Fracture resistance of weakened premolars restored with sonically-activated composite, bulk-filled and incrementally-filled composites (A comparative *in vitro* study)

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ABSTRACT

Background: This study was conducted to assess the effect of sonic activation and bulk placement of resin composite in comparison to horizontal incremental placement on the fracture resistance of weakened premolar teeth.

Materials and method: Sixty sound human single-rooted maxillary premolars extracted for orthodontic purposes were used in this study. Teeth were divided into six groups of ten teeth each: Group 1 (sound unprepared teeth as a control group), Group 2 (teeth prepared with MOD cavity and left unrestored), Group 3 (restored with SonicFill™ composite), Group 4 (restored with Quixfil™ composite), Group 5 (restored with Tertic EvoCeram® Bulk Fill composite) and Group 6 (restored with Universal Tetric EvoCeram® composite using horizontal incremental layering technique). Standardized class II MOD cavity was prepared in all teeth except (group 1).After finishing the restorative procedure of each group according to the manufacturer's instructions, all teeth were stored in deionized distilled water in an incubator at 37°C for seven days.All specimens were subjected to compressive axial loading until fracturein a universal testingmachine.Specimens were examined by a stereomicroscope at a magnification of (20X) to evaluate the mode of fracture .

Results: The results of this study revealed that the control group exhibited the highest fracture resistance compared to all prepared teeth groups (restored or unrestored) and the differences were statistically highly significant ($P<0.01$), except with group 3 (which was restored with SonicFill™ composite) where the difference was statistically significant only ($P < 0.05$).Additionally the results of this study revealed that the prepared unrestored teeth (Group 2) exhibited the lowest fracture resistance compared to all restored groups and the differences were statistically highly significant ($P<0.01$). Meanwhile, among the restored teeth groups, teeth restored with SonicFill™ composite (group 3) exhibited the highest fracture resistance as compared with all other restored groups and the difference was statistically highly significant ($P<0.01$) .On the other hand, no statistically significant differences in fracture resistance were found among groups 4, 5 and 6, which were restored with Quixfil™ composite, Tetric EvoCeram® Bulk Fill composite and Universal Tetric EvoCeram® composite, respectively ($P > 0.05$). Group 3and Group 5 showed mostly mixed mode of failure, while Group 4 showed mostly adhesive mode of failure. On the other hand Group 6 teeth showed different modes of failure.

Conclusions: SonicFill™ composite can be considered as a viable treatment modality for the restoration of weakened maxillary premolar teeth. On the other hand, the time-consuming incremental layering technique can be substituted with bulk filling, using bulk fill materials (Quixfil™ and Tetric EvoCeram® Bulk Fill) for reinforcement ofweakened maxillary premolars.

Key words: Fracture resistance, SonicFill™, bulk fill technique, incremental layering technique. (J Bagh Coll Dentistry 2014; 26(4):22-27).

INTRODUCTION

Unresolved controversy exists concerning the preferred restorative materials and techniques used to restore weakened maxillary premolars to improve their resistance to fracture under occlusal load [(1)].The evolution of composite materials and adhesive techniques has considerably changed the approach to restorations in the posterior area.

The advantages of adhesive restorations are not only of an aesthetic nature, but, above all, relate to the possibilities of conserving a greater amountofhealthy tissue and “reinforcing” the residual dental structure [(2)].It is obvious that dentists have always been looking for a fast and reliable filling technique allowing the reduction of layers, effort and time.

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 [(3)].

Most of these products such as Surefil™ SDR (Dentsply Caulk), X-trafil (VOCO, Cuxhaven, Germany), Venus® Bulk Fill (HeraeusKulzer) and Filtek™ Bulk Fill Flowable Restorative (3M ESPE) are based on a low viscosity composite, and are applied in a bulk layer of 4mm thickness and light cured, then another composite is used to fill the rest of thecavity. This makes the restorative procedure longer and more complex; therefore, these materials should not be classified as true "bulk fill" materials [(4)]. More recently, true "bulk fill" composite resin materials have been introduced such as QuixFill™ posterior restorative (Dentsply) and Tetric EvoCeram® Bulk Fill

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(Ivoclar Vivadent). QuixFill™ posterior restorative offers an extremely high filler load (66% by volume and 86% by weight) and it offers a complete 4mm cure in as little as 10 seconds, while still offering a prolonged working time to allow creation of pre-cure anatomy [5].

