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Effect of different restoration techniques and cavity designs on cuspal deflection of posterior teeth restored with resin composite inlays

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ABSTRACT

Objectives: The aim of this study was to evaluate the influence of different restoration techniques (immediate dentin sealing (IDS) restoration techniques) and cavity designs on the cuspal deflection of posterior teeth that were restored with resin composite inlays.

Methods: Sixty caries-free extracted maxillary premolars were selected and equally divided into two experimental groups. Group D1: MOD cavities were prepared. Group D2: MOD cavity with gingival steps. Each group was subdivided to three subgroups (n = 10) and restored as follows: inlay without IDS; inlay with IDS and adhesive system; inlay with IDS and adhesive system and low-viscosity resin. Cuspal deflection was measured with a micrometer. One-Way Analysis of Variance ANOVA was used to analyze the results.

Results: Cavity design D1 showed the lowest cuspal deflection compared to cavity design D2. In group D1; Inaly without IDS showed the highest significant cuspal deflection (9.85 μm) followed by Inaly + IDS + Low viscosity resin (7.16 μm). The lowest value was obtained for Inaly + IDS group (4.76 μm) with significant difference between all tested restoration techniques. In group D2; Inaly without IDS showed the highest significant cuspal deflection (14.7 μm) followed by Inaly + IDS + Low viscosity resin (11.69 μm). The lowest value was obtained for Inaly + IDS (9.59 μm) with a significant difference between all tested restoration techniques.

Conclusion: IDS and Protect Liner F allowed less cuspal deflection comparable with traditional technique. However, IDS restoration techniques did not decrease the cuspal deflection in case of more extensive loss of dental structure in the premolar teeth.

1. Introduction

Cuspal deflection occurs in the posterior teeth due to their morphological shape. whilst mesio–occlusal-distal (MOD) cavities are done, cuspal deflection is increased [1,2] due to the diminishing in the stiffness of the tooth [3]. This is because of removal of tooth structure, which prompts to prominent weakness of the tooth [4,5].

Several strategies and dental materials have been used to recover the stiffness of MOD prepared teeth [6,7]. The indirect resin composite restorations approach is considered the best choice to restore teeth with large cavities and to conquer polymerization shrinkage [8].

The conventional approaches comprise of taking an impression of the tooth instantly after preparation. Temporary cement is used directly on the prepared tooth for cementation of temporary restoration. The adhesive bond is applied to the tooth after the removal of temporary material, followed by a cementation of permanent restoration with resin cement [9].

Researches [10,11] have proven that using adhesive agents managed to give better bond to newly prepared dentin in contrast to dentin which has remnants of temporary materials. These remnants may motive gap formation, failure in hybrid layer, and hypersensitivity. To overcome these consequences, the immediate dentin sealing (IDS) approach was initiated; this approach consists of applying the adhesive instantly following preparation and before taking the impression. Another approach includes applying both the dentin adhesive system and flowable (low-viscosity) resin composite instantly after tooth preparation [12,13]. It is concluded [14] that application of flowable resin protects the hybridization hence, preserves the integrity of the dentinal seal. Those strategies have the clinical benefits of sealing the freshly cut dentin with a resin instantly and consequently, reducing bacterial

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Table 1
Materials used in the study, their description, manufacturers and their composition.

Material	Description	Manufacturer	Composition
Clearfil SE Bond	Self-etch adhesive system	Kuraray Medical Inc, Tokyo, Japan	Self-etch primer: 10-MDP, HEMA, hydrophilic dimethacrylate, photoinitiator, water Adhesive: 10-MDP, bis-GMA, HEMA, hydrophilic dimethacrylate, microfiller
Protect Liner F	Low viscosity resin	Kuraray Medical Inc, Tokyo, Japan	TEGDMA, Bis-GMA, methacryloyl fluoride-methyl, methacrylate copolymer
Panavia F	Dual-cure resin cement	Kuraray Medical Inc, Tokyo, Japan	ED primer A: HEMA, 10-MDP, 5-NMSA, water, accelerator Kuraray Medical Inc, Tokyo, Japan ED primer B: accelerator, water, sodium benzene sulfinate A-Paste: methacrylate, 10-MDP, quartz-glass, microfiller, photoinitiator B-Paste: methacrylate, barium glass, sodium fluoride, chemical initiator.
Sinofy ™	Indirect lab composite	3M ESPE, St Paul, MN, USA	48wt% Mixture of aliphatic and cycloaliphatic monomers, 40wt% strontium aluminium borosilicate glass macrofillers (0.5–0.7 µm diameter), 5wt% pyrogenic silica microfillers, specifically optimized photo-initiator system, 5wt% special glass ionomerm fillers, 1wt% silane.

