Fracture resistance of endodontically treated premolars with extensive MOD cavities restored with different composite restorations (An In vitro study)

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ABSTRACT

Background: This in vitro study evaluated the fracture resistance of weakened endodontically treated premolars with class II MOD cavities restored with different composite restorations (Low-shrinkage Filtek P90, nanohybrid Filtek Z250 XT and SDR bulk fill). The type and mode of fracture were also assessed for all the experimental groups.

Materials and Method: Fifty 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 five groups of ten teeth each (n=10): (Group 1) intact control group, (Group 2) unrestored teeth with endodontic treatment, (Group 3) restored with (Filtek Z250 XT), (Group 4) restored with SDR bulk-fill flowable composite and (Group 5) restored with Filtek P90 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 group 3, 4 and 5 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 (1.123 Kn) for group 1, (0.545 Kn) for group 2, (0.687 Kn) for group 3, (0.799 Kn) for group 4 and (0.672 Kn) for group 5. Using one way ANOVA test a highly significant difference (P < 0.01) were found among all groups. The use of bulk-fill flowable composite improved the fracture resistance significantly in comparison to silorane and non-significantly to Filtek Z250 XT. Filtek Z250 XT showed better improvement in fracture resistance but with no significant differences in comparison to Filtek P90 composite restorations. 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. 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, endodontically treated teeth, Filtek Z250 XT, SDR. **(J Bagh Coll Dentistry 2014; 26(1):7-15).**

INTRODUCTION

Esthetic dentistry continues to evolve through innovation in bonding systems, restorative materials, and conservative preparation designs. Increased use of composite resin materials for the restoration of the posterior dentition has drawn attention to technological advances in this field. A stable and durable bond between dental materials and tooth substrates is important from both a mechanical and esthetic perspective [1]. Such materials not only seal the margin, but several studies have also shown that the use of adhesive materials can reduce the weakening effect of preparation designs [2,3].

Tooth fracture has been described as a major problem in dentistry, and is the third most common cause of tooth loss after dental caries and periodontal disease.[4]Root-filled teeth are at increased risk of fracture; caries and excessive removal of dentine during root canal treatment, rather than low moisture content and increased brittleness reduce tooth strength [5]. Loss of axial dentine walls, which is common in teeth requiring root filling, greatly weakens teeth [6].

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Adhesive dentistry has considerable advantages in the treatment of weakened tooth structure [7]. The possibility of establishing adequate adhesion between tooth structure and restorations through adhesive materials may eliminate the need for extending cavity preparations to cover cuspal areas to prevent future tooth fracture [8,9]. The choice of materials selected for intracoronal restoration of endodontically treated teeth plays an important role in tooth longevity. Recently, 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]. Further, silorane containing resin was recently introduced as an alternative low-shrinkage material. The subsequent polymerization shrinkage of these silorane-based composites has been reported to be significantly less than that of conventional RBC materials [11,12]. In addition, methacrylate-based Filtek Z250 XT was recently introduced as a nanohybrid universal restorative composite with high filler

loading and improved mechanical properties and clinical performance [13].

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

MATERILS AND METHODS

Teeth selection

Fifty sound upper first premolar teeth with single root extracted for orthodontic purposes were used in this study. Teeth were stored in 0.1 vol% thymol solution for 48 h [14]. Then in distilled water at room temperature [15,16]. Teeth storage lasted for a maximum of 3 months before samples were chosen for the study [17-19]. Teeth of comparable size and shape were selected by crown dimensions after measuring the buccolingual and mesiodistal widths in millimeters [20,21]. Then the teeth were assigned into five groups (n = 10). Once each tooth size was determined the BLW means were calculated for each group. The mean BLW of each group was different by no more than 5% from the other groups [22-25]. Radiographs were taken in the mesio-distal dimensions. Teeth were determined with two canals were selected for the study [26].