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 [6].

Very recently, Kerr and KaVo, after three years of a common development project, launched the SonicFill™ system for posterior restorations. The system consists of a hand piece activated sonically and a special composite formulation, which contains about 83.5% of fillers by weight, mainly silica and barium aluminoborosilicate glass. Upon activation, the sonic energy lowers the viscosity of the composite and extrudes the composite that has initially a thick consistency.

The viscosity change of the composite will ensure a perfect adaptation to the cavity walls and avoids the stickiness of the composite to the instrument. It is not necessary to condense the composite because the high frequency vibration yields intimate adaptation to the cavity walls without voids inclusion. Cavities up to 5 mm of depth are filled in one bulk increment. Upon deactivation of the sonic energy, the viscosity of the composite increases and allows easy adaptation and accurate sculpting morphology of the composite. SonicFill system is indicated for posterior restorations in class I and II and as a buildup material for cusp reconstruction as well as a base after root canal treatment [4].

MATERIALS AND METHODS

Sample selection

Sixty sound human single-rooted maxillary premolar teeth, extracted for orthodontic purposes from patients with agerange from 18-22 yearscollected from different health centers, were used in this study.Teeth were stored in0.1%thymol solution for 48 hours [6], then in deionized distilled water at room temperature [7]. Only sound teeth free from cracks and with regular occlusal anatomy and approximately similar crown size were selected [8]. For each tooth, the maximum bucco-lingual and mesio-distal dimensions and inter-cuspal distance were measured using a digital caliper [9]. The measured dimensions varied with a maximum deviation of not more than 10% from the determined mean. These measurements were used in the distribution of the teeth among the different groups to provide uniformity of tooth size in each group [10].

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)[11]. Each tooth was embedded in a block of self-cured acrylic resin (Veracril, Colombia) in a rubber mold cylinder (2.5cm width-3cm height). The teeth were embedded along their long axes using a dental surveyor.

After the first signs of polymerization, teeth were carefully removed manually from the resin blocks [12].The acrylic covered the roots to within 2 mm of the CEJ, to approximate the support of alveolar bone in a healthy tooth [13]. In order to simulate the periodontal ligament, the Adapta (foil) was removed from the root surface and light body addition silicone impression material (Express™, 3M ESPE, USA) was injected into the acrylic resin blocks in the site that was previously occupied by the tooth root and adapta foil, and the tooth was reinserted into the resin block. A standardized silicone layer that simulated periodontal ligament was thus created taking the thickness of the foil [11].

Sample grouping

The teeth were randomly divided into six groups of ten teeth each according to the type of restorative material used as follows:

Group1: This group comprised ten sound unprepared teeth that served as a control group.

Group 2: An extensive class II MOD cavity was prepared, but the cavity was left unrestored.

Group 3: The MOD cavity was restored with SonicFill™ composite (Kerr Corp., USA).

Group 4: The MOD cavity was restored with Quixfil™ bulk fill composite restorative material (Dentsply DETREY GmbH, Germany).

Group 5: The MOD cavity was restored with Tetric EvoCeram® Bulk Fill composite restorative material (IvoclarVivadent, Liechtenstein).

Group 6: The MOD cavity was restored with Universal Tetric EvoCeram®composite restorative material (IvoclarVivadent, Liechtenstein), using horizontal incremental layering technique.

After the random distribution of the teeth into the six experimental groups, statistical analysis using one-way ANOVA test was done among the groups for the bucco-lingual and mesio-distal dimensions and for the inter-cuspal distance to assure that there were no statistically significant differences among the groups concerning crown dimensions.

