Evaluation of Fracture Resistance in Maxillary Premolar Teeth Restored with Different Direct Composite Restorative Materials

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Abstract

Purpose: This study was conducted to evaluate the effect of three direct resin composite restorative materials on fracture resistance in mesio-occluso-distal (MOD) cavities prepared in maxillary premolars.

Materials and Methods: A total of 25 maxillary premolars were collected and then divided into five main groups (n=5). Group 1 (positive control group): sound teeth with no cavity preparation. Group 2 (negative control group): MOD cavities with no restoration. Group 3: MOD cavities restored with nanocomposite FILTEK™ Z350 XT Group 4: MOD cavities restored with simplified universal composite OptiShade™ and Group 5: MOD cavities restored with universal nano-filled composite Estelite® Sigma Quick.

Results: Group 5 showed the maximum fracture strength value (ranged from 1170-1355 N) followed by Group 4 (998.1-1158 N) then Group 3 (900.9-1097 N) followed by Group 1 (positive control) with fracture strength value ranging from 836.1 to 1059 N. Group 2 (negative control) showed the minimum fracture strength value ranged (380.6-631.6 N). For the significance evaluation of different groups, One-Way ANOVA was performed followed by Tukey’s post hoc test for multiple comparisons which revealed all significant differences between different groups as P-value < 0.05 except for (group 1 # group 3), (group 1 # group 4) and (group 3 # group 4) respectively which were insignificantly different as P-value > 0.05.

Conclusion: Reinforcement of the teeth could be achieved after MOD cavity preparation in maxillary premolars through proper restorative procedures.

Keywords: Fracture resistance, MOD cavities, supra-nano fillers, Universal adhesive

Introduction

Restoring MOD cavities in premolars is a challenging procedure due to the loss of both marginal ridges causes weakening of the remaining tooth structure significantly decreases its resistance to fracture and increases the risk of cuspal deflection, therefore MOD cavities need a restoration that is capable of reinforce the remaining tooth structure and withstand fracture when subjected to high occlusal load [1,2,3].

Composite resin is considered nowadays alternative restorative material for posterior teeth and significantly increases the resistance of the remaining tooth structure to fracture. However, polymerization shrinkage remains the most important intrinsic weakness in resin composite [4,5,6].

The layering concept was developed to provide satisfactory aesthetic properties however it requires more restorative skills and more chairside time [7,8,9]. Single-shade universal composites have recently introduced to simplify shade selection and restorative procedures. OptiShade™ is a highly filled nano-hybrid universal composite developed to simplify inventory management and save clinicians time on shade selection while providing excellent material properties, it features high strength, low shrinkage, and durability for posterior restorations together with outstanding color match, polishability for anterior restorations [10,11].

A recently introduced resin composite Estelite® Sigma Quick which possesses high filler content and spherical supra nano-filler particles of silica and zirconia improved its mechanical...
and esthetic properties with reduced curing time and increasing polymerization conversion rates [12].

Since there is a limitation in research and information available on the mechanical properties of such materials, our study aimed to evaluate fracture resistance in maxillary premolar teeth directly restored with different resin composite restorative materials.

Materials and Methods

Ethical Approval
Our present study has been reviewed and then approved by Badr University in Cairo BUC Institutional Ethical Committee with approval number: BUC-IACUC-230827-34.

Sample Size Calculation
Sample size was calculated depending on a continuous response variable from matched pairs in a previous study [13]. According to this study, matched pairs were normally distributed with a standard deviation (112.44). If the true difference in the mean response of matched pairs was (370.38), we need to study (3) samples for each group to be able to reject the null hypothesis that this response difference is zero with probability (power 0.8 = 80%). The sample size was increased by 20% to compensate for processing and laboratory failures during the assessment. The Type I error probability associated with this test of this null hypothesis is (0.05). Final sample size for each group will be (n=5), total sample size for all groups (n=25).

Grouping of Teeth
A total number of 25 Maxillary premolar teeth were collected to perform this in-vitro study. Extracted teeth were selected for periodontal purposes. After teeth have been cleaned and disinfected, they are divided into 5 main groups according to the restorative protocol used. (n= 5)

- Group 1: Intact teeth (positive control)
- Group 2: Prepared unrestored MOD cavities (negative control)
- Group 3: MOD cavities were restored with universal nanocomposite (Filtek Z350 XT universal composite, 3M)
- Group 4: MOD cavities were restored with simplified universal composite with adaptive response technology (OptiShade™, Kerr)
- Group 5: MOD cavities were restored with universal composite with Radical Amplified Photo polymerization (Estelite® Sigma Quick, Tokoyama).

