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Original Research Article

Cuspal Deflection and Fracture Resistance in Maxillary Premolar Teeth Restored With Bulk-Fill Flowable Resin-Based Composite Materials

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ABSTRACT

Objectives: To evaluate cuspal deflection and fracture resistance of maxillary premolars with class II MOD cavities filled with nanohybrid resin composites lined with SDR or nano flowable resin composite.
Methods: 30 MOD cavities were prepared in extracted human upper premolar teeth. The cavities (n=10) were restored and grouped into three groups. Group I was restored with nanohybrid RBC (Esthet.x-HD), group II was restored with Esthet.x-HD/SurFil SDR flowable composite and group III was restored with Esthet.x-HD/Filtek z350 XT flowable composite. Buccal and palatal cusp deflections were recorded post irradiation using strain-gauge device. All of the specimens subjected to a compressive load in a universal Instron Testing Machine at a crosshead speed of 0.5mm⁄min until fracture was occurred.
Results: There were a high significant difference ($p<0.0001$) between the tested groups.
Conclusions: SDR as 4 mm bulk fill dentin replacement showed good performance as a liner under nano hybrid composite resin restorations.

Keywords: Nano-hybrid resin composite, Bulk Fill, Flowable liner, cuspal deflection, fracture resistance

INTRODUCTION

Polymerization shrinkage stress generated in dental tissues through the bonded interfaces of resin based composite restoration is manifested clinically as cusp deflection. [1,2] 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] As a result, post-operative sensitivity has been associated [4] due to the formation and/or propagation of enamel cracks. [5,6]

The assessment of cuspal deflection during RBC restoration of Class II, mesio-occlusal–distal (MOD), cavities has been extensively investigated in the dental literature using a variety of techniques including photography microscopy with cuspal indices alignment, strain gauges, linear variable differential transformers, interferometry, profilometry, digital-image-correlation or electronic speckle pattern interferometry. [7,8] Mean cuspal deflections of up to 50 mm were recorded using the range of techniques highlighted, [9] however, difficulties were apparent in the methodological approaches employed most notably in the size of the teeth (maximum bucco-palatal-width: BPW), tooth type (molar or premolar) and restoration technique (bulk or incremental) which were often not standardised. [10] Therefore, variations in the previously reported cuspal deflection measurements were often due to non-standardized MOD cavity preparations in non-standardized teeth since contraction of the cusps is dependent upon the remaining tooth structure following cavity preparation. [11]

Flowable RBCs were produced as an intermediate thin layer suggesting to absorb the shrinkage stress generated by a subsequent layer of higher modulus RBC, [12] manifested clinically as a reduction in cuspal deflection. [7,8,13] Recent advances by manufacturers have resulted in bulk-fill flowable RBC bases being marketed for use beneath conventional RBC materials, with a reported depth of cure in excess of 4 mm. [14] Whilst the manufacturers claims that the modified methacrylate resin has a slow polymerization rate through the use of a polymerization modulator, the filler content is reported as 68% wt for SDR. [15]

It has been claimed that strength of a tooth decreases in proportion to the amount of tooth tissue removed, particularly in relation to the width of the occlusal section of the preparation. [16] So, this study was intended to evaluate cuspal deflection and fracture resistance of maxillary premolars with class II MOD cavities; that will be filled with nanohybrid resin composites lined with SDR or nano flowable resin composite. The null hypothesis was that there were high significant differences among restorative materials tested.

MATERIALS & METHODS

In this study two flowable lining materials, SureFil SDR and Filtek Z350 XT Flow were used. The restorative system used was the two step etch and rinse Prime & Bond NT adhesive system with a nano-hybrid Esthet.x HD resin dental composite as shown in table 1.

The restorative materials were used in accordance with manufacturers' instructions and only one operator performed all the procedures of specimen's preparations and all restorative procedures. A light emitting diode (LED) visible-light curing unit was used, and the power density of the light (800 mW/cm2) was checked every 10 specimens with a digital readout dental radiometer.

Table 1: Restorative materials were used in the study.

