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FRACTURE BEHAVIOUR OF DIRECTLY RESTORED PULPOTOMIZED PRIMARY MOLARS WITH BIOMIMETIC VERSUS CONVENTIONAL BILAYERED STRUCTURE; AN IN-VITRO STUDY

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ABSTRACT

Objectives: The aim was to evaluate fracture behaviour of directly restored pulpotomized primary molars with two biomimetic and one bilayered structures. Besides, impact of these structures to restore strength of sound molars was evaluated

Materials and Methods: Fifteen sound and forty-five carious extracted second primary molars were selected to be used in this study. The 15 sound molars were left intact without any preparation as Group A (Intact structure). While standardized access cavity preparation and pulpotomy procedures were performed on 45 carious molars. The pulpotomized molars were divided randomly and equally (n= 15) according to final composite restoration structure into Group B (everX Posterior + G -aenial Posterior) and Group C (everX flow + G -aenial Posterior) as biomimetic structure and Group D (Filtek Bulk Fill Flow + Filtek Z250 XT) as conventional bilayered structure. Each composite resin and its adhesive were applied with strict adherence to manufacture instructions. After thermocycling , each molar was tested for fracture resistance using instron testing machine at 0.5 mm/ min crosshead speed with 4.5 mm rounded end metallic cone. The compressive force inducing fracture in each specimen was recorded in Newton(N) and the fracture pattern was examined visually with aid of magnifying lens. Statistical analysis was done using ANOVA and post-hoc tests at 5% of significance.

Results: Mean fracture resistance value of group A (intact structure) was highly statistically significant than that for groups B and C (biomimetic structures) or group D (bilayered structure) ($p<0.05$). Despite the high fracture resistance values of biomimetic structure groups (groups B and C) than that of bilayered structure group (group D), no statistically significant difference was found on comparison between them ($p>0.05$). Majority of fracture pattern in intact group was type I, while majority in biomimetic groups and bilayered group was types II and III respectively.

Conclusions: Biomimetic restoration showed most favorable outcomes for pulpotomized molars regarding strength and fracture pattern.

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Clinical relevance: Biomimetic restoration utilizing short glass-FRC could be recommended as conservative and time saving restoration for pulpotomized primary molars. Abstract needs to be rewritten in a clearer way.

KEYWORDS: Biomimetic restoration; Short glass fibers; Pulpotomized primary molars; Fracture resistance; Bilayered structure.

INTRODUCTION

Pulpotomized molars have significant loss of natural dental structures due to caries removal and deroofing procedure of pulp chamber which compromise their structural integrity and predispose them to fracture under occlusal forces [1,2]. In addition, long unsupported walls of pulpotomized teeth may be responsible for their compromised strength and fracture susceptibility[3]. Despite stainless steel crown (SSC) is the gold standard restoration for pulpotomized teeth, tooth preparations for crown especially esthetic one requires additional removal of sound structures which further impair its biomechanical properties [1,4]. In addition, subgingival crown margin may damage periodontal tissues or at least cause gingival inflammation [5].

With increasing parental demands of esthetics for their children, the use of aesthetic restorations with optimum fracture strength for pulpotomized teeth had been mentioned in literature[1,6]. Some studies addressed direct composite restoration as alternative esthetic option for pulpotomized teeth instead of traditional SSC [2,3,8,9]. However, polymerization shrinkage, major shortcoming of composite resins, leads to higher stress concertation on tooth instead of restoration and causes unrestorable tooth fracture [10]. Thus, layering placement and sandwich technique using flowable composite or glass ionomer base were recommended to overcome shrinkage stress and enhance strength of pulpotomized teeth [7,10].

During past decade, physical and mechanical properties of composite materials had been dramatically improved to overcome its shortcomings, reduce restorative time, and decrease risk of contamination especially for posterior region [11]. Among them, bulk-fill composites were developed for direct placement of 4-5 mm increment with low shrinkage stress and adequate bond strength [10,11]. Although they showed promising results for pulpotomized primary molars and endodontically treated permanent teeth, their relative predisposition to fracture is still the main problem in such situations [8-12].

EverX Posterior (GC, Japan), short glass -fiber reinforced composite resin (short glass-FRC), was launched in market in 2013 for bulk filling especially in high load-bearing areas [13]. It contains a combination of millimeter-scale of randomly oriented E-glass fibers and inorganic particulate fillers in resin matrix called semi-interpenetrating polymer network resin matrix[13]. It improved mechanical properties and fracture behaviour of endodontically treated permanent teeth more than other bulk fill composite restorations [11,12]. Due to high viscosity and limited esthetic of everX Posterior, its micrometer-scale flowable version (everX flow, GC, Japan) was developed in 2019 to address these challenges [14]. Currently, short glass -FRCs (everX Posterior and everX Flow) are considered dentin replacement materials because of their ~~its~~ microstructures, mechanical properties, and stress absorption capacities resemblance to dentin[14,15].

Biomimetic restoration, short glass-FRC base and esthetic wear resistant composite surface layer, that mimic enamel-fibrous dentin complex structure can restore biomechanics as well as aesthetic for vital permanent teeth[16]. Furthermore, nonvital permanent teeth restored with biomimetic restoration showed higher resistance to fracture and more restorable pattern of fracture compared to other restorations[16-18]. Biomimetic restoration was considered an alternative to traditional post-placement in endodontically treated permanent teeth[15,16,18].

Since short glass -FRCs based biomimetic restoration was not investigated before for pulpotomized primary molars, thus a question was raised about best bilayered structure that could restore its sound strength. Thus, the current in-vitro study aimed to evaluate fracture behaviour of directly restored pulpotomized primary molars with two biomimetic and one bilayered composite structure. Besides, impact of these structures to restore strength of sound molars was evaluated.