Bis-EMA, ethoxylated bisphenol A dimethacrylate; Bis-GMA, bisphenol-glycidyl methacrylate; NMSA, *N*-methacryloxyl-5-aminosalicylic acid; HEMA, hydroxyethylmethacrylate; TEGDMA, triethylene glycol dimethacrylate; MDP, methacryloyloxydecyl dihydrogen phosphate; UDMA, urethane dimethacrylate.

invasion as well as hypersensitivity throughout the temporary period [15].

Jayasooriya and others [16] recorded the presence of lesser gaps at tooth/restoration interface at the surface of the prepared specimens treated with dentin adhesive system and flowable resin in contrast to non-treated specimens.

So that; The purpose of this study was to evaluate the effect of different cavity designs and immediate dentin sealing (IDS) restoration techniques on the cuspal deflection of posterior teeth restored with resin composite inlays.

2. Material and methods

The different materials used in the current study are described in Table 1.

2.1. Specimen grouping

Sixty freshly extracted non-carious human upper premolars were used in the study. The teeth were randomly distributed into two groups according to cavity design (n = 30); MOD cavity (D1) and MOD cavity with gingival steps (D2). Each group was subdivided to 3 subgroups (A, B and C), according to different restoration techniques (immediate dentin sealing (IDS) techniques), then restored as follows: A) inlay without IDS; B) inlay and IDS with adhesive system; C) inlay and IDS with dentin adhesive system and low viscosity resin (n = 10).

2.2. Specimen preparation

Teeth were scrubbed of soft tissues under running water. Surface deposits were carefully removed using a hand scaler. The teeth were selected as having standard premolar crown form and dimensions. Then any teeth having obvious enamel cracks were discarded. The teeth were stored in distilled water in the refrigerator at 4 °C until use. No other preservative was used because of the possibility of altering the organic content of dentin that could interfere with the bonding process.

Each tooth was mounted vertically in a cubic stainless-steel mould using chemically cured acrylic resin. The resin was extended to within 2 mm of the amelocemental junction (approximately the level of the alveolar bone in the healthy tooth).

The maximum bucco-palatal (BP) and mesio-distal (MD) widths for each tooth were measured with a digital micrometer (Mitutoyo; Tokyo; Japan), accurately to 10 µm.

The buccopalatal and mesiodistal widths of each tooth in every group were measured and statistically analyzed so that the mean buccopalatal and mesiodistal width of each group of teeth differed by no more than 5%.

In group D1, a mesio-occlusal-distal MOD cavity was prepared using a diamond fissure bur # 8 mounted in high speed hand piece with a profuse water coolant. The preparation was centred between the buccal and palatal cusps to preserve the maximum dentinal support for both cusps. The buccolingual width was 3 mm and occlusal depth were 3 mm below the enamel-dentine junction.

The second cavity design (D2) had the same criteria as (D1) however, a gingival step was prepared 0.5 mm above the enamel-cement junction on the proximal surfaces of 0.8 mm width.

All measurements were carried out with the digital caliper. Moreover, all the preparation depths were controlled with silicon keys and measured with periodontal probe (probe UNC#12 HDL#6, Hu-friedy, Tuttilnger, Germany).

For standardization, a cylinder, with two inward co-axial holes, was constructed. The cylinder was placed over the tooth with the two holes directed towards the buccal & palatal cusps (2 mm from the tip of the palatal cusps). Then shallow concavities were cut within enamel on buccal and palatal surfaces at these reference points to accommodate the placement of two small glass rings ~2 mm radius of curvature using α- Cyanoacrylate adhesive (Amir Alpha, Cyanoacrylate Adhesive, Cairo, Egypt). Each tooth was secured to a micrometer stage of Universal Length Measuring Microscope (Carl Zeiss Jena; serial no.2510, Germany) at 5X magnification. Microscopically, the cuspal indices were tangentially aligned with the crosshair eyepiece. Then the intercuspal distance was measured between these two reference points. This was considered the intercuspal distance (R1) before restoration.