Brand Name	Specification	Manufacturer	Composition	Patch Number
Esthet.x HD	Nano- hybrid resin composite	Dentsply Caulk, Milford, DE, USA	**Matrix:** U-BisGMA, BisEMA and EGDMA **Filler:** Borosilicate/aluminum/barium glass and silica	183458
SureFil SDR Flow	Bulk- Fill flowable resin composite	Dentsply Caulk, Milford, DE, USA	**Matrix:** Polymerization modulator, dimethacrylate resins (<10% Wt), UDMA (<25% Wt) **Filler:** Ba-B-F-Al silicate glass (<50% Wt), SiO2, amorphous (<5% Wt), Sr-Al silicate glass (<50% Wt), TiO2 (<1% Wt)	9BH
Filtek z350xt Flow	Nano-filled flowble resin composite	3M ESPE; St Paul, MN, USA	**Matrix:** BisGMA (10-15% Wt), TEGDMA (10-15% Wt), BisEMA 6 (1-5% Wt), functionalized dimethacrylate (1-5% Wt) **Filler:** Ceramic (52-60 % Wt), SiO2 (3-11% Wt), ZrOx (3-11% Wt)	3166427
Prime & Bond NT	Two- step- etch and rinse	Dentsply Caulk, Milford, DE, USA	Di- and Trimethacrylate resins PENTA (dipentaerythritolpenta acrylate monophosphate) Nanofllers-Amorphous Silicon Dioxide Photoinitiators Stabilizers Cetylaminehydrofluoride Acetone	0806002408

1. Cuspal Deflection Test

A total of thirty sound extracted maxillary first premolar teeth were collected. In order to be included in the study, the premolars were required to have the following crown dimensions: 9mm bucco-lingual distance; 11mm mesio-distal distance. The collected premolars were observed under magnification (x10) in binocular-stereomicroscope; teeth which had preexisting cracks, caries, developmental defects or attrition were discarded. The selected premolars were carefully cleaned using ultra sonic scalar and then debrided with pumice using rotary brush. The selected premolars were disinfected with 0.2% sodium azide solution for 48 hours. [17] Premolars were stored in normal saline at 37^{o}C, until the time of the test, to prevent dehydration.

The samples were divided into three main groups (10 premolars of each) relative to the dental composite restorative materials used; group I (Esthet.x-HD), group II (Esthet.x-HD/SureFil SDR Flow) and group III (Esthet.x-HD/Filtek z350xt Flow).

A non-retentive MOD slot cavity was prepared, with dimensions of 4±0.3millimetersin depth (without axial wall) and 2±0.3millimeters in facio-lingual width following the conventional outline form. [17] Each cavity was prepared using carbide bur No.59. The depth of the cavity was checked by using a graduated periodontal probe.

Polyvinylchloride (PVC) retention tubes, with a diameter of three centimeters, were used for mounting the prepared teeth. The roots of each tooth had been positioned at the center of the tube, with the long axis parallel to the sides of PVC tube. Each tube was filled with acrylic resin in the dough stage, leaving the crown and two millimeters of the root below the amelo-cemental junction uncovered to accommodate the leads of the strain gauge. Two of strain gauges were connected to the strain gauge indicator; where the gauge constituted one-end connected to a wheatstone bridge, with the other end had been connected to the strain gauge indicator.

All the prepared cavities were etched/primed using total-etch adhesive system (Prime & Bond NT), then cured using LED (Light Emitting Diode) light curing unit for 20 sec. Before mounting a strain gauge, it is should be recalled that the surfaces of the tooth and the strain gauge bonding site were carefully sand- plasted. This preparation consists of sanding away any debris, paint or rust to obtain a smooth but not highly polished surface. Then two precision strain gauges were attached to the buccal and lingual surfaces of each un-restored specimen and were bonded with an auto-cured epoxy adhesive resin. Next, solvents are employed to remove all traces (Fig. 1).

Fig. 1: Occlusal view of the bonded strain on tooth

During polymerization of the adhesive system, the strain gauge recorded the data, then amplified and inserted by (analog to digital card) to specially designed computer program (SPprog). The results appeared as a curve between the time in seconds and the strain in micro strain unit. These readings for the Wheatstone bridge are directly proportional to the internal cuspal deflection of the buccal and lingual cusps of tested specimens. [18] The matrix system was applied before insertion of composite, and then removed before the curing of composite restorative material to avoid pre stresses which resulted from matrix tight.

SIProg Program is fully written in house using Matlab packages. It consists of title bar, menu bar, measuring information panel, processing panel, and option panel and display area.