Teeth mounting

To simulate the periodontal ligament, root surfaces were marked 2 mm below the cemento-enamel junction CEJ and covered with a 0.6 mm thick foil (Adapta foil, Bego, Germany) [27]. 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. After the first signs of polymerization, teeth were carefully removed manually from the resin blocks [28]. The acrylic covered the roots to within 2 mm of the CEJ, to approximate the support of alveolar bone in a healthy tooth [6,29]. In order to simulate periodontal ligament, the Adapta (foil) were removed from the root surface. A light body addition silicone impression material (Aquasil LV Utra, Dentsply) was injected into the acrylic resin blocks in the site that was previously occupied by the tooth root and adapta foil, and the teeth were reinserted into the resin cylinders. A standardized silicone layer that simulated periodontal ligament was thus created taking the thickness of the foil [27].

Sample grouping

The teeth were randomly divided into five groups (10 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 resin based composite (Filtek Z250 XT) (**3M ESPE)** using horizontal incremental layering technique.

Group 4: a class II MOD cavity and endodontic treatment were prepared as in group 2and restored with SDR (**Dentsply, Detrey)** as a flowable base up to 2 mm below the cavity margin and covered with Filtek Z250XT composite.

Group 5: a class II MOD cavity and endodontic treatment were prepared as in group 2 and restored with silorane-based low shrinkage dental composite (Filtek P90) (**3M ESPE)** using horizontal incremental layering technique.

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 [30]. 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 90. Consistency in cavity preparation was ensured by parallel preparation of the facial and palatal walls of the cavity [6].

Endoontic treatment

Endodontic access cavity was prepared, any access cavity wider than the width of the cavity (1/2 the intercuspal distance) was discarded.The teeth were held in moist gauze to prevent dehydration [31]. Root canals were instrumented initially using stainless steel K-files #10 and 15, followed by rotary Ni-Ti instruments (ProTaper, DentsplyMaillefer) using crown-down technique. For standardization purposes, all canals were instrumented up to size F1[32,33]. Then the canals were filled by matching size Protaper gutta-percha points using resin-based sealer (ADSEAL, META Biomed). A resin based sealer was used to avoid the detrimental effect of eugenol-based sealers on

polymerization of composites [34]. 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 [35, 36].

Restorative procedure

Group 3 (Filtek Z250 XT)

In this group, teeth were restored with nanohybrid methacrylate-based Filtek Z250 XT resin composite. A self-etch adhesive (Adper Easy Bond Self etch adhesive, 3M ESPE) was used to bond the restorative material to the cavity walls. The entire cavity was restored incrementally with horizontal placement technique. Each increment was light cured by LED curing device for 20 seconds according to the manufacturer's instructions.

Group 4 (Bulk-fill SDR)

In this group, teeth were restored with a combination of a flowable base of bulk-fill SDR (Dentsply-Detrey) and Filtek Z250 XT resin composite. A self-etch adhesive (Adper Easy Bond) was used to bond the restorative material to the cavity walls. The SDR restorative material was placed in the cavity up to 4mm and light cured according to the manufacturer instructions for 20 seconds by LED curing device (LITE Q, Monitex). As the cavity was filled with the bulk-fill flowable base, the restoration was completed by replacing the remaining part of the cavity (1-2 mm) with one increment of Filtek Z250 XT and with one exposure.

Group 5 (Filtek P90)

In this group, teeth were restored with low shrinkage, Silorane-based, posterior restorative composite (Filtek P90, 3M ESPE, USA). Silorane system adhesive (P90 system adhesive, 3M ESPE AG, Germany) was used to bond the restoration to tooth structure. The adhesive system (P90 system adhesive) was applied according to the manufacturer's instruction. Then, the restoration was built up using horizontal incremental technique with low shrinkage, Silorane-based, posterior restorative composite (Filtek P90, 3M ESPE). Each increment was no more than 2 mm. Each increment was light-cured for 40 seconds using a LED curing device according to the manufacturer instructions.