Promptly after preparing the cavity, each one of IDS restoration techniques was placed on the prepared cavities in groups B and C. For group B, the Clearfil SE Bond adhesive was placed on the prepared dentin surface using a micro-brush then it was kept in place for 30 s. Air-drying was used to remove excess solvent for 5 s. Light-curing for 20 s was then performed using a light-curing unit (Astralis 3, Ivoclar Vivadent, Schaan/Lichtenstein, Austria). In group C, Clearfil SE Bond was applied as described in group B. Subsequently, the low viscosity resin “Protect Liner F” was applied to previously placed adhesive system on the surface with brush-on technique and it was light-cured for 20 s. A cotton pellet soaked in alcohol for 10 s was used to wipe the cured surface of Protect Liner F in order to remove the Oxygen-inhibited layer present on the surface.

The prepared teeth were impressed with polyvinyl siloxanes (Express VPS, 3M ESPE, MN, USA) and impression was poured with die stone (Quick Die, Bisco Inc., IL, USA).

For the preparation of the resin composite inlays; indirect resin composite restorative material (Sinfony, Indirect lab composite, 3M ESPE, MN, USA) was inserted in four horizontal layers on the poured casts (shade D A3.5). Light-curing was done for 60 s for each layer. For the post-curing polymerization; another 60 s of light curing of the restoration is finally done, then polishing discs and silicone tips (Soft-Lex, 3M ESPE, MN, USA) were used to polish and finish the surface.

The inner surface of the inlays was sandblasted before cementation for 10 s with aluminum oxide particles (25–50 µm). Cementation of inlays was carried out using dual-cure resin cement, Panavia F (Kurary America Inc., Dental Department, NY, USA) according to manufacturer's instruction, from facial, lingual and occlusal surfaces for 40 s in each direction. The light curing unit was calibrated at 1200 mw/cm^2 and it was checked using radiometer (Hilux curing light Meter Berlioglu, Dental Ankara, Turkey). The margins of the restoration were finished and polished with polishing discs (Sof-Lex,3M ESPE, MN, USA). All Specimens were stored in water at 37 °C in the incubator (Juan; Model No.30211400, France) then submitted to the cuspal deflection test.

2.3. Cuspal deflection test

The intercuspal distance was measured again, microscopically, after restoration to give the second reading (R2). The difference between the first and the second readings was considered the cuspal deflection after 15 min from the restoration.

2.4. Statistical analysis

Mean and standard deviation (SD) values of cuspal deflection for different cavity designs and restoration techniques were statistically analyzed using One-Way Analysis of Variance (ANOVA) test. The p-value was set to $p = 0.05$.

3. Results

The effect of different cavity designs and IDS restoration techniques on the cuspal deflection of posterior teeth restored with indirect resin composite inlays was presented in Table 2. For all IDS restoration techniques, MOD cavity design (D1) showed the lowest mean cuspal deflection compared to MOD with gingival steps cavity design (D2). For MOD cavity design (D1); Inaly without IDS showed the highest significant mean cuspal deflection (9.85 μm) followed by Inaly + IDS + Low viscosity resin (7.16 μm). The lowest value was obtained for Inaly + IDS group (4.76 μm) with significant difference between all tested restoration techniques. For MOD with gingival steps cavity design (D2); Inaly without IDS showed the highest significant mean cuspal deflection (14.7 μm) followed by Inaly + IDS + Low viscosity resin (11.69 μm). The lowest value was obtained for Inaly + IDS (9.59 μm) with significant difference between all tested restoration techniques.

4. Discussion

Cusp deflection is a bio-mechanical phenomenon, which is quite commonly observed in the posterior teeth restored by resin composite restorations. It is the outcome of interactions between the polymerization contraction stresses of the resin composite and the acquiescence of the cavity wall [17–19]. The clinical significance of cuspal deflection in posterior teeth is the higher the deflection magnitude, the higher the deformation stresses, and subsequently, the greater the likelihood of bond failure. Such failure is characterized by the occurrence of stresses higher than the bond strength at tooth/restoration interface [20].