Cavity preparation

Mesio-occluso-distal (MOD) cavities were prepared in all specimens using a flat-ended diamond fissure bur (4mm cutting height, 1mm diameter) in a high speed turbine handpiece with water coolant that was fixed to a modified dental surveyor, except for group 1, which served as a control. The width of the cavity was standardized 3mm, which approximates one half of the inter-cuspal distance and one third of the bucco-palatal dimension.

The depth of the cavity was 3mm at the pulpal floor level and 4mm at the gingival seat level measured from the palatal cavo-surface margin, with 1mm depth of the axial wall.The buccal and palatal walls of the cavity were prepared parallel to each other[14, 15, 16]. The cavity dimensions used in this study are shown in Figure1.

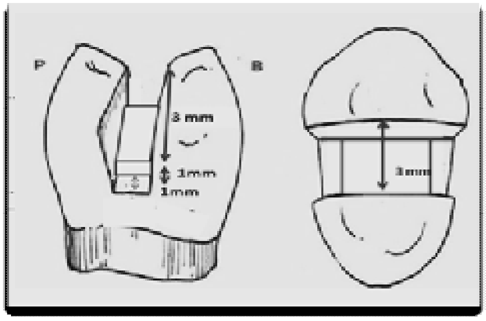

Figure 1: Diagram showing the dimensions of the MOD cavity preparation.

Before preparation of the teeth, an outline of the cavity was drawn with a super color marker [17]. Tooth preparation was carried out with aid of modified dental surveyor in order to standardize the cavity preparation.Teeth showing pulpal exposure after preparation were discarded [10].The depth of the cavity was checked with a graduated periodontal probe and the width of the cavity was checked using a digital caliper [18].

Adhesive procedure

SuperMat® Adapt®SuperCap® Matrix system (Kerr Corp.)was used in this study and changed for each restoration.Single Bond Universal Adhesive (3M ESPE) was usedfor groups 3 to 6 prior to composite resin placementwith the self-etch technique following the manufacturer's instructions and light cured with a LED light curing unit with a light intensity of 600 mw/cm^2 (Woodpecker® LED.C Wireless Curing Light) for 10 seconds according to the manufacturer's instructions.

Restorative procedure

The three bulk fill composite materials SonicFill™(Kerr Corporation, USA), Quixfil™ compositematerial (Dentsply DeTrey GmbH)and Tetric EvoCeram® Bulk Fill composite material (IvoclarVivadent, Liechtenstein) were applied to the cavity in a single bulk increment of 4mm according to the manufacturer’s instructions. CompoRoller™ was used to compress the material, adapting the margins; removing the excessand sculpting anatomy.

Each restoration was then light cured for 20 seconds according to the manufacturer's instructions. Additional light curing from the buccal and palatal sides for 20 seconds was done according to the manufacturer's recommendation. Group 6 was restored with Universal Tetric EvoCeram® composite using horizontal incremental technique. The cavity was filled with two increments of 2 mm each since the total depth of the cavity was 4 mmusing CompoRoller™ instrument, followed by light curing for 20 seconds from occlusal direction according manufacturer’s instructions.Afterfinishing the restorative procedure, all teeth were stored in deionized distilled water in an incubator at 37°C for seven days before testing [31].

Mechanical testing

All specimens were subjected to compressive axial loading until fracture in a computer-controlled universal testing machine (LARYEE, China) with a crosshead speed of the 0.5 mm/minute. The load was applied parallel to the long axis of the teeth using a steel bar 8 mm in diameter, touching the occlusal surface of the tooth at the slopes of the cusps rather than the restoration [15].

All samples were loaded until fracture and the maximum breaking loads were recorded in kN. The mode of failure was evaluated under a stereomicroscope (Altay biovision line, Italy) at a magnification of (20 X).The mode of failure was recorded and classified as adhesive, cohesive and mixed modeof failure [13].

RESULTS

The descriptive statistics of fracture resistance of all groups with the percentage of increase in fracture resistance are shown in Table 1. One-way ANOVA test revealed a statistically highly significant difference among the groups as shown in Table 2. Further comparisons among groups were done using the Least Significant Difference test (LSD test) to see where the significant difference occurred as shown in Table 3.