After finalizing samples restoration, all the specimens were finished with diamond finishing burs and polished with cups and points using composite polishing paste (SDI, Austria). All the specimens were stored after preparation and restoration in an incubator at 37 C° for one week, at 100 % relative humidity in deionizedwater before testing. Placing specimens in water for one week is enough for composite to reach maximum stage of equilibrium of water sorption [37].

Mechanical testing

All specimens were subjected to compressive axial loading until fracture in a computer controlled universal testing machine (WDW 2006, China). The crosshead speed was 0.5 mm/minute. A steel bar (8 mm in diameter) was placed at the center of the occlusalsurface and applied in parallel to the long axis of the tooth and to the slopes of the cusps (rather than the restoration).[14]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. Photographs were taken using a digital camera to determine type of fracture [29]. 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 [32]. 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× [6].

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)**. In this study, intact sound teeth (Group 1) presented the highest mean value (1.1235 Kn), whereas prepared but unrestored teeth with endodontic treatment (Group 2) showed the least fracture strength (0.5454 Kn).

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

Group	Mean	SD	Percentage of reduction in strength	Percentage of increase in strength
Group 1	1.123	.217		100
Group 2	0.545	.087	51.45	
Group 3	0.687	.132	38.79	61.21
Group 4	0.799	.128	28.88	71.12
Group 5	0.672	.042	40.13	59.87

The results of this study showed that the percentage of reduction in strength for the prepared unrestored teeth group was the highest (51.45%) among the other experimental groups. On the other hand, regarding restored groups, the percentage of increase in strength was the highest for teeth restored with SDR (Group 4) (71.12%) in comparison with teeth restored with Filtek Z250 XT (Group 3) (61.21%) and those restored with Filtek P90 (Group 5) (59.87%).ANOVA test revealed that there was a statistically highly significant difference among all groups ($P < 0.01$), **(Table 2)**. Therefore, least significant difference (LSD) test was used to evaluate the significance of difference between groups at a level of significance of (0.05).

Table 2: ANOVA test

	Sum of squares	df	Mean square	F-test	*P-value*
Between groups	1.924	4	.481		
Within groups	.816	45	.018	26.532	.000
Total	2.740	49			

LSD test showed that there were statistically highly significant differences ($P < 0.01$) between the unprepared and all prepared teeth, either restored or unrestored. Additionally, there were significant differences in fracture resistance between the prepared, unrestored teeth group (Group 2) and all the restored teeth groups ($P < 0.05$). On the other hand, no significant difference in fracture strength was noted when comparing teeth restored with Filtek Z250 XT (Group 3) to those restored with SDR (Group 4) and Filtek P90 (Group 5) ($P > 0.05$). However, a significant difference was existed between teeth restored with SDR (Group 4) and those restored with Filtek P90 (Group 5) **(Table 3)**.

Table 3: LSD test

(I) factor	Std. Error	P-value	Sig.
Group 1 (Control)	.0602	.000	HS
	.0602	.000	HS
	.0602	.000	HS
	.0602	.000	HS
Group 2 (Unrestored Teeth)	.0602	.023	S
	.0602	.000	HS
	.0602	.040	S
Group 3 (Filtek Z250 XT)	.0602	.071	NS
	.0602	.804	NS
Group 4 (SDR)	.0602	.041	S

Fracture type and mode

The results of this study showed that intact sound teeth (Group 1) had 8 samples with favorable fracture type and 2 samples with unfavorable type. Whereas other groups like group 3, group 4 and group 5 had 9 samples presented unfavorable fracture type and 1 sample with favorable fracture. In addition, all 10 samples of group 2 had unfavorable fracture type **(Table 4)**.

Table 4: Type of fracture in the study

Group	Fracture type		Total
	Favorable	Unfavorable	
Group 1	8 (80%)	2 (20%)	10
Group 2	0	10 (100%)	10
Group 3	1 (10%)	9 (90%)	10
Group 4	1 (10%)	9 (90%)	10
Group 5	1 (10%)	9 (90%)	10

Fracture mode

As presented in **table (5)**, teeth restored with FiltekZ250 XT (Group 3) and those with SDR (Group 4) exhibited 9 sampleswith adhesive mode of failure and only one with cohesive failure. However, those restored with Filtek P90 (Group 5) presented 1 samplewith adhesive failure, 8 samples with mixed type of failure and 1 sample with cohesive type of failure.

