# Fracture Resistance of Endodontically Treated Premolar Teeth with Extensive MOD Cavities Restored with Different Bulk Fill Composite Restorations (An *In vitro* Study)

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## ABSTRACT

**Background:** The present in-vitro study was undertaken to evaluate and compare fracture resistance of weakened endodontically treated premolars with class II MOD cavities restored with different bulk fill composite restorations (EverX posterior, Alert, Tetric EvoCeram Bulk Fill, and SDR). The type and mode of fracture were also assessed for all the experimental groups.

**Materials and Method:** Forty-eight human adult maxillary premolar teeth were selected for this study. Standardized extensive class II MOD cavities with endodontic treatment were prepared for all teeth, except those that were saved as intact control. The teeth were divided into six groups of eight teeth each (n=8): (Group 1) intact control group, (Group 2) unrestored teeth with endodontic treatment, (Group 3) restored with (TetricEvoCeram Bulk Fill), (Group 4) restored with SDR bulk-fill flowable composite, (Group 5) restored with EverX Posterior composite and (Group 6) restored with Alert composite. . All specimens were subjected to compressive axial loading until fracture in a universal testing machine. The data were statistically analyzed using one-way ANOVA test and LSD test. Macroscopic fracture type were observed and classified into favorable and unfavorable. Specimens in groups 3, 4, 5 and 6 were examined by stereomicroscope at a magnification of 20× to evaluate the mode of failure into adhesive, cohesive or mixed.

**Results:** The mean fracture load was (1.2505Kn) for group 1, (0.371Kn) for group 2, (0.512 Kn) for group 3, (0.6435 Kn) for group 4, (0.608 Kn) for group 5, and (0.8315) for group 6. Using one way ANOVA test a highly significant difference ($P < 0.01$) were found among all groups. The use of Alert composite (which contain micro glass fiber) improved the fracture resistance significantly in comparison to other groups. SDR bulk-fill flowable composite showed better improvement in fracture resistance but with no significant differences in comparison to EverX composite restoration (which contain Short E-glass fiber filler). The type of failure was unfavorable for all the restored groups.

**Conclusion**: All experimental composite restorations showed significant improvement in the resistance to cuspal fracture in comparison to unrestored one (group 2). However, under the conditions of this study, direct composite restorations should be considered as a valid interim restoration for weakened endodontically treated teeth before cuspal coverage can be provided.

**Key words**: Fracture resistance, fiber reinforced composite, bulk fill. . **(J Bagh Coll Dentistry 2017; 29(2):26-32)**

## INTRODUCTION

The restoration of endodontically treated teeth is one of the topics more studied and controversial in dentistry. Questions and contradictory opinions remain about clinical procedures and materials to be used to restore these teeth, once fractures are often related [1].

However, the longevity of the tooth is often dictated by the coronal restoration and its ability to prevent leakage and resist fracture.

The inherent elastic properties of intact enamel and dentine are altered when even just an occlusal cavity is prepared without endodontic access, creating a reduction in fracture resistance [2].

With the removal of both marginal ridges in a mesial-occlusal-distal (MOD) cavity preparation and in conjunction with an endodontic access cavity, a dramatic increase in cuspal deflection is observed [3].

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Tooth fracture resistance seems to be only partially recovered when MOD preparations are associated with an endodontic access and restored with composite resin [4].

Adhesive dentistry has considerable advantages in the treatment of weakened tooth structure [5]. The choice of materials selected for intracoronal restoration of endodontically treated teeth plays an important role in tooth longevity.

In an attempt to reduce some of the time and effort needed for layering and adaptation when placing posterior composites, new materials have been introduced and termed "bulk fill" materials [6].

Recently, short fiber reinforced composite (ever X Posterior) had a fiber length in millimeter scale (1–2 mm), was introduced as a restorative composite resin [7]. The composite resin is intended

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to be used as base filling material in high stress bearing areas especially in large cavities of vital and non-vital posterior teeth.

Further, Alert (Jeneric/Pentron, USA) had fiber length in micrometer scale (20–60 µm). Reinforcing effect of the fiber fillers is based on stress transfer from polymer matrix to fibers but also behavior of individual fiber as a crack stopper [8]. Previous study of Garoushi et al. showed how short fiber fillers could stop the crack propagation and provided increase in fracture resistance of composite resin [8]. Alert showed high values of echanical parameters, which seems to be a result of high filler load level. The most important and extensively investigated variable for physical performance in dental composite resins is filler loading [9].

