

The Impact of Insert Application on the Cuspal Deflection and Microleakage in Mesio-Occluso-Distal (MOD) Cavities of Maxillary Premolars Restored with Resin Composite

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Abstract

Objective: This study was conducted to investigate the efficacy of insert application on the cuspal deflection and microleakage of maxillary bicuspid restored with resin composite restoration.

Methods: Sixty sound upper human premolars were selected and divided equally into two groups for cuspal deflection measurement and microleakage assessment. Standardized mesio-occluso-distal (MOD) cavities were prepared. Each group was subdivided according to the type of insert used into equally three subgroups (n = 10); the first group (A0), no insert was applied (resin composite only) (3M Filtek TM Z250 XT), while in the second group (A1); partially polymerized glass fiber post insert (everstick post) was used, while in the third group (A2); fully polymerized glass fiber post insert (rely X TM fiber post) was applied.

Cuspal deflection measured at 5 minutes, 60 minutes and after thermocycling and cyclic loading, using universal measuring microscope at 5 x magnification. The microleakage assessed gingivally and occlusally after thermocycling and cyclic loading. Cavities were restored and the inserts were applied between the composite increments. The results were recorded, tabulated and statistically analyzed.

Results: The insert application in resin composite restoration produced a statistically significant decrease in cuspal deflection and microleakage both gingivally and occlusally.

Conclusion: The problem of cuspal deflection and microleakage in complex cavities prepared in premolars can be greatly controlled by utilizing inserts.

Keywords: Resin Composite; Inserts; MOD Cavities; Occlusal Loading; Cuspal Deflection; Microleakage

Introduction

Resin based composites have become an important solution with the increased demands for esthetics and conservation of the tooth structure. Nevertheless, their limitations, such as polymerization shrinkage and subsequent stresses, affect the survival rate of such restorations.

Stresses associated with polymerization shrinkage had a dramatic effect on the tooth structure. If their magnitude is higher than bond strength to tooth structure, critical consequences develop within the tooth structure such as cuspal deflection, enamel micro cracks and post-operative sensitivity. On the other hand, if the polymerization stresses are higher than bond strength, bond failure and marginal leakage with subsequent recurrent caries will occur [1,2].

The failure of many posterior resin composite restorations was caused mainly by secondary caries and fracture [3]. Therefore, many modifications in the matrix and fillers had been developed to improve the marginal adaptability and mechanical properties of resin composite.

Modifications of the resin matrix involve alternation of the methacrylate matrix with silorane or ormocer. These modifications showed a significant decrease in the polymerization shrinkage and associated stresses [4]. Recently, bulk-fill composites have been introduced that could be applied in increment as thick as 4 mm with lower polymerization shrinkage and subsequent stresses compared to incrementally placed resin composites [5,6].

Regarding the fillers, application of glass mega fillers and fiber inserts had been proposed to improve the mechanical properties and decrease the polymerization shrinkage with its destructive sequelae [7,8]. Fiber inserts are composed of a resinous matrix reinforced with either fabricated from carbon fiber, prefabricated glass and quartz fiber or polyethylene fibers [9].

Cuspal deflection can be assumed as an indirect indicator to assess the polymerization stresses established from polymerization shrinkage [10]. Marginal integrity of the resin composite restoration may be assessed by dye penetration test. Thus, this study was carried out to elaborate the effect of using glass fiber inserts; partially and fully polymerized on the cuspal deflection and microleakage in complex class II cavities in maxillary premolars.

Materials and Methods

Table 1: Materials used in the study, composition, manufacturer and lot number.