Table 5: Mode of fracture in the study groups

Group	Fracture mode			Total
	Adhesive	Cohesive	Mixed	
Group 3	9 (90%)	1 (10%)	-	10
Group 4	9 (90%)	1 (10%)	-	10
Group 5	1 (10%)	1 (10%)	8 (80%)	10

DISCUSSION

In this in vitro study the fracture resistance and fracture pattern of endodontically treated premolars with weakened class II MOD cavities restored with different composite restorations have been evaluated. Maxillary first premolars were chosen for this study because the cuspal inclines render them more susceptible to force that may promote cusp fracture [26]. Mesio-occlusal distal (MOD) cavities were prepared in this study to simulate a situation that is often found clinically and has been extensively reproduced in other clinical studies. The general effect of MOD cavity preparations is the creation of long cusps, thus there is a need for a restoration that not only replaces the tooth structure, but also increases thefracture resistance of residual tooth and promotes effective marginal sealing [38].

Each specimen was subjected to compressive axial loading until fracture using a universal testing machine. In this study, the applied force speed was 0.5 mm/min. It was stated that lower speeds are accompanied by greater plastic deformation and, thus, higher fracture resistance measurements will be recorded [39]. The choice of load direction (parallel to the long axis of the tooth) was also designed to simulate physiological function and to obtain a degree of non-axial loading through existing occlusal contact variations [29]. In which during function the occlusion generates non-axial forces resolved into their vectors along the cuspal side. So the load was applied along the long axes to distribute stresses more evenly between the residual dental tissues and the restorative material simulating a physiologic occlusion [40].

Fracture resistance among all experimental groups

Intact teeth (Group 1) presented the highest mean fracture load (1.1235 Kn). A statistically high significant difference with other experimental groups was existed. This may be due to the presence of the palatal and buccal cusps with intact mesial and distal marginal ridges which form a continuous circle of dental structure, reinforcing the tooth [41, 42]. On the other hand, prepared unrestored teeth with endodontic treatment (Group 2) presented the least mean fracture resistance value (0.545 Kn) and the highest percent of reduction in strength (51.45%) with significant difference when compared with the other groups. This may be due to the type and quality of the remaining tooth structure, especially the cusps and marginal ridges which form a circle of dentin and enamel, which has an influence on fracture resistance. Due to endodontic treatment with MOD cavity preparations, the strength of the tooth was considerably reduced; therefore, when forces are applied they act as a wedge between the buccal and lingual cusps in non-restored teeth; thus, decreasing the mean fracture resistance values and promoting more catastrophic types of fractures [43].

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 which presented (0.5454 Kn) mean value. These findings may be due to the ability of adhesive composite restorations to transmit and distribute functional stresses through restorative material-tooth interface due to mechanical interlocking of resin with peritubular/intertubular dentin and hybrid layer formation, with the potential to reinforce the weakened tooth structure.[42-44]Teeth restored with

Filtek Z250 XT (Group 3) showed (0.6876 Kn) mean fracture load and (61.21%) percent of increase in strength with a significant increase in fracture strength when compared with group 2. These findings may be attributed tothe high filler loading of Filtek Z250 XT (81.8 wt.%, 67.8 vol.%). Besides, Filtek Z250 XT has silica/zirconia clusters "nanoclusters" with average filler size 0.1-10 microns and 20 nm surface modified silica [13].