In addition, SDR restorative material designed to be used as a base in class I and class II restorations. It has handling characteristics typical of flowable composite, but can be placed in 4 mm increments with minimal polymerization stress. It is designed to be overlaid with methacrylate based universal posterior composite replacing missing occluso-facial enamel [10].

On the other hand, Tetric EvoCeram® Bulk Fill material is another bulk fill material which can also be placed in increments of up to 4 mm and can achieve high marginal adaptation to the floor and walls of cavity preparation, eliminating the need for a flowable liner as reported by the manufacturer. The patented shrinkage stress reliever technology increases marginal integrity and decreases polymerization shrinkage, with a resultant decrease in the probability of tooth deformation, post-operative sensitivity, microleakage, and secondary caries [11].

So this study was conducted to evaluate the ability of these bulk fill restorative composite materials to restore the strength of weakened endodontically treated premolars.

## MATERIALS AND METHODS

### Teeth selection

Forty eight sound upper first premolar teeth with two roots extracted for orthodontic purposes with age range from 18-22 years, collected from different health centers in Baghdad city, were used in this study.

Teeth were stored in 0.1 vol% thymol solution for 48 h [12]. Then in distilled water at room temperature [13]. Teeth of comparable size and shape were selected by crown dimensions after measuring the bucco-lingual and mesio-distal widths in millimeters [14].

### Teeth mounting

Each tooth was embedded in a block of self-cured acrylic resin (Vertex, Switzerland) in plastic cylinders (2.5cm×2.5cm). The teeth were embedded along their long axes using a surveyor. The acrylic covered the roots to within 2 mm of the CEJ, to approximate the support of alveolar bone in a healthy tooth [15].

Some authors stated that fracture load was unaffected by either thermal cycling or the presence of a simulated periodontal ligament [15] and therefore neither was included in this study.

### Sample grouping

The teeth were randomly divided into six groups (8 teeth in each group) according to the type of the restorative material that was used.

**Group 1:** sound control group.

**Group 2:** a class II mesio-occluso-distal (MOD) cavity was prepared with extensive endodontic access cavity involving the removal of the axial dentin. Endodontic treatment was completed and the MOD cavity left unrestored.

**Group 3**: a class II MOD cavity and endodontic treatment were prepared as in group 2 and restored with Tetric Evoceram bulkFill.

**Group 4:** a class II MOD cavity and endodontic treatment were prepared as in group 2 and restored with resin based composite (EverX) (**GC**) up to 2 mm below the cavity margin and covered with GC posterior composite.

**Group 5:** a class II MOD cavity and endodontic treatment were prepared as in group 2 and restored with SDR (DENTSPLY) as a flowable base up to 2 mm below the cavity margin and covered with GC posterior composite.

**Group 6:** a class II MOD cavity and endodontic treatment were prepared as in group 2 and restored with Alert condensable composite (Pentron)

### Cavity preparation:

All of the teeth, except for group 1 which served as intact control, received MOD cavity preparation by the aid of a modified dental surveyor with no proximal steps and flat floor [16].The dimensions of the cavity preparations were such that remaining tooth structure was weakened. The bucco-lingual width of the occlusal isthmus and the proximal boxes was one half of the intercuspal width. Cavity floor was prepared (1

mm) coronal to the CEJ and the total depth of the cavity was (5-6 mm) measured from the cavosurface margin of the palatal cusp.

The cavo-surface margins were prepared at 90º with rounded internal line angles. Consistency in cavity preparation was ensured by parallel preparation of the facial and palatal walls of the cavity [15]. The depth was measured by graduated periodontal probe and the dimensions were checked using dental vernier from different points of the prepared cavity [17].

### Endodontic treatment

Endodontic access cavity was prepared by the aid of dental surveyor, any access cavity wider than the width of the cavity (1/2 the intercuspal distance) was discarded and not included in the study. The teeth were held in moist gauze to prevent dehydration [18]. Root canals were instrumented initially using stainless steel K-files #10 and 15, followed by rotary Ni-Ti instruments (WaveOne, Dentsply Maillefer) using crown-down technique. According to the manufacturer instructions, and in most cases, the technique only requires one hand file followed by one single WaveOne file to shape the canal completely until it achieved the working length. For standardization purposes, all canals were instrumented up to size primary [19]. After that the canals were filled by matching size WaveOne gutta-percha points using a resin based sealer (AH plus, DentsplyMaillefer). A resin based sealer was used rather than eugenol-based sealer to avoid the detrimental effect of eugenol-based sealers on polymerization of dental composites [20]. Then, chemical cured glass-ionomer restorative material (Riva self -cure, SDI, Austria) was used to seal the access cavity up to the level of the pulpal floor [21].

