCeram there is a highly significant difference between (B1&B2) Table 3 because the use of Vivaglass base material, there is less volume of composite needed for restoration that results in a less shrinkage force, the polymerization shrinkage stress of RMGIC is much lower than that of the composites, and the RMGIC under the composites reduced the level of polymerization shrinkage of the composites, this showed by Alomari et al 17 reported that cuspal deflection was also lower in the MOD cavity when RMGIC was used as a base material than that cavities restored with the composite resin only. Castaneda-Espinosa et al 21 and Kwon et al 22 found that RMGIC intermediate layer promoted significant decrease in polymerization contraction force values of the restorative system. While Taha et al 4 concluded that the placement of glass ionomer did not significantly reduce the amount of cuspal deflection, but its placement is beneficial in reducing strain and marginal leakage.

The gradual increase in positive cuspal deflection behaviors could be relate to bond failure between restoration and tooth could have relaxed the cuspal deflection. Bond failure is unlikely to be consistent across different samples because it is expected to be strongly dependent on individual samples and preparation conditions. Stress relaxation of the resin composite could also reduce cuspal flexure. It is known that a composite restoration exhibits some stress relaxation due to water absorption. Stress relaxation can be caused by the viscoelastic properties of composites, while water absorption may increase relaxation through hydrolysis (chemical degradation of the polymers) and plasticization (water induced molecular mobility) effects 16).

The Silorane-based composite showed less water uptake (hygroscopic expansion) than dimethacrylate-based composite this is due to the Silorane-based composite revealed increased hydrophobicity due to the presence of the siloxane species in its composition this decreased water sorption, solubility and associated diffusion coefficient compared with dimethacrylate resin based composites, also the nano-composites seemed to be more degraded by longer storage in water than the microhybrids 6,23,26,27).

In regard to the effect of light-curing glass ionomer on the cuspal deflection after water storage periods, the total amount of hygroscopic expansion (Positive cuspal deflection) after four weeks water storage Table 3 for (A1 &B1) was slightly higher than that in the cavity restored with Silorane or Tetric EvoCeram only (A2&B2), this occurred because the HEMA present in the liquid of the RMGIC is hydrophilic in nature, and materials with a higher HEMA content have consequently higher water sorption and statistically there is a non significant difference in all water storage periods as shown in Table 3, other studies Yap 25 Mortier et al 26 showed that the RMGIC absorbed more water than the resin composite, there results were significant, the difference could be due to different composites materials and to different sample size.
Under the experimental conditions in this study the initial shrinkage deformation was returned almost completely to the natural tooth dimension after 4 weeks water storage, the results comparable with Versluis et al 5, while Segura and Donly 27 reported that more than 97% of the cuspal deflection caused by polymerization shrinkage of a resin composite restoration was reported to have recovered after 6 months immersion in water. Thus the amount of hygroscopic expansion and its clinical impact may vary with material characteristics.

REFERENCES