Title bar is the name of the current program which called Strain Indicator Program (SIProg). In the measuring information panel, the user can select restorative material, scientific name and trade name. In the processing panel, the application of flowable composite can be chosen by selecting its checkbox to edit its polymerization time in seconds. The polymerization time can also be edited via processing condition panel. Then, the total polymerization time was calculated and displayed in the Total polymerization time edit box. The SIProg is now ready for processing by clicking on Start, Continue, Pause and Stop pushbuttons. Then, the corresponding graphs are displayed in Buccal and Lingual cusp area. The maximum, minimum, average and range of strain reading are displayed to the left part of the SIProg interface. [19]

The collected data of both buccal and lingual cuspal deflection were recorded and tabulated to a Microsoft Excel software Program. One way analysis of variance (ANOVA) was performed to determine the effect of restorative resin composite tested with and without application of flowable composite resin. Tukey Post Hoc test was then performed to determine the significant differences between each two groups.

2. Fracture Resistance Test

A total of fifty extracted maxillary premolar teeth were selected, cleaned and stored for fracture resistance test according to the criteria mentioned before in cusp deflection test. The teeth were divided into five groups as follow:

Group I: Esthetex-HD.

Group II: Esthet.x-HD/SureFil SDR Flow.

Group III: Esthet.x-HD/Filtek z350XT Flow.

Group IV: un-prepared teeth (-ve control group).

Group V: prepared un-restored teeth (+ve control group).

The roots of the teeth were embedded in self cure acrylic resin contained in polyvinyl chloride (PVC) rings, as described in the cusp deflection test. The specimens had been stored in distilled water until being prepared and tested.

All of the specimens subjected to a compressive load in a universal Instron Testing Machine at a crosshead speed of 0.5 mm ⁄min until fracture was occurred. The specimens were placed on the lower platen of the testing machine. A steel sphere (8 mm in diameter) rigidly attached to the upper cross head was brought into contact with both the buccal and lingual cusps of the tooth. The areas of contact were modified by round diamond rotary instrument to prevent lateral deflection of the steel sphere.

It should be ensured that there was no contact between the restoration and the sphere before the test was performed. Fracture loads were recorded in kilograms and interpreted using one-way analyses of variance (ANOVA). Tukey Post Hoc test was then performed to determine the significant differences between each two groups. The level of significance was set at ($P < 0.05$).

RESULTS

1. Cuspal Deflection

a. Buccal cusp evaluation

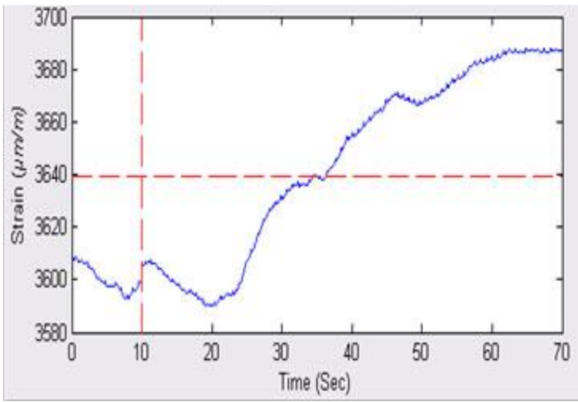
One way analysis of variance (ANOVA) was performed to determine the effect of restorative resin composite tested with and without application of flowable composite resin on the buccal cusp deflection. The results revealed a highly significant differences among the tested materials ($p<0.0001$).

The Tukey Post Hoc test was then performed to determine the significant differences between each two groups (Table 2). There was a high significant differences between all the tested resins composite except between group I (Esthet-x HD) and group III (Esthet-x HD/Filtek z350 XT Flow) where there was no statistical significance difference between the two groups [$p=0.0691$] at $p<0.05$.

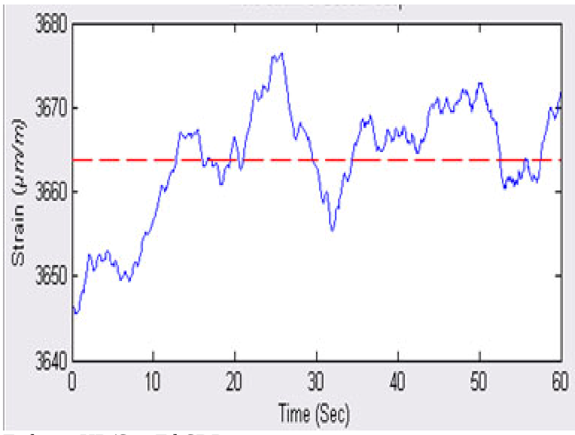
Table 2: Tukey Post Hoc test results of buccal cusp deflection of tested composite specimens.