The results of this study revealed that the control group exhibited the highest fracture resistance compared to all prepared teeth groups (restored or unrestored) and the differences were statistically highly significant (P<0.01), except with Group 3 (which was restored with SonicFill™ composite) were the difference was statistically significant only (P < 0.05).

Additionally the results of this study revealed that the prepared unrestored teeth (Group 2) exhibited the lowest fracture resistance compared to all restored groups and the differences were statistically highly significant (P<0.01).

Among the restored teeth groups, teeth restored with SonicFill™ composite (Group 3)exhibited the highest fracture resistance as compared with all other restored groups and the difference was statistically highly significant (P<0.01) .

On the other hand, no statistically significant differences in fracture resistance were found among Groups 4, 5 and 6, which were restored with Quixfil™ composite, Tetric EvoCeram® Bulk Fill composite and Universal Tetric EvoCeram® composite, respectively (P>0.05). Concerning the fracture mode, Group 3 and Group 5 showed mostly mixed mode of failure, while Group 4 showed mostly adhesive mode of failure. On the other hand, Group 6 showed different modes of failure.

Table 1: Descriptive statistics of fracture resistance of each group in kN

Groups	Mean	SD	Percentage of increase in fracture resistance
Group1	1.18250	0.094	100%
Group 2	0.55633	0.029	- 53%*
Group 3	1.0726	0.110	90.7%
Group 4	0.88533	0.079	74.8%
Group 5	0.855	0.046	72.3%
Group 6	0.897	0.048	75.85%

***Percentage of decrease in fracture**

Table 2: One-way ANOVA test for comparison of significance among different groups

	Sum of Squares	df	Mean Square	F	Sig.
Between groups	1.377	5	0.275	50.062	.000 (HS)
Within groups	0.165	30	0.006		
Total	1.543	35			

Table 3: LSD test between the different groups

Groups		Mean Difference	S.E.	Sig.
G 1	**G2**	.626167*	.042829	.000 (HS)
	G 3	.109833*	.042829	.016 (S)
	G 4	.297167*	.042829	.000 (HS)
	G 5	.327500*	.042829	.000 (HS)
	G 6	.285500*	.042829	.000 (HS)
G 2	**G 3**	-.516333*	.042829	000 (HS)
	G4	-.329000*	.042829	.000 (HS)
	G5	-.298667*	.042829	.000 (HS)
	G6	-.340667*	.042829	.000 (HS)
G 3	**G4**	.187333*	.042829	.000 (HS)
	G 5	.217667*	.042829	.000 (HS)
	G6	.175667*	.042829	.000 (HS)
G 4	**G5**	.030333	.042829	.484 (NS)
	G6	-.011667	.042829	.787 (NS)
G 5	**G 6**	-.042000	.042829	.335 (NS)

*** The mean difference is significant at the 0.05 level.**

DISCUSSION

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 (19).This is in agreementwith Santos and Bezzera (20).

In this study, the lowest fracture resistance mean value presented by the prepared unrestored teeth which was statistically highly significant when compared with all other groups could be attributed to thetype and quality of the remaining tooth structure after MOD cavity preparationas teeth with large MOD cavities are severely weakened due to the loss of the reinforcing tooth structures,specially the cuspsand marginal ridges, so become more susceptible to fractureThis is also in agreement with Santos and Bezzera (20).

In this study, it is clearly seen that all composite resin restored teeth displayed higher fracture resistance than the prepared but unrestored teeth (Group 2) regardless of the type of composite material used and with varying percentages of increase in fracture strength as shown in Table 1.This 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 (21).

Among the restored groups, Group 3 (which was restored with SonicFill™ composite) showed the highest fracture resistance mean value and the highest percentage of increase in fracture resistancewith statistically highly significant difference as compared with all other restored groups. This could be attributed to the followings:

1. Better adaptation of SonicFill™ composite to the cavity walls owing to its fluctuating viscosity as a result of sonic activation delivered through the SonicFill™hand piece. Sonic activation lowers the viscosity of the SonicFill™ composite dramatically, up to 87%, which is related to special rheological modifiers that react to sonic activation delivered through the SonicFill™ hand piece during its placement, increasing its flowability and providing superior adaptation to the cavity walls, and thus making the frequency and size of critical voids located at the margin and along line angles of the cavity less pronounced compared to conventional putty-like composites [(22)].

