Fracture Resistance of Maxillary First Premolars with Class II Cavity Preparation that Filled with Different Restorative Materials

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Abstract

Background: Severely damaged teeth by caries or trauma and restored with different types of restoration have susceptibility to fracture so the teeth should be reinforced with the best biomimetic restoration to resist fracture. **Objectives:** To evaluate and compare the fracture resistance of large and medium size class II cavities of maxillary first premolars filled with amalgam, Equia Forte, Cention Forte, Tetric EvoCeram Bulk Fill, Tetric PowerFill Bulk Fill, everX Posterior. Also to evaluate the failure mode of each restored tooth. **Materials and Methods:** Class II cavities were prepared on 160 maxillary first premolars which were divided into eight groups: (1) positive control, (2) negative control, (3) amalgam filled teeth, (4) Equia Forte filled teeth, (5) Cention forte filled teeth, (6) Tetric Evoceram bulk filled teeth, (7) Tetric Powerfill bulk filled teeth, and (8) everX Posterior filled teeth. The samples were thermocycled for 5000 cycles with a temperature ranging from 5°C to 55°C. The fracture test was done by applying load with a crosshead of 1 mm/min. **Results:** Two-way ANOVA revealed significant differences among the groups ($P = 0.05$), Tukey HSD *post hoc* test revealed that the high fracture resistance of everX Posterior filled teeth (1180.9059 Newton) was nearly similar to that of positive control. **Conclusion:** everX Posterior can be considered as dentin-replacing material to reinforce the teeth against fracture.

Keywords: Bulk fill, fiber composite, fracture resistance, mechanical properties

Introduction

Restorative dentistry is the branch of dentistry that uses biomaterials to repair lost tooth structure while restoring the esthetics, function, and strength of teeth.[1]

It gets harder to effectively reinforce the cavity when more dentin is lost due to dentin's natural toughening mechanism.[2] Tensed collagen fibrils resist separation, and compressed apatite crystals contribute to the stiffening of these fibers, resulting in dentin rigidity and resistance to collapse under masticatory force.[3]

Amalgam and dental composites were the most regularly utilized materials for direct restorations for decades. Recently dental composites have grown in popularity and are beginning to replace amalgam due to amalgam toxicity and unpleasant appearance.[4]

Composite resins have the drawbacks of shrinkage, which leads to marginal gap, postoperative sensitivity, secondary caries, cusp deflection, enamel crack, and fracture.[5] Although many strategies were suggested to overcome the shrinkage, the tooth still had low resistance to load.[6] Fracture resistance of a particle composite is lower than dentin due to lack of fiber so fiber-reinforced restoration has been proposed to address this issue.[7] Cusp-supporting design's goal is to replace all lost dentin tissue, limiting the thickness of the overlying material to

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the thickness of the enamel. The design is inspired by nature and is known as a direct biomimetic bi-layered repair.[8]

Objectives

This *in vitro* study aimed to evaluate and compare the fracture resistance of large and medium size class II cavities of maxillary first premolars that were filled with different types of restorations and evaluated the mode of fracture.

Materials and Methods

Inclusions criteria

A total of one hundred sixty maxillary first sound premolars were extracted for orthodontic or periodontal purposes, all the teeth that were used in this study had regular occlusal anatomy and absence of caries, restoration, attrition, abrasion, erosion, cracks, fracture and any other type of tooth abnormalities. The teeth that were selected had an intercuspal distance (6.5 ± 0.5 mm), a bucco-palatal dimension (9.5 ± 0.5 mm), and a mesio-distal dimension (7.5 ± 0.5 mm)

Preservation of teeth

The teeth were cleaned by hand scalar, and examined under a Stereomicroscope at ×20 magnification (Optika, Bergamo, Italy), the teeth were stored with 0.1% Thymol solution for 1 week for disinfection.[9] Teeth were stored in distal water to keep teeth hydrated until the time of study, the water was changed every week to prevent bacterial growth.[10]