It was stated that higher filler loading reduces volumetric shrinkage and minimizes the development of shrinkage stresses in RBCs. This was attributed to the reduction in the amount of resin, thereby reducing the component responsible for shrinkage [45, 46]. Furthermore, it was concluded that the use of low shrinkage composite restorations significantly strengthen maxillary premolars with MOD preparations under compression loadings [25]. The presence of nanocluster provides increased mechanical properties and improves the damage tolerance and enhances the longevity of nanocluster RBC restorations [47-49]. In this research, the fracture load of teeth restored with Filtek Z250 XT (Group 3) (0.6876 Kn) was higher than that of those restored with Filtek P90 (Group 5) (0.6726Kn). Additionally the percentage of increase in strength of teeth restored with Filtek Z250 XT (Group 3) was higher than those restored with Filtek P90 (Group 5). This may be due to the differences in the filler loading and type. The filler loading of Filtek Z250 XT restorative system which is higher than that of Filtek P90 (76 wt. %, 55 vol.%). In addition, Filtek Z250 XTcomposite material has silica/zirconia clusters "nanoclusters" with average filler size 0.1-10 microns and 20 nm surface modified silica in comparison with the spherical filler particles of Filtek P90 (0.1-2 μm) [13]. It was reported that if filler contents were increased with decreasing particle size and inter-particle spacing, this would increase the fatigue limit due to increased obstacles for crack growth [50]. In addition, it was concluded that nanocluster particles possess different mechanical properties compared with filler particles possessing a spheroidal or irregular morphology. Additionally, the incorporation of nanoclusters particles into a conventional resin matrix may modify the subsequent failure mechanisms and provide enhanced damage tolerance unique to nanoclusters reinforced RBCs [51].

In this study, the mean fracture load for teeth restored with SDR was (0.799 Kn) which was the highest among the restored groups with no significant difference in comparison to group 3 (Filtek Z250 XT). The percentage of increase in

strength was (71.12%) which is the highest in comparison with the other restored groups. 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. In which the shrinkage stress generated by a subsequent layer of higher modulus resin composite can be absorbed by an elastic intermediary layer, thereby reducing the stress at the tooth-restoration interface manifested clinically as a reduction in cuspal deflection [52]. Further, the results of this study showed that there was a significant difference existed between teeth restored with SDR (Group 4) and those restored with Filtek P90 (Group 5)**.** These findings may be attributed to the elastic buffer effect of using low viscosity flowable composite and the characteristic low contraction stress and low modulus of elasticity of SDR flow in comparison with silorane restorative material which had only low polymerization shrinkage. It was stated that SDR flow achieved significantly lowest contraction stress ($1.1 \pm .01$MPa) in contrast to silorane-based composite ($3.6 \pm .03$MPa). Moreover, the elastic modulus of SDR flow (9.2 MPa) was lower than that of Filtek P90 (12.5 MPa) [53, 54]. Besides, it was stated that the flexural modulus of Filtek P90 (7.9 MPa) is higher than that of SDR flow (4.9 MPa) [53]. Moreover it was 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 [55, 56].

In this study, the mean load value of teeth restored with Filtek P90 (Group 5) was the lowest among the restored groups (0.6726 Kn) and the percentage of increase in strength (59.87%) was the lowest in comparison with restored teeth groups. However, group 5 had a significant increase in fracture strength when compared with the unrestored group 2. It was reported that restoration with Filtek P90 improved the fracture strength of endodontically treated teeth in comparison with unrestored teeth [42].This may be due to the strengthening effect of adhesive restoration which was discussed previously, in addition to the low polymerization shrinkage features of silorane-based composite restorations [57].Additionally, the low mean value of fracture load of Group 5 may be due to the high flexural modulus of silorane [55, 56]

Fracture type and mode

Based on the findings of this study, 80% of the samples in the intact control group (Group 1) presented favorable fracture type. However, all the samples in the unrestored teeth group (Group 2) presented unfavorable fracture type (100%). These findings may be due to the presence of the palatal and buccal cusps with intact mesial and distal marginal ridges in the control group and the weakening effect of cavity preparation and endodontic treatment in unrestored teeth with endodontic treatment which was discussed previously.