Material	*P* value
Group I versus Group II	<0.0001
Group I versus Group III	0.0691
Group II versus Group III	<0.0001

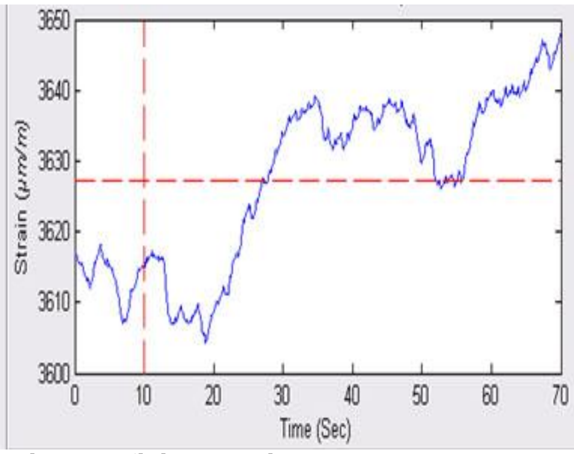
*Significant difference at p< 0.05



Esthet-x HD



Esthet-x HD/SureFil SDR



Esthet-x HD/Filtek z350 xT Flow

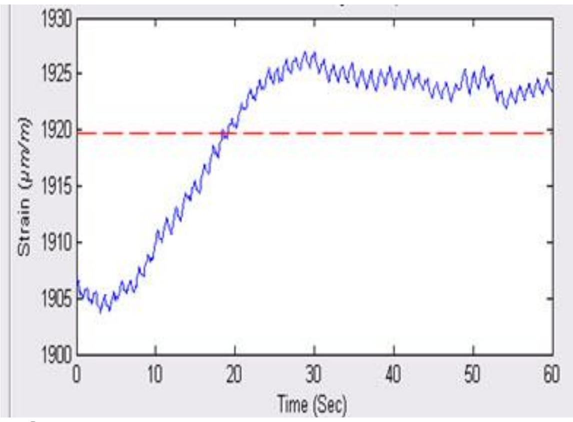
Fig. 2: showing the output curves drawn by (SIProg) of Buccal cusp

b. Lingual cusp evaluation

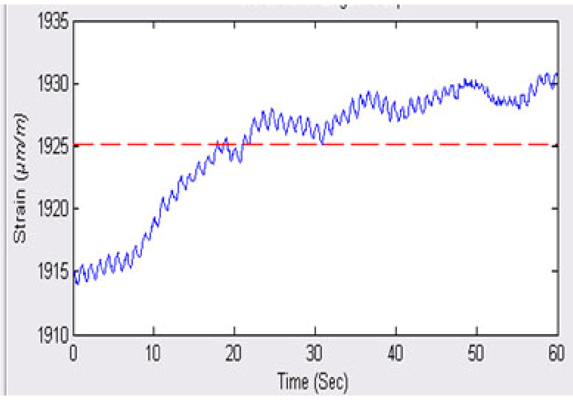
One way analyses of variance (ANOVA) was performed to determine the effect of restorative resin composite tested with and without application of flowable composite resin on the lingual cusp deflection. The results of One-way ANOVA revealed high statistically significant difference between the tested composite materials ($P < 0.0001$). The Tukey Post Hoc test (Table 3) was then performed to determine the significant intra-group differences and showed that, high significant differences were found between all the tested resins composite.

Table 3:Tukey Post Hoc test results of lingual cusp deflection of tested composite specimens.