Mold preparation

The root surface of each tooth was immersed in molten wax for 3 s up to 4.0 mm below the Cemento–Enamel junction and the distance was measured by Digital Vernier Caliper, to simulate the Alveolar bone and Periodontal ligament (0.2–0.3 mm in thickness).[11] Each tooth was secured to the surveyor's vertical arm to position the teeth along their long axis then it was pushed into the polyvinyl chloride cylindrical mold (21 mm internal diameter, 15 mm height) that was filled with cold cure acrylic.[12] After polymerization, the wax was substituted with light vinyl polysiloxane impression material (Bonasil A+, DMP Co., Attiki, Greece).[3]

Study design

One hundred sixty teeth were categorized into eight groups, each group contains twenty teeth, and the main group was divided into two subgroups based on the type of cavity, each subgroup containing ten teeth, the groups were as follows:

Group I: Positive control (sound intact teeth)

Group II: Negative control (prepared teeth without filling)

Group III: Teeth filled with amalgam non-gamma 2 (IvoclarVivadent, Schaan, Liechtenstein(

Group IV: Teeth filled Equia Forte HT Fil (GC, Tokyo, Japan(

Group V: Teeth filled Cention Forte (IvoclarVivadent(

Group VI: Teeth filled with Tetric EvoCeram bulk fill (IvoclarVivadent(

Group VII: Teeth filled with Tetric Power Fill bulk fill (IvoclarVivadent(

Group VIII: Teeth filled with everX Posterior, the last 1 mm occlusal was filled by Essentia Universal Composite (GC(

Cavity preparation and stamp technique

The stamping technique was done by using Exaclear vinyl polysiloxane impression material (GC) which was dispensed in a Gutta-percha container that was used as a tray, The stamping technique was utilized to restore the natural counters of the teeth and avoid overfilling which can cause early fracture and affect the outcome.[8,13]

Cavity preparation was done with the aid of a modified Dental Surveyor which had a high-speed handpiece attached with water coolant, a Digital Vernier Caliper, and a periodontal prop were used to ascertain the dimensions of the cavity which should be as follows:

- Occlusal width in a large-size cavity 2/3 intercuspal distance as shown in Figure 1a1 while in medium-size cavity 1/3 of the intercuspal distance.
- Occlusal box depth = 3 mm from the deepest point of the central groove as shown in Figure 1a2.
- Axial wall height = 1.5 mm. as shown in Figure 1a3.
- Proximal box width = 1/2 of Bucco-Lingual width as shown in Figure 1a4.
- Gingival seat width = 2 mm as shown in Figure 1b.

Each group of teeth was filled with restorations according to manufacturer instructions. All samples were kept in distilled water at 37°C for 24 h in a laboratory incubator to complete the material setup.[6] The samples underwent thermo cycling in the water to simulate intraoral thermal alteration for 5000 cycles, the temperature of water ranged from 5°C-55°C, with a dwell time of 30 s. and transfer time was 10 s.[14-17] Universal Testing Machine (Gester International Co., Fujian, China) was used to undertake static compressive stress. The machine consists of a metallic ball-shaped tip (6 mm diameter) which was vertically aligned with the center of the occlusal surface of each tooth, touching the slopes of the Buccal and Lingual cusps, load was applied using a crosshead moving at rate of 1 mm/min.[18-21] The maximum load was recorded in Newton until failure occurred, Figure 2 represents Universal Testing Machine

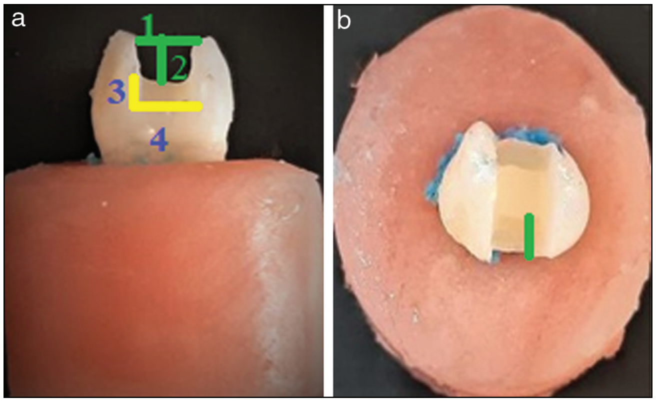

Figure 1: Cavity dimensions: (a) 1 = occlusal width, 2 = occlusal box depth, 3 = axial wall height, 4 = proximal box width and (b) occlusal view illustrate the gingival seat