### Mechanical testing

All specimens were subjected to compressive axial loading until fracture in a computer controlled universal testing machine (LARYEE, China). The crosshead speed was 0.5 mm/minute. A steel bar (8 mm in diameter) was placed at the center of the occlusal surface and the tooth with its acrylic block was fixed to the base of the testing machine whose position was adjusted in such a position that the bar was applied in parallel to the long axis of the tooth and to the slopes of the cusps (rather than the restoration) [12]. All samples were loaded until fracture while maximum breaking loads were recorded in Kilo Newton (Kn) by a computer connected to the loading machine.

### Assessment of fracture type and mode

Macroscopic fracture patterns were observed after ink perfusion of each sample for 5 min to stain the exposed dentin and highlight fracture lines. Photographs were taken using a digital camera to determine type of fracture [22]. Further the type of failure was also determined and categorized as favorable and unfavorable fractures. Unfavorable fracture was denoted if the fracture line was below the CEJ extending to the radicular portion. On the other hand, favorable fracture was denoted if the fracture line above the CEJ [19].

The mode of failure was assessed into adhesive mode in which the failure occur at tooth\restoration interface, cohesive mode in which the failure occur within the restoration and mixed mode of failure in which the failure was both adhesive and cohesive. The mode of failure was evaluated under a stereomicroscope at a magnification of 20× [15].

## RESULTS

### Fracture resistance values of all experimental groups

The mean values, standard deviation (SD) and the percentage of increase and decrease in strength are presented for each group in (Table1).

**Table 1: Mean values, standard deviation (SD) and percentage of reduction and increase in strength for each group**

| Group | Mean (KN) | SD | Percentage of reduction in strength | Percentage of increase in strength |
|-------|-----------|------|-------------|-------------|
| Group 1 | 1.25 | 0.16 | | 100% |
| Group 2 | 0.37 | 0.07 | 70.33% | - |
| Group 3 | 0.51 | 0.09 | 59.00% | 41.00% |
| Group 4 | 0.64 | 0.10 | 48.54% | 51.46% |
| Group 5 | 0.61 | 0.11 | 51.38% | 48.62% |
| Group 6 | 0.83 | 0.11 | 33.5% | 66.50% |

In this study, intact sound teeth (Group 1) presented the highest mean value (1.2505 Kn), whereas prepared unrestored teeth with endodontic treatment (Group 2) showed the least fracture strength (0.371 Kn).

Among the restored teeth groups, those restored with Alert (Group 6) showed the highest mean

value (0.8315Kn), while teeth restored with Tertic EvoCeram® Bulk Fill composite (Group 3) presented the lowest mean value (0.512 Kn). On the other hand, the fracture strength of teeth restored with SDR (Group 4) and EverX (group5) was (0.6435Kn) and (0.608Kn) respectively. ANOVA test revealed that there was a statistically highly significant difference among all groups ($P <$ 0.01), **(Table 2)**.

**Table 2: ANOVA test of fracture resistance mean values for all groups.**

|  | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| **Between Groups** | 3800329.75 | 5 | 760065.95 | 59.078 | .000 (HS) |
| **Within Groups** | 540353.50 | 42 | 12865.56 | | |
| **Total** | 4340683.25 | 47 | | | |

The results of LSD test showed the significance between groups (Table 3).

**Table 3: LSD test**

| Variables | | Mean Difference | Sig. |
|---|---|---|---|
| **+ve control** | **Unrestored** | 878.75 | .000 (HS) |
| | **Ivoclar** | 738.50 | .000 (HS) |
| | **SDR** | 607.00 | .000 (HS) |
| | **EverX** | 642.50 | .000 (HS) |
| | **Alert** | 419.00 | .000 (HS) |
| **Unrestored** | **Ivoclar** | -140.25 | .018 (S) |
| | **SDR** | -271.75 | .000 (HS) |
| | **EverX** | -236.25 | .000 (HS) |
| | **Alert** | -459.75 | .000 (HS) |
| **Ivoclar** | **SDR** | -131.50 | .025 (S) |
| | **EverX** | -96.00 | .098 (NS) |
| | **Alert** | -319.50 | .000 (HS) |
| **SDR** | **EverX** | 35.50 | .535 (NS) |
| | **Alert** | -188.00 | .002 (HS) |
| **EverX** | **Alert** | -223.50 | .000 (HS) |

**Fracture type**

From Table (4), the results of this study showed that intact sound teeth (Group 1) had 7 samples (87.5%) with favorable fracture type and 1 sample (12.5%) with unfavorable type. Whereas other groups like group 2, group 3 and group 6 had 7 samples (87.5%) presented unfavorable fracture type and 1 sample (12.5%) with favorable fracture. In (group 5) there was 5 samples (62.5%) with unfavorable fracture and 3 samples (37.5%) with favorable fracture. In addition, the type of fracture

of (group 4) was 4 samples (50%) with favorable fracture type and the other 4 samples had unfavorable fracture type.