To simulate periodontal ligaments, a light body polyvinyl siloxane impression material was applied to cover the root of each tooth and then fixed perpendicularly using self-cured acrylic resin. To facilitate restoring the original anatomy, occlusal surface impression for each tooth was taken to make an occlusal stamp.

**Table 1: Organic Matrix Composition and Inorganic Filler Composition**

<table>
<thead>
<tr>
<th>Material</th>
<th>Manufacturer</th>
<th>Organic Matrix Composition</th>
<th>Inorganic Filler Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>OptiShade™</td>
<td>Kerr, CA, USA</td>
<td>• BisGMA</td>
<td>• Percentage of spherical silica and zirconia particles 81% by weight and 64 % by volume with an average particle size of 5 – 400 nanometers in addition to 400 nm barium glass particles.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• BisDMA</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>• TEGDMA</td>
<td></td>
</tr>
</tbody>
</table>
**FILTEK™ Z350 XT** 3M/ESPE, St Paul MN, USA

- BisGMA
- UDMA
- TEGDMA
- PEGDMA
- Bis-EMA(6) resins.
- Filler percentage 78.5% by weight and 63.3% by volume of silica fillers (20 nm) and zirconia fillers (4 – 11 nm) with average cluster particle size is 0.6 - 10 microns.

**Estelite® Sigma Quick** Tokuyama, Dental Co. Tokyo

- Bis-GMA
- TEGDMA
- Filler percentage 78% by weight (63% by volume) of SiO2, ZrO2 (200 nm), PFSC (average 0.2 μm).

**All bond universal** Bisco, chaumburg, USA

- HEMA
- MDP
- Bis-GMA
- Ethanol
- Filler percentage 78% by weight (63% by volume) of SiO2, ZrO2 (200 nm), PFSC (average 0.2 μm).

Table 1: Materials composition as described by manufacturers

**Cavity Preparation**
Standardized MOD cavities were prepared for all groups except for teeth in group 1 (+ve control group) using high-speed handpiece and flat end parallel-sided diamond fissure bur. The cavity preparation dimensions were performed as follows: Cavo-surface angle was 90°, roundation of all line and point angles and the axio-pulpal line angle, the pulpal depth was 2 mm from the cavo-surface margin to the pulpal floor and 4 mm to the gingival seat, the bucco-lingual dimension was 3 mm. No bevel was performed. The occlusal depth and the bucco-lingual width were measured with the same periodontal probe. Storage of Teeth in distilled water for all groups was done until the time of the restorative procedure.

**Fracture Resistance Testing**
Storage of all specimens were performed in distilled water for five days at room temperature until testing time. A universal testing machine was used to test the fracture resistance. All data were collected, tabulated, and statistically analyzed.

**Statistical Analysis**
IBM SPSS software package version 24.0. (Armonk, NY: IBM Corp) and Graph Pad Prism 18 was used for statistical analysis of the obtained results. One Way ANOVA followed by Tukey’s post hoc test were used for multiple comparisons of data which revealed as means and standard deviations for all groups.

**Results**
As a descriptive study, group 5 showed the maximum fracture strength value (1170-1355 N) with a mean ± standard deviation (1276±68.52 N) followed by group 4 with a maximum fracture strength value (998.1-11158 N) with a mean ± standard deviation (1076±67.09 N), as listed in Table (2) and showed in Figure (2). Group 2 showed the minimum fracture strength value (380.6-631.6 N) with a mean ± standard deviation (486.4±84.81 N) followed by group 1 with fracture strength value ranged (836.1-1059 N) with a mean ± standard deviation (953.5±91.81 N) and finally group 3 (900.9-1097 N) with a mean ± standard deviation (1016±79.59 N), as listed in Table (2) and showed in Figure (2).

For the significance evaluation of different groups, One Way ANOVA was performed followed by Tukey’s post hoc test for multiple comparisons which revealed all significant differences between different groups as P-value < 0.05 except for (group 1 # group 3), (group 1 # group 4) and (group 3 # group 4) respectively which were insignificantly different as P-value > 0.05, as listed in Table (3).
### Table 2: Descriptive Statistics of Fracture Resistance (N) of Different Groups