Brand	Composition	Manufacturer	Lot no.#
Nanohybrid resin composite (3M ESPE Filtek™ Z250 XT)	Matrix: Bis-GMA, UDMA, Bis-EMA, TEGDMA. Fillers: (%81.8 by weight) Silica particle 20 nm and Zirconia/Silica particle 10-0.1 microns	3M ESPE, St. Paul, MN, USA	NA82485
Partially polymerized glass fiber post (everstick post)	Light curing resin impregnated continuous unidirectional E-glass fibers arranged in bundles, Bis-GMA, PMMA.	Stick Tech Ltd, Turku, Finland	20130315P 210
Fully polymerized glass fiber post (rely X™ fiber post)	AR-glass fibers embedded into a fully polymerized epoxy resin matrix in continuous unidirectional and equal distribution.	3M ESPE, St. Paul, MN, USA	197001208
3M ESPE Single bond universal adhesive	MDP Phosphate Monomer, Dimethacrylate resins, HEMA, Vitrebond™ Copolymer, filler, Ethanol, water, initiators and silane.	3M ESPE, St. Paul, MN, USA	6463494

- 1) Bis-GMA (bisphenol A-glycidyl dimethacrylate), 2) UDMA (urethane dimethacrylate), 3) Bis-EMA (bisphenol A-ethoxylated methacrylate), 4) TEGDMA (triethylene glycol dimethacrylate), 5) MDP (10-Methacryloyloxydecyl dihydrogen phosphate), 6) HEMA (hydroxyethyl methacrylate), 7) PMMA (polymethyl methacrylate).

Selection of teeth

A total of 60 human maxillary first premolar teeth with approximately similar crown size and regular occlusal anatomy, extracted for orthodontic purposes and free from caries, cracks or defects were selected for this study. The selected teeth were thoroughly cleaned and stored in physiological saline which is changed every week until usage [5].

Root surfaces were marked 2 mm below the crown margin to simulate the biologic width and to mimic the alveolar bone support in healthy tooth and then covered with wax. Specimens were then imbedded in auto-polymerizing acrylic resin surrounded by a plastic mold, using dental surveyor. After the first signs of polymerization, teeth were removed from the resin blocks and the wax spacer was removed. Light body silicone-based impression material was injected into the acrylic resin alveolus, and the teeth were reinserted into the test block. The thin layer of silicone material simulated periodontal ligament [11], since all the premolars were scheduled to be subjected to cyclic loading.

Cavity preparation

Standardized mesio-occluso-distal (MOD) cavity was prepared with the occlusal isthmus was half the intercuspal distance. The proximal box width was two-thirds the intercuspal distance. The cavity depth was 4mm from the cavity margin. The cavosurface margins were prepared at 90°. All internal line angles were rounded. Each bur was used for preparing 5 cavities then replaced [4].

Samples grouping

The prepared samples were randomly divided equally into 2 groups: first group for cuspal deflection measuring, and the second group for microleakage assessment. Each group was further subdivide into 3 subgroups (n = 10) according to restoration technique. The intercuspal distance of group 1 samples was measured before restoring them. Two small glass rings with ~1.5 mm radius of curvature are applied with adhesive bonding agent to shallow concavities within the enamel on the outer surface 0.5 mm below the both cusp tips.

Restoration of the maxillary premolars

Selective acid etching technique is used for bonding resin composite restorations. Enamel surface of the prepared cavities is etched with 37% phosphoric acid gel (3M ESPE Scotchbond™ etchant) followed by application of universal bonding agent (3M ESPE Single bond universal adhesive) to the prepared cavities and light cured with LED curing unit (3M ESPE Elipar™ S10) according to manufacturer instructions. Every tooth was encircled by a metallic matrix band held firmly by a matrix retainer (Tofflemire, USA) for restoring them.

Each subgroup was restored by a different technique. In the first one, teeth were restored with a resin composite in two increments with no insert (A₀). In the second subgroup, teeth were restored with resin composite with insert of partially polymerized fiber post (everstick post) (A₁). While in the last subgroup, teeth were restored with resin composite with insert of fully polymerized post (RelyX™ post) (A₂). In the second and third subgroups, the posts were cut to fit the mesio-distal dimension of cavity with leaving 0.5 mm from each side, then first increment of resin composite was applied, half of the insert was dipped in the first increment. The first increment was cured followed by the second increment application and curing.

The matrix band was removed, additionally light cured from the mesial and distal directions for 40 seconds, finished and polished by a low speed hand-piece with a graded series of flexible discs (Sof-Lex™, 3M ESPE, St. Paul, MN, USA).