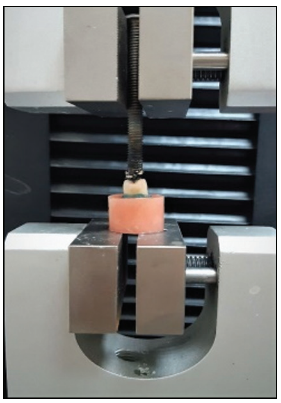

Figure 2: Universal testing machine and the tooth under compressive force

Ethical approval

The study was conducted in accordance with the Helsinki Declaration's ethical guidelines. The study was approved by the Research Ethics Committee board of Mosul University, Dentistry Collage with a reference number (UoM.Dent/H.DM.1/23) on January 9, 2023.

Statistical analysis

The analyses were conducted using a statistical software program called Statistical Package for social science (IBM SPSS, version 26.0, Chicago, IL, USA). Kolmogorov-Smirnov tests, Levene Statistic, descriptive statistics including mean and standard deviation, Two-Way analysis of variance (ANOVA), and Tukey multiple analysis range test were utilized. The significance level was set to $P = 0.05$.

Results

Depending on the mean values of the tested group, the teeth that were filled with everX Posterior have a mean value (1180.9059 N) nearly similar to a positive control (1182.9878 N) and higher than the other group, it followed

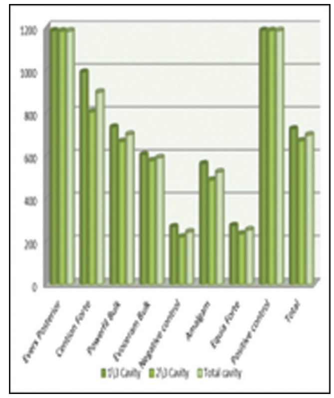

Figure 3: Mean values of load bearing capacity for each type of restorations with 1\3, 2\3 cavity, and total cavities

by teeth filled with Cention Forte, PowerFill Bulk fill, EvoCeram Bulk fill, amalgam, and Equia Forte, negative control respectively, Figure 3 shows the mean values of load bearing capacity for each type of restoration with a cavity of 1\3, 2\3 of intercuspal distance and the Total of both cavities Two-Way ANOVA results showed that there are significant differences in fracture resistance among teeth filled with a different type of restoration in 1\3 and 2\3 class II cavities. Table 1 represents Two-Way ANOVA Analysis.

Tukey HSD *post hoc* test which was performed at $P = 0.05$. The groups were organized in homogeneous subsets of data representing the mean value of teeth fracture resistance for each group. The teeth that were filled with everX Posterior showed nearly similar fracture resistance values of natural teeth on the other hand teeth that were filled with Equia forte had fracture resistance values near the negative control. Table 2 represents Tukey HSD *post hoc* test.

Mode of failure

The fracture pattern was analyzed visually, the results showed four various modes of fracture which distributed among the specimens according to restoration type, the modes are:

- Mode I: Fracture in restorative material as in Figure 4.
- Mode II: Fracture in tooth and restoration as in Figure 5.
- Mode III: Fracture of one cusp, intact restoration as in Figure 6.
- Mode IV: Longitudinal fracture as in Figure 7.[6]

Figures 8-11 summarize the percentage of each restoration failure according to the mode of failure.

Discussion

Fracture resistance is a mechanical parameter that describes the resistance of brittle materials to the catastrophic propagation of faults under an applied force, hence

Table 1: Two-way ANOVA analysis tests, test of between-subjects effects

Source	Type III sum of squares	Df	Mean square	*F*	*P*
Corrected model	19,294,683.252	15	1,286,312.217	619.676	0.000
Intercept	77,610,573.097	1	77,610,573.07	37,388.587	0.000
Cavities	121,687.208	1	121,687.208	58.622	0.000
Fillings	19,051,084.332	7	2,721,583.476	1,311.112	0.000
cavities fillings	121,911.712	7	17,415.959	8.390	0.000
Error	298,912.678	144	2,075.782		
Total	97,204,169.027	160			
Corrected total	19,593,595.930	159			