**Table 4: Type of fracture in the study groups**

| Group | Fracture type | |
|---|---|---|
| | **Unfavorable** | **Favorable** |
| **Group 1 (Sound)** | 1 (12.5%) | 7 (87.5%) |
| **Group 2 (Unrestored)** | 8 (100%) | 0 (0%) |
| **Group 3 (Ivoclar)** | 7 (87.5%) | 1 (12.5%) |
| **Group 4 (SDR)** | 4 (50%) | 4 (50%) |
| **Group 5 (EverX)** | 5 (62.5%) | 3 (37.5%) |
| **Group 6 (Alert)** | 7 (87.5%) | 1 (12.5%) |
| **Total** | 31 | 17 |

**Fracture mode**

As presented in **Table (5)**, teeth restored with Tetric EvoCeram (Group 3) exhibited 7 samples (87.5%) with adhesive mode of failure and only one (12.5%) with mixed failure, and those with SDR (Group 4) show 4 samples (50%) with cohesive mode of failure and 4 samples (50%) with adhesive mode of failure.

However, those restored with EverX (Group 5) presented 3 sample (37.5%) with cohesive failure, 4 samples (50%) with adhesive type of failure and 1 sample (12.5%) with mixed type of failure, and those restored with Alert (Group6) exhibit 6 samples (75%) with adhesive mode of failure, and 2 samples (25%) with mixed mode of failure.

**Table 5: Fracture mode of the restored samples**

| Group | Fracture mode | | | Total |
|---|---|---|---|---|
| | **Cohesive** | **Adhesive** | **Mixed** | |
| **Group 3** | 1 (12.5%) | 1 (12.5%) | 6 (75%) | 8 |
| **Group 4** | 1 (12.5%) | 6 (75%) | 1 (12.5%) | 8 |
| **Group 5** | 2 (25%) | 5 (62.5%) | 1(12.5%) | 8 |
| **Group 6** | | 6 (75%) | 2 (25%) | 8 |

## DISCUSSION

Despite its limitations, fracture testing remains a common experimental method of evaluating restorative procedures for root filled teeth.

Fracture resistance, as it pertains to dental materials, has been defined as the "highest load a sample can withstand."

**Fracture resistance of intact teeth (Group 1)**

The highest fracture resistance mean value presented by the intact teeth **(Group 1)** could be attributed to the presence of intact palatal and buccal cusps with intact mesial and distal marginal ridges which form a continuous circle of dental

structure, reinforcing the tooth and maintaining its integrity [4].

This is in agreement with Shivanna and Gopeshetti [23]. Furthermore, there was a statistically high significant difference with other experimental groups **(Table 3).**

**Fracture resistance of prepared unrestored teeth (Group 2)**

In this study, the lowest fracture resistance mean value presented by the prepared unrestored teeth (Group 2) which was statistically highly significant when compared with all other groups could be attributed to the type and quality of the remaining tooth structure after MOD cavity preparation, as teeth with large MOD cavities are severely weakened due to the loss of the reinforcing tooth structures, specially the cusps andmarginal ridges, so become more susceptible to fracture.

**Fracture resistance of the restored groups**

In this study, it is clearly seen that all composite resin restored teeth displayed improved fracture strength than the prepared but unrestored teeth group with endodontic treatment (Group 2) which presented mean value.

The statistically highly significant differences in fracture resistance between the unrestored and restored groups could be due to the micro-mechanical bonding between the adhesive system and the tooth structure and hybrid layer formation, which tend to bind the walls of the cusps together and strengthen the remaining tooth structure, and distribute the forces more evenly among the various interfaces in composite restorative material, that have been bonded to enamel and dentin by adhesive bonding agent. This reduction in localized forces offers greater opportunity for reinforcing the tooth structure and increases the fracture resistance of the cusps [24].

On the other hand, the increase in the fracture resistance of restored teeth could be attributed to that all composite materials used in this study are considered low-shrink materials, and it had been shown that the use of low shrinkage composite materials increased the fracture resistance of teeth.

This finding comes in agreement with Hamouda and Shehata who concluded that the use of low shrinkage composites significantly strengthened maxillary premolars with MOD preparations under compression loadings [17].