Aging

The samples were subjected to aging by thermocycling and mechanical cyclic loading. Thermocycling was performed by subjecting samples to 500 cycle. Every cycle involves immersion into 2 water paths with temperature of 55 and 5°C for 30 second in each path with 5 seconds delay time.

Each sample was subjected to 10,000 cycles by computer controlled materials testing machine (Model LRX-plus) at loads between 10 N and 150 N with a load profile in the form of a sine wave at frequency of 1 Hz. Force was applied with a custom made load applicator attached to the upper movable part of the machine to be placed at the center of the occlusal surface of the samples.

Cuspal deflection measurement

Cuspal deflection measured using a universal measuring microscope (Carl Zeiss-Germany, serial No. 2510) at 5 x magnification providing a level of confidence of approximately 95%. The cuspal indices were tangentially aligned with the eyepiece cross hacter. Then, the intercuspal distance was measured between these two reference points (Figure 1).

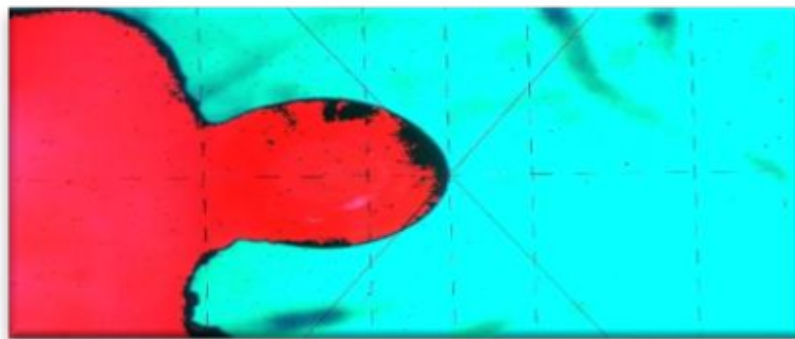


Figure 1: Photomicrograph of the tangential alignment of the cuspal index with the eyepiece cross hacter.

The baseline reading was measured before restoring the teeth.

The intercuspal distance measured after curing at 5 minutes, 60 minutes and after thermocycling and load cycling. The baseline record was subtracted from the subsequent records to obtain the change in the intercuspal distance.

Microleakage assessment

After samples aging, the apices of the roots were sealed using sticky modeling wax. Two coats of nail polish were applied on all teeth surfaces with the exception of the restoration and 1 mm band around the periphery of the restorations and left to dry. Teeth were immersed in 2% methylene blue for 24 hours at room temperature, then washed thoroughly to remove excess dye. A low speed diamond disc (BesQual, NY 11373, USA) used to section the teeth mesio-distally at the mid line of the restoration to evaluate dye penetration proximally, and then each half was sectioned bucco-lingually to evaluate the dye penetration occlusally. The sectioned specimens were examined under a stereomicroscope (Leica Micro System Ltd, Germany) at 25x magnification to determine the extent of microleakage in (mm) using image analysis.

Statistical analysis

The obtained data was tested using Shapiro-Wilk test for normality and equality of variances (Levene’s test) followed by parametric statistical tests. Analysis of Variance (ANOVA) was used to study the cuspal deflection for different inserts used and within the same group at different time intervals and to study microleakage for different insert types used. Tukey’s post-hoc test was used for pair-wise comparison between means when ANOVA test was significant. Independent t-test was used to compare between the gingival and occlusal microleakage. Statistical analysis was performed with IBM® SPSS® (SPSS Inc., IBM Corporation, NY, USA) Statistics Version 21 for Windows. P-values less than 0.05 were considered to be statistically significant in all tests.

Results

Cuspal deflection results

The results of cuspal deflection are represented in table 2 and figure 2. The results of cuspal deflection of resin composite restorations with no insert (A₀) showed the highest inward cuspal deflection values at 60 minutes after polymerization (-21.13 μm ± 5.25) followed by values at 5 minutes after polymerization (-22.49 μm ± 6.35), while least inward cuspal deflection recorded in samples subjected to thermocycling and cyclic loading (-14.47 μm ± 5.61) with a statistical significant difference between the three subgroups.