<table>
<thead>
<tr>
<th>Gp 1</th>
<th>Gp 2</th>
<th>Gp 3</th>
<th>Gp 4</th>
<th>Gp 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>N</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Min</td>
<td>836.1</td>
<td>308.1</td>
<td>900.9</td>
<td>998.1</td>
</tr>
<tr>
<td>Med</td>
<td>940.7</td>
<td>491.0</td>
<td>1029</td>
<td>1063</td>
</tr>
<tr>
<td>Max</td>
<td>1059</td>
<td>613.6</td>
<td>1097</td>
<td>1158</td>
</tr>
<tr>
<td>M</td>
<td>953.5</td>
<td>486.4</td>
<td>1016</td>
<td>1076</td>
</tr>
<tr>
<td>SD</td>
<td>91.81</td>
<td>84.81</td>
<td>79.59</td>
<td>67.09</td>
</tr>
<tr>
<td>SEM</td>
<td>41.06</td>
<td>37.93</td>
<td>35.59</td>
<td>30.01</td>
</tr>
<tr>
<td>Lower 95% CI</td>
<td>839.5</td>
<td>381.1</td>
<td>917.6</td>
<td>992.6</td>
</tr>
<tr>
<td>Upper 95% CI</td>
<td>1068</td>
<td>591.7</td>
<td>1115</td>
<td>1159</td>
</tr>
</tbody>
</table>

*Groups: Gp 1; +ve control, Gp 2; -ve control, Gp 3; FILTEK™ Z350 XT, Gp 4; OptiShade™, Gp 5; Estelite® Sigma Quick

### Table 3: Tukey’s Post Hoc Test Showing Multiple Comparisons Between Different Groups

<table>
<thead>
<tr>
<th>Groups</th>
<th>MD</th>
<th>95.00% CI of diff.</th>
<th>Sig</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gp 1 # Gp 2</td>
<td>-467.1</td>
<td>317.7 to 616.5</td>
<td>*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gp 1 # Gp 3</td>
<td>-62.90</td>
<td>-212.3 to 86.49</td>
<td>Ns</td>
<td>0.7175</td>
</tr>
<tr>
<td>Gp 1 # Gp 4</td>
<td>-122.4</td>
<td>-271.8 to 27.00</td>
<td>Ns</td>
<td>0.1424</td>
</tr>
<tr>
<td>Gp 1 # Gp 5</td>
<td>-322.9</td>
<td>-472.3 to -173.5</td>
<td>*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gp 2 # Gp 3</td>
<td>-530.0</td>
<td>-679.4 to -380.6</td>
<td>*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gp 2 # Gp 4</td>
<td>-589.5</td>
<td>-738.9 to -440.1</td>
<td>*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gp 2 # Gp 5</td>
<td>-790.0</td>
<td>-939.4 to -640.6</td>
<td>*</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Gp 3 # Gp 4</td>
<td>-59.49</td>
<td>-208.9 to 89.90</td>
<td>Ns</td>
<td>0.7560</td>
</tr>
<tr>
<td>Gp 3 # Gp 5</td>
<td>-260.0</td>
<td>-409.4 to -110.6</td>
<td>*</td>
<td>0.0004</td>
</tr>
<tr>
<td>Gp 4 # Gp 5</td>
<td>-200.5</td>
<td>-349.9 to -51.11</td>
<td>*</td>
<td>0.0054</td>
</tr>
</tbody>
</table>

*Groups: Gp 1; +ve control, Gp 2; -ve control, Gp 3; FILTEK™ Z350 XT, Gp 4; OptiShade™, Gp 5; Estelite® Sigma Quick

**Figure 2:** Bar Chart revealing Descriptive Statistics of Fracture Resistance (N) of Different Groups

**Figure 2:** Fracture Resistance

### Figure 2: Bar Chart revealing Descriptive Statistics of Fracture Resistance (N) of Different Groups

Fracture Resistance

- **Gp 1:** 953.5
- **Gp 2:** 486.4
- **Gp 3:** 1016
- **Gp 4:** 1076
- **Gp 5:** 1276

**Groups:** Gp 1; +ve control, Gp 2; -ve control, Gp 3; FILTEK™ Z350 XT, Gp 4; OptiShade™, Gp 5; Estelite® Sigma Quick
Discussion
In the present study, comparison of fracture resistance of maxillary premolar teeth restored with different resin composite materials FILTEK™ Z350 XT, OptiShade™ and Estelite® Sigma Quick the null hypothesis stated that there are no statistically significant differences in fracture resistance between different resin composites were rejected since Estelite® Sigma Quick showed high fracture resistance that was statistically significant than other two composite groups.

In our present study, the prepared untreated group (negative control) showed the minimum fracture resistance value (380.6-631.6 N), this could be attributed to that the amount of lost tooth structure in the prepared cavity is strongly correlated to its fracture resistance after restoration. Also, in the present study, performing MOD cavities in premolar teeth reduced the structural integrity of the tooth with more susceptibility to fracture which explains the lowest fracture resistance of the negative control group [14,15].

