

Evaluation of cuspal deflection in premolar teeth restored with low shrinkable resin composite (*in vitro* study)

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Abstract

Objectives: This study evaluated cuspal deflection in premolar teeth restored with low shrinkable resin composite. **Materials and Methods:** A total of 40 human premolars were used for cuspal deflection evaluation in this study. Each group was divided into four equal groups according to the type of resin composite and the adhesive used as follows: group A: Using low shrinkable resin composite (silorane) with its adhesive system; group B: Using low shrinkable composite (silorane) with G-bond; group C: Using Filtek Z350 composite with G-bond; and group D: Using Filtek Z350 composite with AdheSE. Cusp deflection was detected using Universal measuring microscope and laser horizontal metroscope. **Results:** This study was done to investigate the effect of polymerization shrinkage stresses of two resin composite materials (Filtek Z350 and Filtek P90) on cuspal deflection of mesio-occluso-distal restoration. For this study, the extracted non-carious maxillary second premolars were selected. Forty teeth that showed no more than 5% variation in their dimensions were used. A significant increase in cuspal deflection of cavities restored with the methacrylate-based (Filtek Z350) compared with the silorane (P90) resin-based composites was obtained. **Conclusion:** The change in the organic matrix or materials formulation of the resin composite using silorane has a positive effect on controlling the cusp deflection.

Key words: Cusp deflection, laser horizontal metroscope, resin composite, silorane

INTRODUCTION

Many developments have been made in the field of resin composites for dental applications. However, the manifestation of shrinkage due to the polymerization process continues to be a major problem. The composite shrinkage creates stresses within the material at the tooth structure interface, which might manifest clinically as cuspal deflection, which in turn

compromises 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.^[1,2] Typical resin composites applied in restorative dentistry exhibit volumetric shrinkage values from less than 1% up to 6%, depending upon the formulation and the curing condition.^[3-5] Recently, a new category of

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resin matrix for dental composite was developed based on ring-opening monomers.^[6] This hydrophobic composite is derived from the combination of siloxane and oxirane, and thus has the name silorane.^[7] The major advantages of this innovative restorative material are its reduced shrinkage and its mechanical properties comparable to those of methacrylate-based composites.^[8]

Filtek silorane comes with a two-step self-etch adhesive, commercialized as Silorane System Adhesive (SSA). First, a hydrophilic self-etch primer [Silorane System Adhesive Self-Etch Primer (SSA-Primer)] is applied and light-cured separately prior to the application of a hydrophobic adhesive resin [Silorane System Adhesive Bond (SSA-Bond)]. SSA-Bond is methacrylate-based, and is therefore compatible with conventional methacrylate composites as well. Further details on how SSA-Bond links to the silorane composite are currently not known, but according to the technical information provided by 3M-ESPE (Australia), SSA-Bond contains a hydrophobic bifunctional monomer in order to match the hydrophobic silorane resin.^[9,10] Compared to the methacrylate-based restorative materials, the new silorane-based material had the lowest polymerization shrinkage, but an overall mixed mechanical performance. The silorane-based material had relatively higher flexural strength/modules and fracture toughness, but relatively lower compressive strength and microhardness than the methacrylate-based restorative materials.^[11]

The ring-opening chemistry of the siloranes enables them to have first time shrinkage values lower than 1 vol% and the mechanical parameters such as E-modulus and flexural strength to be comparable to those of clinically well-accepted methacrylate-based composites.^[12]

The novel resin is considered 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 silorane composite polymerizes by a cationic ring-opening process, which is insensitive to oxygen. This overcomes the disadvantage of the oxygen inhibition layer found in methacrylate-based composites.^[13,14] Siloranes were also stable and insoluble in biological fluids simulated using aqueous solutions containing either epoxide hydrolase, porcine liver esterase, or dilute HCl.^[15] The silorane-based composite revealed decreased water sorption, solubility, and associated diffusion coefficient,

compared with conventional methacrylate-based composites.^[16,17]

Cusp deflection is the result of interactions between the polymerization shrinkage stress of the composite and the compliance of the cavity wall, and is a common biomechanical phenomenon observed in teeth restored with composites.^[3]

The purpose of this study was to evaluate cuspal deflection in premolar teeth restored with low shrinkable resin composite.