	No insert		Everstick post		RelyX post		P-value
	Mean (μm)	SD	Mean (μm)	SD	Mean (μm)	SD	
Cuspal deflection after 5 minutes	-21.13 ^{a B}	5.25	-13.91 ^{b B}	3.32	-14.98 ^{b B}	3.79	0.001
Cuspal deflection after 60 minutes	-22.94 ^{a A}	5.37	-15.24 ^{b A}	1.28	-15.93 ^{b A}	4.06	0.013
Cuspal deflection after aging	-14.47 ^{a C}	5.61	-9.05 ^{b C}	4.49	-8.89 ^{b C}	3.31	0.028
P-Value	≤ 0.001		≤ 0.001		≤ 0.001		

Table 2: Cuspal deflection of three different groups at the different time intervals. Results with the same letter are not significantly different within the same subgroup (p ≤ 0.05). Small letters indicate the difference within the same row. Capital Letters indicate the difference within the same column.

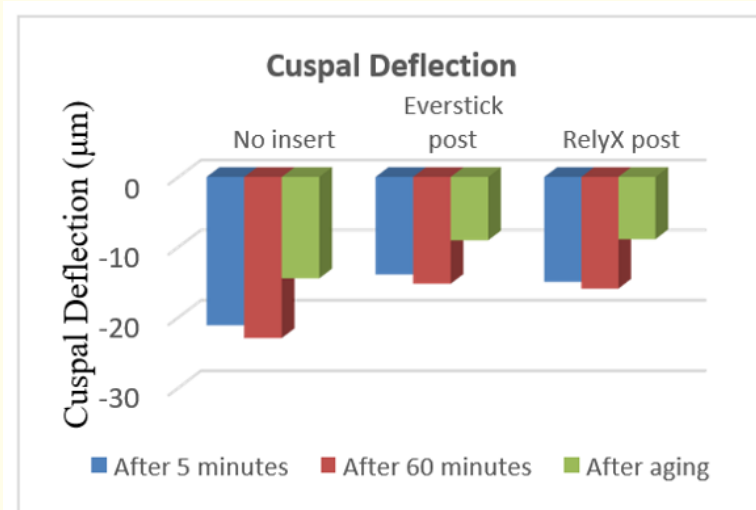


Figure 2: Cuspal Deflection of the tested groups.

The results of cuspal deflection of resin composite restorations with partially polymerized glass fiber insert 1 (A₁) showed the highest inward cuspal deflection values at 60 minutes after polymerization (-15.24 μm ± 1.28) followed by values at 5 minutes after polymerization (-13.91 μm ± 3.32), while least inward cuspal deflection recorded in samples subjected to thermocycling and cyclic loading (-9.05 μm ± 4.49) with a statistical significant difference between the three subgroups.

The results of cuspal deflection of resin composite restorations with fully polymerized glass fiber insert 2 (A₂) showed the highest inward cuspal deflection values at 60 minutes after polymerization (-14.98 μm ± 3.79) followed by values at 5 minutes after polymerization (-15.93 μm ± 4.06), while least inward cuspal deflection recorded in samples subjected to thermocycling and cyclic loading (-8.89 μm ± 3.31) with a statistical significant difference between the three subgroups.

Moreover, the results of inward cuspal deflection in resin composite restoration with no insert (A₀) was statistically significant higher than the resin composite restorations with both partially and fully polymerized glass fiber post (A₁ and A₂). On the other hand, there was no statistically significant difference between the values of composite resin restorations with inserts (A₁ and A₂).

Microleakage results

The results of microleakage assessment are represented in table 3 and figure 3. The highest depth of dye penetration value was recorded occlusally and gingivally in the resin composite restorations without inserts (A₀) (2.21 mm ± 0.44 and 2.41 mm ± 0.41 respectively) which statistically significantly lower than the resin composite restoration with partially polymerized fiber post (A₁) occlusally and gingivally (1.14 mm ± 0.28 and 1.13 mm ± 0.41 respectively) and resin composite restoration with fully polymerized fiber post (A₂) occlusally and gingivally (1.26 mm ± 0.34 and 1.14 mm ± 0.31 respectively) with no statistical significant difference between the two groups (A₁ and A₂).