$P = 0.05$

Table 2: Tukey HSD *post hoc* test

Types of filling	*N*	Subset					
		1	2	3	4	5	6
Negative control	20	244.1612					
Equia forte	20	254.1680					
Amalgam	20		523.8271				
Evoceram bulk fill	20			590.3719			
Powerfill bulk fill	20				699.1112		
Cention forte	20					896.2019	
EverX posterior	20						1180.9059
Positive control	20						1182.9878
Sig.		0.997	1.000	1.000	1.000	1.000	1.000

Figure 4: Mode I

Figure 5: Mode II

Figure 6: Mode III

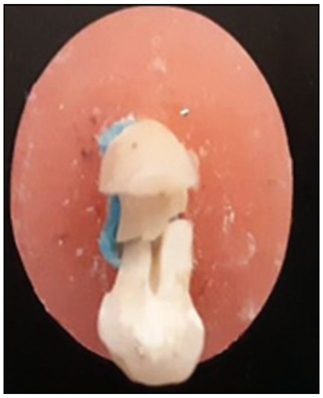

Figure 7: Mode IV

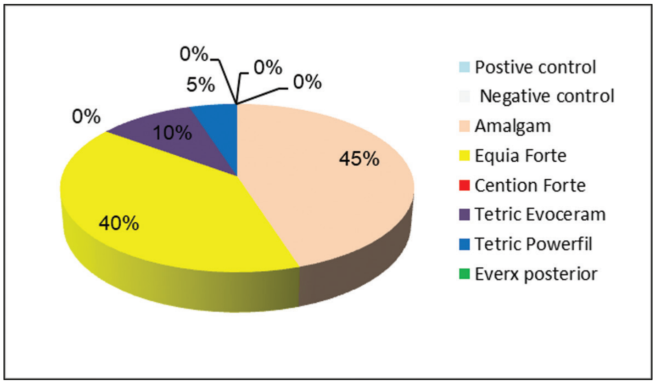

Figure 8: Percentage of restoration failure in mode I

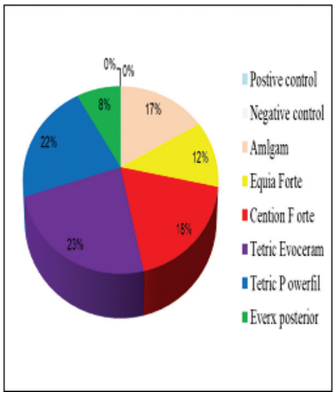

Figure 9: Percentage of restoration failure in mode II

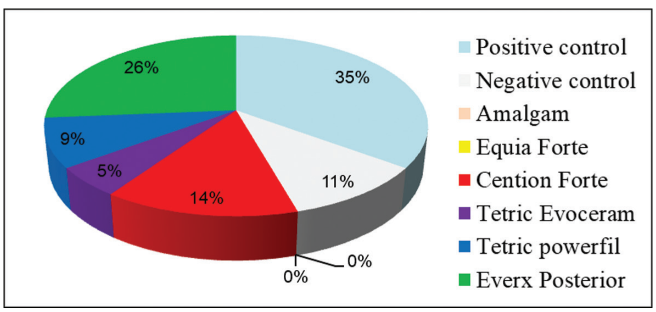

Figure 10: Percentage of restoration failure in mode III

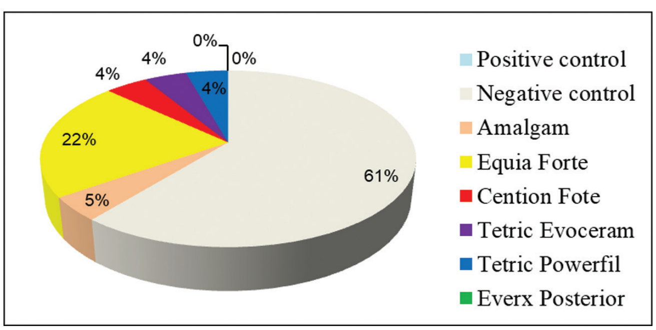

Figure 11: Percentage of restoration failure in mode IV

describes the material's damage tolerance. A material with a high fracture toughness can withstand crack initiation and propagation better.[7]