MATERIALS AND METHODS

Forty human premolars extracted for orthodontic reasons stored in normal saline were used. The selected teeth were placed 3 mm below the cemento-enamel junction in an acrylic mold with dimensions of 15 mm internal diameter, 25 mm external diameter, and 20 mm height. The teeth set in the acrylic mold were fixed with a vice and a large Mesiooccluso distal cavity (MOD) cavity was prepared [Figure 1]. The mesio-distal proximal box was extended 0.5 mm bucco-lingually, and the width of the axial and gingival walls of the box was 1 mm. The width and depth of the pulpal wall of the MOD cavities was 2 × 3 mm. The reference point for cavity depth was the central groove. The reference point for measuring the specimens before and after the procedure was two metal tips (cut from dental needle C-K Ject, Korea, Queens Singapore) for each specimen (0.5 × 4 mm) that was fixed (using Clearfill SE Bond) horizontally and perpendicular to the long axis of the specimen at the cusp tip of the tooth, one buccally and the other lingually. The end of this tip was located beyond the buccal and lingual tooth contour by 2 mm in order to be attached to the microscope probes during cusp deflection measurement.



Figure 1: MOD cavity

The specimens were divided into two main equal groups according to the type of resin composite and then further subdivided into four equal subgroups as follows:

- Subgroup A: Using low shrinkable resin composite (Filtek™ P90 Silorane shade A2; 3M ESPE, St Paul, MN, USA) with its adhesive system
- Subgroup B: Using low shrinkable composite (Filtek P90 Silorane shade A2; 3M ESPE) with G-bond (GC, Tokyo, Japan)
- Subgroup C: Using Filtek™ Z350 (3M ESPE) composite with G-bond (GC)
- Subgroup D: Using Filtek Z350 (3M ESPE) composite with AdheSE (Ivoclar Vivadent, Schaan, Liechtenstein)

Cuspal deflection was detected by Universal measuring microscope (Carl Zeiss, Jena, Germany) [Figure 2] and Universal horizontal metroscope (Universal-Langen messer; Carl Zeiss) [Figure 3]. The buccal and lingual cusp movements were recorded for 2000 s and the measured value (as a function of time) was stored on a computer through a data acquisition board.

Ethics of the study

- Patients’ consent was obtained
- Approval of the ethical committee of Al-Azhar University, Faculty of Oral and Dental Medicine, Egypt (under number 490/2013) was obtained.

Statistical analysis

The difference between groups was statistically analyzed using one-way analysis of variance (ANOVA) followed by pair-wise Newman–Kuels (NK) *post-hoc* test at the significance level of $\alpha = 0.05$.



Figure 2: Universal measuring microscope

RESULTS

Inter-cuspal distance test results (Mean ± SD) including cuspal deflection measured in micrometers are summarized in Table 1.

It was found that group C recorded the highest cuspal deflection mean value ($414 \pm 22 \mu\text{m}$), followed by group D ($408 \pm 38 \mu\text{m}$) and then group B ($360 \pm 31 \mu\text{m}$). Meanwhile, group A recorded the lowest cuspal deflection mean value ($138 \pm 29 \mu\text{m}$).

Change in cuspal deflection over time

Cuspal deflection (μm) for Filtek P90 and Filtek Z350 are presented in Figures 4–7. Changes in cuspal deflection over time of Filtek P90 with its adhesive (group A) were $3.5 \mu\text{m}$ at 5.7 min after curing, $-0.7 \mu\text{m}$ at 11.5 min, $-0.5 \mu\text{m}$ at 17.3 min, $0.4 \mu\text{m}$ at 23 min, $0.2 \mu\text{m}$ at 28.2 min, and $-0.8 \mu\text{m}$ at 34.6 min, while those of Filtek Z350 with AdheSE adhesive (group D) were $-3.4 \mu\text{m}$ at 5.5 min after curing, $-4.3 \mu\text{m}$ at 11.18 min,

Table 1: Inter-cuspal distance test results (mean±SD) and cuspal deflection for all groups after composite insertion

Groups	Inter-cuspal distance (μm)		Cuspal deflection (μm) difference
	Before	After	
A (silorane + its adhesive)	12.61 ± 0.46	12.60 ± 0.47	0.01
B (silorane + G-bond adhesive)	12.84 ± 0.49	12.80 ± 0.50	0.03
C (Z350 + G-bond adhesive)	12.67 ± 0.36	12.62 ± 0.35	0.05
D (Z350 + AdheSE adhesive)	11.81 ± 0.60	11.77 ± 0.61	0.04