**Comparisons among different bulk fill materials (Groups 3, 4, 5 and 6)**

Among the groups restored with the bulk fill materials, the group restored with Alert **(Group 6)** showed the highest fracture resistance mean value and highest percentage of increase in fracture resistance with statistically highly significant difference as compared with groups restored with SDR **(Group 4)**, EverX **(Group 5)**, and Tertic EvoCeram® Bulk Fill composite **(Group 3)** respectively.

This result could be attributed to the following reasons:
1. Better mechanical properties of Alert composite as compared with the other bulk fill materials (SDR and TetricEvoCeram® Bulk Fill) including higher flexural strength, higher fracture toughness and higher flexural modulus. This is in accordance with the results of Garoushi et al. [25].
2. Alert is a fiber-reinforced composite withfiber length in micrometer scale (20–60 μm) whichmayexplained the difference in fracture toughness values amongthe other materials (SDR and Tetric EvoCeram® Bulkfill). Reinforcing effect of the fiber fillers isbased on stress transfer from polymer matrix to fibers but alsobehavior of individual fiber as a crack stopper [8].
3. Alert showed high values of mechanical parameters, which seems to be a result of high filler load level (conventional and microglass fiber 84 wt%, 62 vol. %). The most important and extensively investigated variable for physical performance in dental composite resins is filler loading [9].Previous studies found a positive correlation between filler loading and mechanical performance [26].
4. Alert has low polymerization shrinkage [27]. It is claimed by some authors that the polymerization shrinkage of composite resins plays an important role on the debonding of the adhesive interface [28] this is consequently maydecrease the fracture resistance.

In this study, the new short fiber reinforced composite (EverX) **(Group 5)** showed fracture resistance (0.608 kn) which is lower than that of Alert (0.831 kn) with high significant difference.

EverX contains short E-glass fiber fillers with length ranging from 0.6 to1.5mm (main 0.8 mm), resulting in random orientation of the short fibers within the composite restorations. Random fiber orientation and lowered cross-linking density of

the polymer matrix by the semi-IPN structure likely had a significant role in mechanical properties [29].

In spite of its high mechanical properties, it give lower values of fracture resistance than groups 4 and 6, this may be due to:

1. The length of fibers in millimeter scale does not provide good adhesion to hybrid layer than that provided by micro glass fibers that present in Alert.
2. Alert, had a higher flexural modulus value than EverX, as found by Garoushi although there was non-significant difference between them [25].
3. Some authors have shown low values of fracture toughness of a fiber containing dental composite [30].
4. In a study of different bulkfil composites, the degree of conversion was measured by Raman spectroscopy, the materials SDR, EverX and Tetric Evoceram BulkFil was 67.6%, 61.6%, and 56.7% respectively [31].

In **(group 4),** teeth were restored with flowable, bulk-fill base (SDR). The findings of this study revealed that the mean fracture load for this group was (0.6435 Kn) which is higher than the restored groups 3 and 4 with no significant difference in comparison to group 4 (EverX).

These findings may due to the elastic buffer effect of using a low-viscosity flowable composite. It was determined that polymerization shrinkage and the concomitant stresses upon the restoration-tooth interface have an influence upon the final outcome of extensive composite resin restorations. These findings come in agreement with Cara et al; Atiyah and Baban [32,33]. Moreover Lohbauer et al., postulated that high flexural modulus has been identified to inhibit the ability of a material to resist deformation due to loading and the accumulation of surface and bulk defects resulting in premature failure [34].

Also, considering bulk fill placement technique, it has been found that SDR has good internal adaptation in high c-factor cavities [35].

Composite Tetric EvoCeram Bulk Fill, containing filler load of 60% by volume demonstrated the significantly lower fracture toughness and flexural strength values. In other words, this study demonstrated the absence of a direct relationship between volumetric content of inorganic particles and fracture resistance parameters (fracture toughness and flexural strength) [36].

Moreover, the combination of lower compressive strength, lower flexural strength, lower flexural modulus and lower fracture toughness of Tetric EvoCeram® Bulk Fill composite as found by Tiba et al. [37] could be attributing factors for the lower fracture resistance and lower percentage of increase in fracture resistance of teeth restored with Tetric EvoCeram® Bulk Fill composite as compared with Alert™ composite and others (SDR and EverX).

Within limitations of this experimental study, the following conclusions could be drawn:

1- Sound nonrestored teeth present significantly higher fracture resistance compared with other groups (restored and unrestored) in this study.
2- Teeth restored with Alert that contain filler (conventional and micro glass fiber), showed the highest fracture resistance among all restored groups with statistically high significant difference.
3- Direct composite restorations should be considered as a valid interim restoration for endodontically treated teeth before cuspal coverage.

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