	No insert		Everstick post		RelyX post		P-value
	Mean (mm)	SD	Mean (mm)	SD	Mean (mm)	SD	
Occlusally	2.21 ^a	0.44	1.14 ^b	0.28	1.26 ^b	0.34	≤ 0.001*
Gingivally	2.41 ^a	0.41	1.13 ^b	0.41	1.14 ^b	0.31	≤ 0.001*
P-value	0.573 (NS)		0.957 (NS)		0.338 (NS)		

Table 3: Microleakage values within different groups gingivally and occlusally. Results with the same letter are not significantly different within the same subgroup (p ≤ 0.05). Small letters indicate the difference within the same row.

*: Significant Difference; NS: Not Significant Difference.

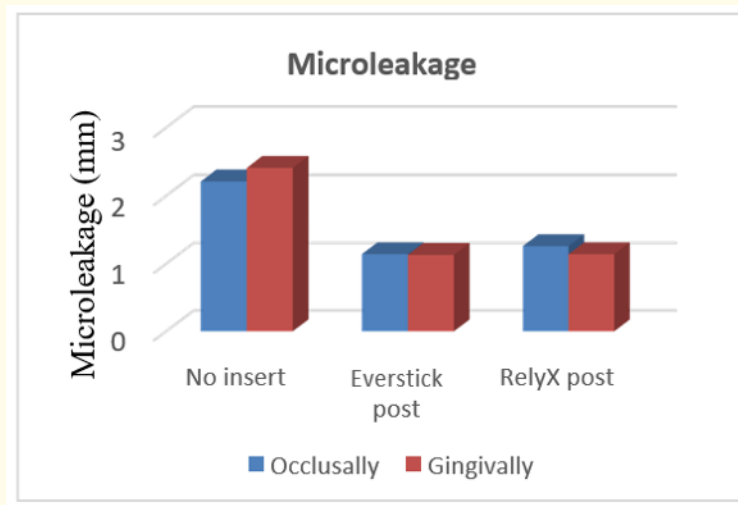


Figure 3: Microleakage of the tested groups.

Moreover, the results of depth of dye penetration showed no statistically significant difference gingivally and occlusally within the same group.

Discussion

Polymerization shrinkage remains a major shortcoming in resin composites that complicates the application of such versatile materials. Stress development is dictated by the complex interplay of many factors, the most prevalent of which is related to the material itself. A linear relationship exists between stress development and the volumetric shrinkage of the material, its modulus of elasticity and the degree of conversion [12].

During the pre-gel phase, stress relaxation of the polymerizing material is ensured through its flow. However, after gelation this flow ceases and cannot compensate for stresses created at the tooth-restoration interface. If this stress does not surpass the bond strength of the adhesive, it is manifested clinically as cuspal deflection, which is a commonly occurring biomechanical phenomenon with resin composite restorations [2,13,14].

Moreover, the resultant stresses could affect the tooth-restoration interface resulting in debonding or enamel microcracks at the cavity margins; both would result in microleakage with its sequelae of postoperative sensitivity, pulpal irritation and recurrent decay [6,13,15].

In the current study, the results revealed the occurrence of inward cuspal deflection. This cuspal deflection may be related to many factors such as the preparation of a large MOD cavity which weakened the remaining tooth structure by removing the marginal ridges in addition to loss of enamel continuity, therefore the viscoelastic nature of dentine was pronounced. Moreover, this large cavity required more resin composite material for filling with more polymerization shrinkage occurred and the cuspal deflection was favored and was more noticeable [5,16,17].

Furthermore, using a nanohybrid resin composite for restoring the prepared premolars rather than bulk fill, silorane or ormocer based resin composites showed higher polymerization shrinkage [4,5,10,14,16]. The stresses developed from the polymerization shrinkage of resin composite restoration were transmitted to the adjacent dental tissues via the adhesive interface producing the cuspal deflection [2,18].