2. Better mechanical properties of SonicFill™ composite as compared with the other compositematerials (Quixfil™composite, Tetric EvoCeram® Bulk Fill compositeand universal Tetric EvoCeram®composite) including higher compressive strength, higher flexural strength and higher fracture toughness and fracture work, with an intermediate flexural modulus between Quixfil™ and Tetric EvoCeram® Bulk Fill[(24,25,26)].Such differences in the mechanical properties among the three different bulk fill materials used in this study could be attributed to the differences in the type and size of fillers and the difference in filler loading.

On the other hand, the statistically non-significant differencesinfracture resistance among Group 4, Group 5&Group 6 even though Quixfil™ composite has higher filler loading than the universal and bulk fill versions of Tetric EvoCeram® composite could be due to that Quixfil™ composite is a microhybrid composite, while the other two composite materials are nanohybrid composites, and hence nanotechnology might have compensated the effect of higher filler loading of Quixfil™ resulting in statistically non-significant differences in fracture resistance.

Concerning the fracture mode, Group 3 (SonicFill™Group) showed mostly mixed type of failure (80%) (Cohesive type in restoration within the upper part of the restoration and adhesive type in the remaining part).This could be attributed to the following:

1. Proper adaptation of the material to cavity walls without void formation owing to its fluctuating viscosity combined with the low shrinkage and contraction stress upon curing of bonded SonicFill™ composite.Low contraction stressreduced the possibility of the composite pulling away from the tooth surface during polymerization with subsequently low cuspal deflection.

2.High mechanical properties of SonicFill™ (especially its high fracture toughness and fracture work), which made the material able to absorb the applied load and preserve the tooth-restorationinterface, up to the point at which the applied load exceeded the fracture toughness limit of the material, thus underwent cohesive failure in the upper part of the restoration and lost its ability to transmit the applied load and preserve the tooth-restoration interface, hence underwent adhesive type of failure.

3. Another possible contributing factor for this finding might be the high bond strength of Single Bond Universal Adhesive to enamel [(28)].

Group 4 (Quixfil™Group) showed mostly adhesive type of failure (90%). This may be attributed tothe heavy viscosity of Quixfil™ composite, which might hindered the appropriate adaptation of the material to the cavity walls, resulting in void formation at the tooth restoration interface [(23)]. On other hand the high flexural modulus of Quixfil™ composite as a result of its high filler loading might not allowed the material to absorb the applied load and undergo plastic deformation; instead, the increased stresses from theapplied load were transferred to the tooth-restoration interface, resulting in adhesive type offailure before the material would fail mechanically [(29)]. Also the resin matrix of Quixfil™ composite serves to give the resin mixture a high cohesion [(30)].

Group 5 (Tertic EvoCeram® Bulk Fill Group) showed mostly mixed mode of failure (80%). This could be attributed to the low shrinkage stress of Tertic EvoCeram® Bulk Fill composite according to manufacturer's information.This is in agreement with Van Ende *et al.* [(27)], who found that for materials with low shrinkage stress, mixed failure was the predominant type of failure rather than de-bonding with subsequent adhesive failure. This is also in agreement with El Gezawi *et al.* [(29)] who found that most failures of bulk fill composites were mixed.

Group 6 showed cohesive type of failure in 50%, adhesive type of failure in 30% and the other 20% showed mixed type of failure. This finding might be due to the incorporation of voids or contamination between composite layers. Voids developed from resin porosity contain oxygen and form polymerization inhibiting zone resulting in bond failures between increments [(31)].

SonicFill™ composite can be considered as a viable treatment modality for restoration of weakened teeth. It is obvious that dentists have always been looking for a fast and reliable filling technique allowing the reduction of layers, effort and time; therefore, the time-consuming incremental layering technique can be substituted with the bulk fill technique using bulk fill materials (Quixfil™ and TetricEvoCeram® Bulk Fill) for reinforcement of weakened teeth.

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