In this study, it was revealed that 90 % of the samples of teeth restored with Filtek Z250 XT presented unfavorable type of fracture. In addition, the majority of the samples in this group (Group 3) presented adhesive type of failure (90%). This may be due to that Filtek Z250 XT characterized by high compressive strength (385 MPa) and fracture toughness (2.03 MPa m1/2) [13]. It was stated that high compressive strength materials translate to sustained resistance against a heavy load, especially when used as a posterior restoration [58]. Further, the fracture toughness represents the material's ability to be plastically deformed without fracture, or the amount of energy required for fracture and it also represents the material's ability to resist crack propagation [59]. Therefore, Filtek Z250 XT may have a higher resistance to crack propagation, so the failure occurred at the weakest link which is the tooth/composite interface. In addition, self-etch adhesive exhibits a weak hybrid layer, which is generally accompanied by a weak adhesive layer which may explain the high percentage (90%) of adhesive failure in teeth restored with Filtek Z250 XT (Group 3) [14]. However, these findings should be supported by scanning electron microscope (SEM) to evaluate the failure point whether it isbetween the restoration and bonding, bonding and the tooth or within the adhesive layer.

In this study, the majority of the teeth restored with SDR (Group 4) presented 90% with unfavorable type of fracture. Moreover, 90% of the samples presented adhesive mode of failure**.** As discussed previously, SDR restorative material is characterized by low elastic modulus (9.5 MPa) [53] which may explain the higher load values among the restored groups. However, the low elastic modulus may explain the severity of fracture type presented in this group. In which the stresses in the compression test were transmitted to the adjacent tooth structure. This may in turn results in the concentration of stresses in the inner dentine and occurrence of unfavorable fracture. It was concluded that the higher the elastic modulus

of the restorative material when the joint of restorative material / dental structure is stressed, the lower the deformation of dental structures. In contrast, the low elastic modulus of composite resin promoted less restoration stiffness and a greater distribution of stresses produced by the compression test to adjacent tooth structure which resulted in catastrophic type of fracture [43]. Additionally, the weak adhesive layer of self-etch adhesive that used in this study may explain the high percentage (90%) of adhesive failure in this group [14]. However, these findings should be further investigated by the aid of SEM.

On the other hand, teeth restored with Filtek P90 (Group 5) presented 90% of the samples with unfavorable type of fracture. The majority of the samples (80%) exhibited mixed mode of failure. These findings may be dueto the inability of silorane-based restorative material to resist crack propagation and to plastically deform before fracture under compressive loading. These findings may also be due to the effect of low fracture toughness of silorane (1.64 MPam1/2) [58].Additionally, it was revealed that the silorane polymerization starts with the initiation process of an acidic cation that opens the oxirane ring and generates a new carbocation, subsequently, chain propagation and cross-linking polymerization follows [57]. However, during this process, the acidic Si–OH groups on the quartz-filler particles can potentially result in an undesired initiation of the cationic polymerization process. This unwanted process can increase the overall number of impure pockets of unreacted oxirane monomers and can potentially induce failure of the material when subjected to a compression stress [60].

In addition to the effect of low fracture toughness, the occurrence of high percentage (80%) of cohesive failure may be due to the low compressive strength property (254 MPa) of silorane-based restorative material [58]. Furthermore, it was recognized that the ring-opening polymerization of the silorane is cationic reaction and that no oxygen inhibition layer exists on the surface of the composite after polymerization in air which plays a very important role in adhesion between successive resin layers [61]. It was stated that a decrease in shear bond strengthbetween the layers in the silorane composite and an increase in the cohesive failure was noted between those successive layers [61]. These findings may explain the high percentage (80%) of cohesive mode of failure in teeth restored with Filtek P90.

Finally, based on the findings of this study and in term of fracture resistance, resin composite restoration of weakened endodontically treated premolars provides some strengthening effect; however, the dependence on this type of restorations resulted in unrestorable fracture type. Perhaps direct restorations should be considered as a valid interim restoration for weakened root filled teeth before cuspal coverage can be provided. Furthermore, this restoration is material dependent, which must be taken in consideration in the selection of appropriate composite material that could enhance the fracture resistance of endodontically treated teeth.

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