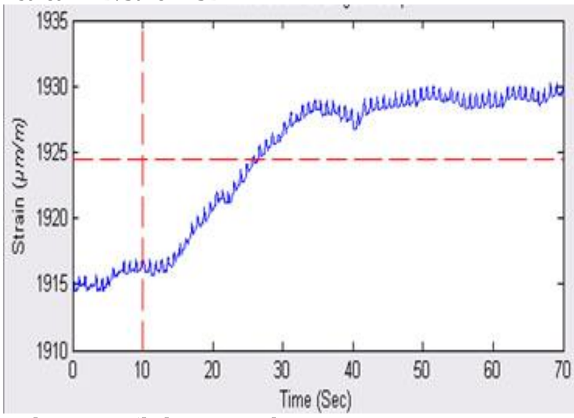
Material	*P* value
Group I versus Group II	<0.0001
Group I versus Group III	0.005
Group II versus Group III	<0.0001



Esthet-x HD



Esthet-x HD/SureFil SDR



Esthet-x HD/Filtek z350 xT Flow

Fig.3: showing the output curves drawn by (SIProg) of lingual cusp

2. Fracture Resistance

One way analyses of variance (ANOVA) was performed to determine the effect of restorative resins composite tested on the fracture resistance. The results revealed high statistically significant difference between the tested composite materials ($P < 0.0001$).

The Tukey Post Hoc test (Table 4) was then performed to determine the significant intra-group differences and showed high significant differences between all the tested resins composite except between group I

(Esthet-x HD) and group III (Esthet-x HD/Filtek z350 XT Flow) where there was no statistical significance difference between the two groups [p=0.018] at p<0.05.

Table 4:Tukey Post Hoc test results of fracture resistance of tested composite specimens.

Material	*P* value
Group I versus Group II	<0.0001
Group I versus Group III	0.018
Group II versus Group III	<0.0001

*Significant difference at p< 0.05

DISCUSSION

SDR or SureFil SDR was introduced to the market as flowable resin composite. Claiming that it would allow a 4 mm bulk placement in one layer due to reduced polymerization stress, being mandatorily covered by a 2 mm layer of conventional resin composite. [20]

1. Cuspal Deflection

Cuspal movement has been used to study the influence of restorative procedures and restorative materials' properties on teeth by number of authors. [21-25] A number of different measurement devices had been used including dial gauge, LVDT variable displacement transducers and the deflection of a metal strip. These techniques suffered from the difficulty of identifying a suitable reference point on the tooth surface. The reference point may be a cusp tip a point level at the top of the cavity. Another problem was found, the displacement measurement method of this type were the load which may be applied by the transducer to keep it in contact with the tooth. [22] To overcome these problems, Strain gauges were used in this study and they were relatively small, having a grid area of only two millimeters. It had been reported that cusp fracture in restored teeth commonly occurs in this area and it was considered that this was likely to be the region subjected to the highest strains. [26]

In the current study, the Class II MOD cavity design was chosen for RBCs [22] as it would weaken the remaining tooth structure to favor cuspal deflection. It had been reported that the matrix band placement on teeth prepared with MOD cavities may cause cuspal bending and pre-stress the tooth prior to polymerization of the composite restoration. So, in this study the matrix and band system had been removed before starting curing of the materials.

The highest cuspal deflection values were recorded with nan-ohybrid restorations lined with nano-flowable resin composite which were not significantly differed than restorations restored with nano-hybrid resin composite without liner. This may be due to its high bond strength with tooth structure. The high deflection values may be explained by the higher contraction stresses resulted from polymerization reaction of nano-hybrid resin composite and low filler content and high volumetric polymerization shrinkage of flowable composite resin.

Interestingly, when the bulk-fill flowable RBC base was used to restore the Class II cavities to within 2 mm of the cusp in a single increment, the mean cuspal deflections recorded were significantly reduced compared with the oblique incremental filling technique when nano-hybrid was employed. This may be due to decreased polymerization shrinkage stresses reported by SurFil SDR flowable resin composite.

2. Fracture resistance

A higher failure load is accepted to be the criterion for better strength and durability characteristics of dental restorations. An important characteristic of lining material is their ability to adequately resist compressive forces during restoration placement and later, during mastication. [27]

There was a high significant difference in the mean fracture resistance values between the different types of composite resin restorative materials. The highest fracture resistance value was recorded with nano-hybrid resin composite restorations lined with SDR, while the least value recorded with nano-hybrid resin composite restorations without liner which were not significantly differed than nano-hybrid resin composite restorations lined with nano-flowable resin composite.

These results may be explained by the excellent bonding ability between the buccal and lingual cusps which made the tooth act as one unit. In addition to decreased polymerization shrinkage stresses reported by SDR flowable resin composite.

CONCLUSION

Based on these results, it can be concluded that SDR as 4 mm bulk fill dentin replacement showed good performance as a liner under nano hybrid composite resin restorations.

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