In our study, regardless the type of the resin composite material used, all restored groups revealed significant differences regarding fracture resistance than the negative group. This could be attributed to the use of innovative adhesive material single bond a universal which is considered universal adhesive system that acts as internal splinting to reinforce the weekend tooth structure due to the chemico-mechanical bonding which occurs between hybrid layer, bonding agent, and tooth structure which reinforces tooth structure making restoration to the tooth as one single unit and so increasing fracture resistance [16].

Also, in our present study, it was found that regardless of resin composite materials used, all restored groups showed high fracture resistance value than intact positive control group with insignificant differences between the 3rd and 4th groups FILTEK™ Z350 XT and OptiShade™ respectively, and significant difference with group 5 Estelite® Sigma Quick [17]. The literatures have always reported that new resin composite materials together with the introduction of nanocomposite beside innovations in bonding have resulted in obtaining mechanical properties comparable to that of sound tooth. Also, these results might be due to performing a conservative standardized cavity preparation which in turn maximizes the remaining sound tooth structure and increases resistance of restored teeth to fracture [18].

Our findings are in accordance with many studies which revealed that fracture resistance of maxillary premolar teeth depends upon the amount of remaining tooth structure preserved after cavity preparation, and so following the concept of minimal intervention dentistry to preserve the maximum amount of tooth structure has been applied in our study to maintain function and mechanics that increase the fracture resistance of premolar teeth and increase its longevity after restoration [19,20].

However, our results contradicted with that of Megahed et al., 2020, Atalay et al., 2016 and Santos et al., 2005 whom revealed that resin composite partially reinforce cavitated teeth compared to sound teeth [21,22,23]. Also, our findings were in contrast with Ahmed et al., 2020 stated that highest significant fracture resistance value was presented by sound teeth due to preservation of marginal ridges mesially and distally moreover presence of intact buccal and palatal cusps results in reinforcing the tooth maintaining its integrity and increasing fracture resistance [24]. Moreover, the available restorative materials are unable to fully restore lost mechanical properties due to cavity preparation which results from the multiple interfaces between resin composite, bonding and tooth structure which represent different challenges during adhesion [25,26].

On the other hand, Dalpino et al., 2002 and others showed no significant difference in fracture resistance between sound teeth and that restored with resin composite [27]. According to the monoblock concept which means bonding different interfaces and tooth structures to behave as a single unit [14]. This successful bonding helps in obtaining a more favorable stress distribution and a higher fracture resistance. Also, selection of appropriate adhesive can provide monoblock restoration which successfully behaves functionally as a homogenous unit and can finally be comparable with sound tooth structure.

In this study, the reason for selecting maxillary premolar teeth for the evaluation of fracture resistance was done as it was found that it is the most susceptible teeth for vertical fracture clinically owing to their complex anatomy [28]. Also, the reason for performing MOD cavities in premolar was considered as a challenging procedure since premolar teeth become weakened with the loss of marginal ridges which in turn dramatically influences fracture resistance related to the occlusal stresses resulting during mastication [29].

In our study, OptiShade™ resin composite was selected as it is considered and belongs to a group of composites named Single shade universal resin composites also known as SSURCs which are nowadays clinically preferred to facilitate shade selection. In addition, they have the cost savings by reducing the amount of waste associated with expired products [30]. Majority of the studies focus on the esthetic properties and shade matching of OptiShade™ simplified composite regardless their mechanical or physical properties.

In the present study Group 5 Estelite® Sigma Quick showed the highest fracture resistance (1191-1361) that was statistically significant than other resin composite groups which are group 3 FILTEK™ Z350 XT and group 4 OptiShade™ and also than group 2 positive control. This variation in fracture resistance among different resin composites may be attributed to the difference in the chemical composition of the organic matrix, filler content, filler size and filler loading [31,32].

Our results were in accordance with those of Hada and Panwar, in 2019, whom attributed their results to that Estelite® Sigma Quick provides high polymerization activity based on the improvements in matrix conversion from monomer to polymer and its stability in ambient light provided by Radical amplified photo-polymerization initiator which known as RAP technology.
Conclusion

Reinforcement of the teeth after MOD cavity preparation in maxillary premolars could be achieved through restorative procedures and it is correlated to application of minimal intervention dentistry concept together with quality of bonding and type of restorative material used.

References


35. Estelite® Sigma Quick 5-year Clinical Performance Report. The Dental Advisor. 2014.