The significance of simulating periodontal ligaments to more accurately mimic clinical situations and demonstrate how periodontal ligaments and alveolar bone may absorb masticatory stresses in a laboratory setting. Periodontal fiber compression offers the tooth crucial support when an excessive force is applied.[22]

Thermo cycling was used to imitate the environment of the oral cavity. For composite restorations, 1 year of clinical service is equal to 10,000 thermal cycles. In our analysis, 5000 cycles, or 6 months of clinical service, were included as a variable. Between 5000 and 10,000 cycles, the water reaches the interface which is extremely vulnerable to water damage and is quickly harmed, leading to connection rupture and the loss of strength and flexural modulus.[23-25]

The negative control group had the lowest value of fracture resistance due to cross loss of tooth structure, the loss in two marginal ridges led to the loss of 63% of tooth stiffness.[2] Amalgam is stiff and brittle, unlike composite.[23] Equia Forte has an extremely brittle nature, in addition to low deformability, low strength, and high elastic modulus when compared with other materials.[26,27]

Tetric PowerFill bulk fill and Tetric EvoCeram bulk fill have the same monomers Bis-GMA, UDMA, Bis-EMA, and fillers to reduce polymerization shrinkage effect and hence an improvement of other mechanical properties. Additionally, the reduction in the inter-particle distance between the nanofiller with the smooth and rounded borders of these spherical fillers could be the reason for high compressive strength, lessens the tendency for crack formation and propagation, and dispenses stress more consistently throughout the composite resin.[28] Tetric PowerFill only has β-allyl sulfone, PBPA, and DCP. DCP has a cyclic aliphatic structure, which possibly enhances mechanical capabilities that aid in the explanation of The fracture resistance of Tetric PowerFill is higher than Tetric EvoCeram bulk fill.[29]

Cention Forte is the capsulated form of Cention N and it has the same properties.[30] Cention Forte has alkalizing bioactive properties that aid in remineralization, Because of its strongly cross-linked polymer structure, Cention Forte has good flexural strength, dual cure properties, high mechanical qualities, and very little viscosity.[31] No research comparing the fiber-reinforced composite everX Posterior with Cention Forte has been conducted to date. EverX Posterior restorations consist of resin PMMA, Bis-GMA, and TEGDMA forming a matrix called a semi Interpenetrating Polymer Network, inorganic fillers with electrical (E)-glass fibers. This composition plasticizes the polymer matrix to some extent, improves bonding, decreases the effect of shrinkage, and increases fracture resistance as well as flexural strength.[32] The flexural modulus is close or equal to the modulus of dentin 15-20 GPa.[33] The glass fiber impregnated in the matrix, its diameter of 17 µm, and length is 1-2 mm which is an effective means for reinforcing the restoration by delivering the force from the matrix to the fiber and then distribute the force away from the center. This high fiber-to-particle ratio aimed to mimic the fibrous structure of the dentin, bridging toughening phenomenon is a result of the reinforced fibers' ability to bend and rub against their encasings during debonding.[3,34,35]

The proportion of favorable fractures was higher in the fiber-reinforced composite group, where the fibers gradually break, causing the crack to spread from one fiber to the next and lowering the energy wave of the final failure by absorbing and distributing the force, the fibers cause fracture propagation to be diverted away from the center of the material toward the edges. On the other hand, the filler particle composites make the crack easily pass through the whole thickness leading to bulk fracture from the Occlusal aspect towards the apical direction without much deflection due to the lack of tensile strength, leading to more unfavorable fracture.[2,3]

Conclusion

(1). According to the results of this study fiber-reinforced composites can be used as a bulk fill material under composite restoration which is more preferable than using Cention Forte, Tetric PowerFill Bulk Fill, Tetric EvoCeram Bulk Fill, amalgam, and Equia Forte. We believe that the short glass fibers scattered throughout the everX Posterior gave more resistance to fracture than additional filler in the restoration.

(2). The teeth that filled with everX Posterior had a more favorable mode of fracture than another group with particle reinforcement restoration owing to fiber that had a crucial role in distributing the force away from the center to the periphery of restoration.

(3). Teeth with medium size cavities had fracture resistance value better than teeth with large cavities due to the minimal amount of tissue loss.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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