Figure 3: Universal horizontal metroscope

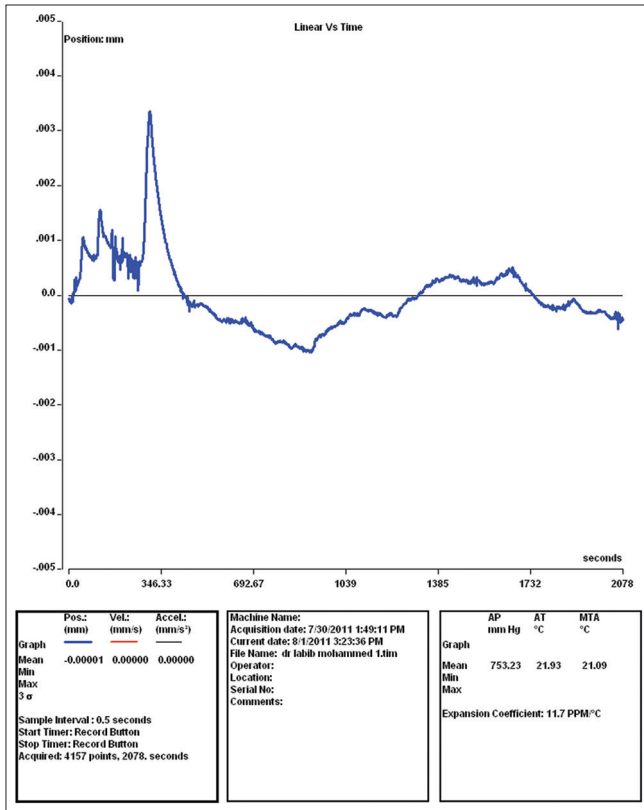


Figure 4: Cusp deflection of silorane with its adhesive system

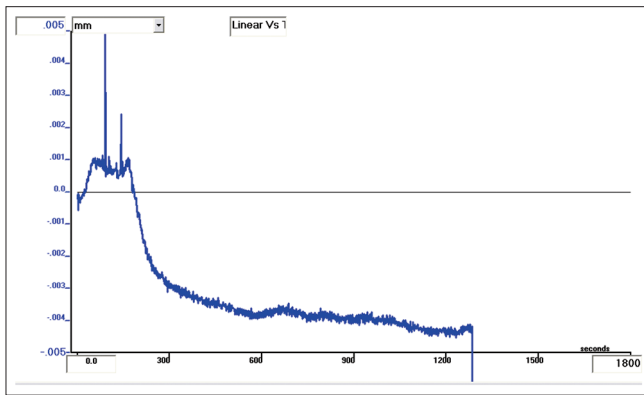


Figure 6: Cusp deflection of Filtek P90 with G-bond adhesive

−4.1 μm at 16.7 min, −3.9 μm at 22.3 min, −5.3 μm at 27.9 min, and −6.3 μm at 33.5 min.

Cuspal deflection (μm) for Filtek P90 and Filtek Z350 are presented in Figures 4–7. Changes in cuspal deflection over time of Filtek P90 with G-bond (group B) were −2.9 μm at 5.7 min after curing, −3.1 μm at 11.5 min, −3.5 μm at 17.3 min, −3.9 μm at 23 min, and −4 μm at 28.2 min, while those of Filtek Z350 with G-bond (group C) were −2.9 μm at 5.5 min after curing, −3.8 μm at 11.18 min, −4.1 μm at 16.7 min, −9.7 μm at 22.3 min, and −9.9 μm at 27.9 min.