Premolars were used in this study because they are more susceptible to cusp deflection than other posterior teeth. This is due to their anatomical shape, crown volume and crown/root proportion. The cavity dimensions were standardized in all test specimens, mimicking the case of progressive caries, for which the tooth becomes mutilated. Slot cavity preparation was done. The cavity design was done to debilitate the structure of the tooth, favoring cuspal deflection and create a clinical simulation of the real situation performed for inlay cavities [21–23].

Generally, the results of this study showed an inward cuspal deflection for all the specimens, proving that strong adhesion was achieved to cause tooth deformation by the contractile composite resin [24]. This cuspal deflection may be also related to the loss of tooth stiffness, when the marginal ridges were removed in MOD cavities allowing for tooth deformation [25].

For all restorations, MOD cavity Design D1 showed the lowest mean cuspal deflection compared to MOD with gingival steps cavity design D2. This was expected as the extent of cuspal deflection is directly related to loss of tooth structure. Extensive tooth removal motivates a depletion in tooth rigidity [26] and need more resin composite when restored, causing greater contraction forces [27].

Group B, with cavity design D1, in which IDS with the dentin adhesive system only was done, it showed cuspal deflection (4.76 μm), that was statistically lower than group A with cavity design D1 (9.85 μm), which no IDS technique was done. A potential justification for this verdict might be that the Clearfil SE Bond adhesive system was directly placed on the prepared dentin. Researches [28] have revealed that resin adhesives could give a better bond to the newly prepared cavity instantly after being prepared, comparing with dentin that was contaminated with provisional materials, thus improving the dentin bond strength and, accordingly, cuspal deflection will be reduced.

In group C (IDS with the adhesive system and low viscosity resin) with cavity design D1, the cuspal deflection was moderate, at (7.16 μm), which was significant. This finding agreed with some studies [29] that revealed an improved dentin bond strength with this applied technique, the capacity of this bond was mirrored in the methodology of cuspal deflection. However, a previous study [30–32] contradicted our findings. They concluded that; low-viscosity resin application did not add significantly to reduce cuspal deflection. This can be explained by the differences in the test conditions regarding tooth morphology, cavity size and test conditions.

The outcome of the present study showed that neither IDS restoration techniques nor low viscosity resin placement had contributed to a reduction in cuspal deflection of teeth with extension of cavity preparation. These records coincide with previous studies [33,34]. Reinforcement of enamel by the whole dentin volume, makes it more liable to cuspal deflection, that clarifies the highest values gained for the cuspal deflection in group A, inlay restoration, with cavity design D2. These findings were also in agreement with those of other researches [33,34] which confirmed that distinctive restorative approaches could

Table 2
Mean and standard deviation values (SD) of cuspal deflection for different cavity designs and IDS restoration techniques.

Cuspal Deflection		Cavity Design				p-value
		MOD + Gingival steps		MOD		
		Mean	SD	Mean	SD	
Restoration Technique	Inlay Without IDS	9.85^a	.52	14.70^a	1.04	≤0.001*
	Inaly + IDS	4.76^c	.68	9.59^c	1.03	≤0.001*
	Inaly + IDS + Low Viscosity Resin	7.16^b	.69	11.69^b	.94	≤0.001*
p-value		≤0.001*		≤0.001*		

Means with the same letter within each Column are not significantly different at p = 0.05.
* = Significant.

not enhance the sound tooth resistance. Nonetheless, application of bonded restorations had been preferred for strengthening the remaining structures of the tooth [35] despite that the full strength is not improved [35,36]. This finding agreed with preceding studies [37] which agreed that the loss of dental structure produces a reduction in the tooth rigidity, and subsequently cuspal deflection will increase. These findings were in agreement with those of Rosa at al [38]. that verified when different types of cements used for inlay cementations, none of the groups compensated the stiffness of natural teeth.

This research explains that the degree of tooth preparation affects the cuspal deflection. Moreover, cuspal deflection showed lower mean values with IDS restoration techniques and Clearfil SE Bond when the luting adhesive technique with Panavia F was performed. Conservative cavity preparations are advised for indirect resin composites restorations to decrease cuspal deflection stresses, circumventing traditional amalgam cavity designs.

5. Conclusions

Under the limits of the current study, it can be concluded that IDS restoration techniques may offer a good alternative to conventional adhesive methods in case of more extensive loss of dental structure in the premolar teeth.

Conflicts of interest

The authors declare no conflict of interests.

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