The cuspal deflection was measured 5 minutes post curing of the restoration, as the highest percentage of cuspal deflection occurs during the first 5 minutes [16,19] because exchanging of loosely Van der Waals forces with shorter covalent bonds. As the polymer chains grow in length and cross-linking occurs, polymerization shrinkage is accompanied by an increase in rigidity. Subsequently, the majority of polymerization was allowed to occur, cuspal deflection measurement was repeated after 60 minutes post curing [20]. Tauböck, *et al.* reported that 89% of polymerization shrinkage after 24 hours was completed 60 minutes post-curing [12].

The results of the present study revealed the highest percentage of inward cuspal deflection for all restorative techniques occurred during the first 5 minutes, followed by a period of slow contraction of 60 minutes where the majority of polymerization was allowed to occur. This was in accordance with Min., *et al.* [20], Elsharkasi, *et al.* [16] and Yarmohamadi, *et al.* [4].

The results of the current investigation showed a relative recovery of cuspal deflection after thermocycling and mechanical cycling. The recovery of resin composite shrinkage after water sorption has recorded by many authors investigated conventional, bulk-fill methacrylate, ormocer and silorane resin composites [4,21-23]. This could be explained by three reasons.

The first reason; the hygroscopic expansion occurred to the resin composite during water immersion at thermocycling process. Water sorption affects resin composite into two contrasting process; first process results in shrinkage due to leaching out of unreacted monomers, secondary process results in expansion due to diffusion of the water into the material until equilibrium [4,6,21,24].

The second reason; the degradation of the adhesive bond may be due to two factors. Firstly, the temperature changes during thermo-cycling exert a thermal stresses over adhesive junction due to the difference in coefficient of thermal expansion and contraction between tooth and restoration [25]. Secondly, the hydrolytic degradation of resin matrix and the fillers debonding of the adhesive due to incorporation of hydrophilic monomers into its composition (i.e. HEMA, MDP and polyalkenoic acid "Vitrebond™ Copolymer") [24,26,27]. On the other hand, Costa, *et al.* [28], Sauro, *et al.* [27] reported the mechanical cycling had no effect on the bond strength of the used adhesive.

The third reason; stress relaxation is the relief of stresses occurred in the viscoelastic materials that are under continuous strain. Due to the viscoelastic nature of dentine, resin composite and adhesive, they tend to show some degree of stress relaxation from stresses developed from polymerization shrinkage [6,15].

Microleakage test was carried by immersing the specimens in 2% methylene blue because of the simplicity of the test. The lower molecular weight of the dye enables the molecule to penetrate the dentinal tubule mimicking the bacterial toxins [29-31].

The results of the current work showed different degrees of microleakage of all tested samples after thermal and mechanical aging. This indicate a relative disintegration of the adhesivelayer.

There was no statistical significant difference between microleakage values occlusally and gingivally in the three groups. This was contradictory to the results with Khamverdi, *et al.* [25] this could be related to the difference in the adhesive type. They used a self-etching adhesive while this study involved using of universal adhesive.

Generally, the results of the current investigation revealed that the application of both inserts declined the inward and outward cuspal deflection and the microleakage either occlusally or gingivally. This could be due to several reasons acting synergistically. Insert application replaces part of shrinkable matrix with unshrinkable pre-cured part (insert) with subsequent decreasing the overall amount of polymerization shrinkage [31,32]. Moreover, fibers decrease the shrinkage of resin composite from the margins toward light curing which increase its adaptability and stability of tooth structure. Furthermore, the strengthening effect of the fibers increase the resistance to destructive conditions during thermal or mechanical aging [31].

The results of the present study were in a harmony with Agrawal and Kapoor [31] and Aggarwal, *et al* [33]. Tsujimoto, *et al.* reported increase in the bond durability by increasing mechanical properties of resin composite materials after fiber reinforcement [34]. On the contrary, Sharafeddin, *et al.* [29] reported that fiber incorporation within composite resin had no statistical significant decrease in microleakage gingivally. This may be explained by the difference in the study design.

Conclusion

In essence, the contraction and resultant stresses generated by resin composite polymerization are a major problem in adhesive restorations. Use of insert technology in clinical dentistry has some promise for reducing such shrinkage-stress and its consequences. However, further investigations are needed to anticipate the variable factors that might affect the clinical performance.

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