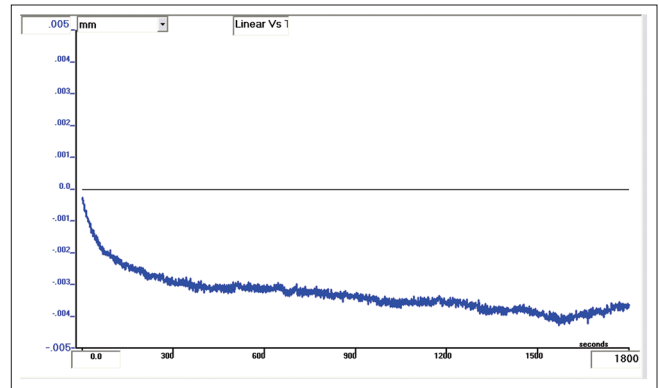


Figure 5: Cusp deflection of methacrylate with AdheSE adhesive system

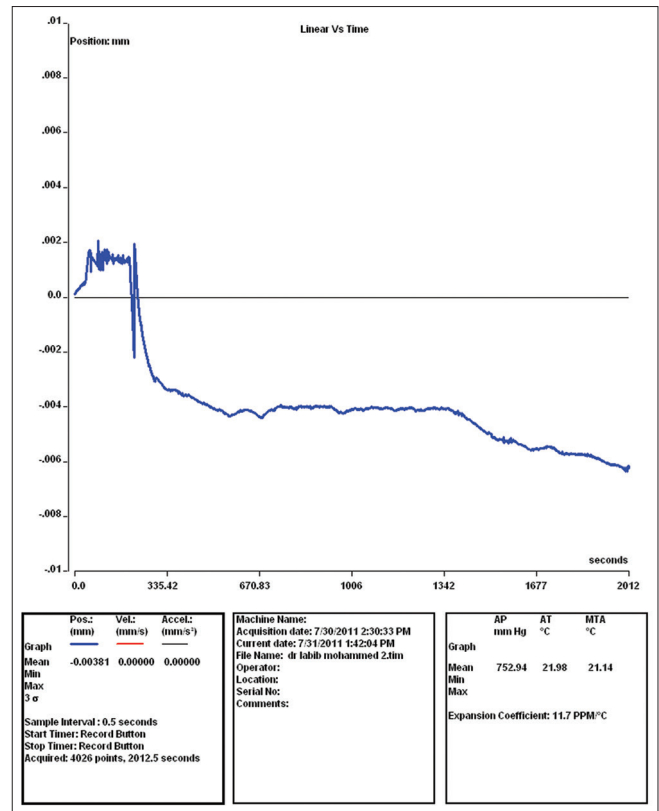


Figure 7: Cusp deflection of methacrylate with G-bond adhesive

DISCUSSION

The effect of polymerization shrinkage of resin-based composite materials on the *in vitro* cuspal flexure of restored teeth has been reported by numerous investigators.^[18,19] It has been suggested that such contact-displacement measuring methods may provide erroneous results since a suitable reference point on the cusps is difficult to identify.^[20]

The preparation of large MOD cavities from upper premolars in the current study was designed to weaken

the remaining tooth structure to favor potential cuspal movement. It might be argued that the weakening of the palatal and buccal cusps through the preparation of large MOD cavities in the current study was not clinically relevant since the MOD cavities may be too extensive for direct composite fillings. However, the number of Resin based composite (RBC) restorations currently placed in clinical practice has increased since the introduction of improved resin chemistry, filler morphology, and associated adhesive systems of modern RBC materials. Moreover, the toxicity and aesthetic concerns of amalgam and the increased chairside procedure time and cost of indirect restorations have justified the increased use of RBC materials for large restorations,^[21] such as the MOD cavities utilized in the current study. The magnitude of cuspal deflection is dependent on several factors, namely, the size and configuration of the cavity,^[22] and the mechanical–physical properties of the restorative material and the bonding system.^[23]

Deflection of the cusps through light irradiation of the restorative resin-based composite material will only occur if there is sufficient resistance to polymerization shrinkage associated with the adhesive properties at the tooth/restoration interface. In the current study, each cavity with each resin-based composite type exhibited cuspal deflection. The significant increase in cuspal deflection of cavities restored with the methacrylate-based (Filtek Z350) compared with the silorane (P90) resin-based composites might be attributed to the differences in polymerization reaction (monomer chemistry) between the free radical and cationic species, respectively. Irradiation of P90 results in fragmentation of the photoinitiator and it generates a “super-acid” catalyst with oxonium ions as the reactive species, which subsequently protonates the functional group of the oxirane molecule.^[24-26]

After molecular rearrangement, the positively charged species proceeds in three dimensions to form a tightly cross-linked network.^[24] The reactive species of P90 do not get extinguished as rapidly as the free radicals throughout the polymerization of Filtek Z350. The stress developed at the tooth–restoration interface remains responsible for the deleterious effects of polymerization shrinkage *in vivo* and may only be derived from a combination of material properties, restoration geometry, and interfacial adhesive quality of the tooth and filling material.^[26] From a clinical perspective, it was proposed that the significant reduction in the cuspal deflection of cavities restored with P90 compared with Filtek Z350 might be

advantageous in terms of clinical longevity. It may be speculated that a decrease in polymerization shrinkage stress and a reduction in the associated deleterious effects, such as microleakage, are manifested as a significant decrease in the polymerization shrinkage of P90 compared with Z350. Therefore, polymerization shrinkage stress is not only dependent upon the volumetric shrinkage of the restorative material but also on the nature of the interfacial bond between the RBC restorative and the associated tooth structure.

CONCLUSION

The change in the organic matrix or materials formulation of the resin composite using silorane composition, has a positive effect on controlling the cusp deflection.

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Conflicts of interest

There are no conflicts of interest.

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