MATERIALS AND METHODS

This study was conducted after obtaining approval from the Dental Research Ethics Committee of the Faculty of Dentistry, Mansoura University Code No. (M0209023PP). The sample size of this study was estimated with G*Power analysis software Version 3.1.9.2. at 80% power and 0.05 significance level based on previously published in vitro study of Kaur et al who evaluated the effect of different core build-up materials on fracture resistance of endodontically treated permanent teeth(18). The results of analysis revealed that 15 second primary molar within each group was enough for fracture resistance test.

Forty-five carious and fifteen sound recently extracted second primary molars for dentoalveolar abscess or orthodontic treatment were included in this study after fulfillment of following inclusion criteria: a) carious molars have buccal, lingual and one intact proximal surface, b) at least one half of root length should be present, c) occlusal caries should not exceed two thirds of intercuspal width, and d) proximal caries should be away from cemento-enamel junction (CEJ) with at least 2-mm. After removal of any deposits, cleaning, and disinfection, the primary molars were stored in saline solution until conduction of study.

The roots of all primary molars were coated with 0.2-mm layer of low-viscosity polyvinyl siloxane impression material simulating periodontal ligament and then inserted vertically 2-mm below CEJ in aluminum ring containing acrylic resin simulating alveolar bone [19]. Each molar was mounted in acrylic resin with its long axis perpendicular to horizontal plane and the buccal and lingual cusps in same plane to ensure equal distribution of loading force during testing procedures.

Fifteen sound molars were left intact without any preparation as Group A (Intact structure). While conventional pulpotomy procedures were performed on other forty -five carious second primary molars. After initial caries removal with slow-speed round bur, mesio- or disto-occlusal access cavity to pulp chamber was prepared according to caries extent using high-speed diamond fissure bur under water spray to simulate clinical procedure of pulpotomy. Any sharp line angles were rounded, and final convenience form of pulp chamber was completed. A millimeter periodontal probe was used to standardize cavity dimensions so that occlusal and proximal bucco-lingual width was two-third intercuspal width and proximal gingival depth was 2-mm above CEJ. Buccal and lingual cavity walls were prepared parallel to each other, and all internal line angles were rounded.

After dryness, 1-mm reinforced zinc oxide eugenol followed by 1- mm glass ionomer cements were placed on pulpal floor of each pulpotomized molar. Any excess cement on cavity walls was removed with sharp excavator and T- matrix band was placed around each molar. The entire cavity walls and enamel margins were treated with 35% Scotchbond universal etchant (3M, USA) for 30sec, rinsed, gently dried, and left moist. After that, pulpotomized molars were randomly and equally (n=15) divided according to final composite restoration structure into Group B and Group C as biomimetic structure and Group C as conventional bilayered structure.

In the Group B (everX Posterior + G-aenial Posterior structure), based on manufacturers' instructions, G-aenial one-Step Self-etching bonding agent (GC, Japan) was actively applied against cavity walls with micro-brush applicator, air-dried, and light-cured. Then, cavity was restored in 4-mm increments with packable everX Posterior composite except the last occlusal 2-mm that was restored with Nano-hybrid G-aenial Posterior composite (GC, Japan). While Group C (everX Flow + G-aenial Posterior structure) was restored as in group B except flowable everX Flow was used instead of packable everX Posterior.

In the Group D (Filtek Bulk Fill Flow + Filtek Z250 XT structure), based on manufacturers' instructions, Adper Easy One-step Self-etching bonding agent (3M, USA) was actively applied against cavity walls with micro-brush applicator, air-dried, and light-cured. Then, cavity was restored in 4-mm layers with flowable Filtek Bulk-Fill Flow composite (3M, USA) except the last occlusal 2-mm that was restored with Nano-hybrid Filtek Z250 XT composite (3M, USA).

After matrix removal, all restorations were properly finished and polished to proper anatomy using Sof-Lex discs (3M, USA). All restored molars were subjected to 500 thermocycles between 5°C -55°C and dwell time of 30-sec. Then, all primary molars were tested for fracture resistance using computer-controlled instron machine (Instron Inc, USA). The compressive load was applied on center of occlusal surface and parallel to long axis of specimens using 4.5 mm rounded end metallic cone at 0.5 mm/min crosshead speed. The compressive force in Newton(N) inducing fracture was displayed on machine panel.

Pattern of fracture in each molar was examined visually with aid of magnifying lens and classified as: Type 1; minimal tooth fracture, Type 2; fracture of buccal or lingual cusps but intact restoration, Type 3; fracture of less than buccal or lingual one-half of crown, Type 4; fracture of more than buccal or lingual one-half of crown, and Type 5; severe crown fracture, vertical splitting into buccal and lingual halves [12].

Fracture resistance values and frequency of fracture pattern for each group was collected, tabulated, and analyzed using SPSS program for windows version 25 (SPSS Inc, USA). Comparison between fracture resistance of different groups was done with One-way ANOVA and post-hoc Tukey tests at 5% level of significance.

RESULTS

Mean value of fracture resistance and standard deviation (SD) expressed in (N) for 4 groups is presented in Table (1). The highest mean of fracture resistance was recorded for Group A (Intact structure) and was statistically significant than that for three restored groups ($p<0.05$). However, difference between mean fracture resistance of group B, C, and D was non-significant ($p>0.05$). Despite the high fracture resistance values of groups B and C (biomimetic structure) than that of group D (bilayered structure), they were still lower than that of group A (intact structure).

Number (N) and percentage (%) of fracture patterns in each group is shown in table (2). Majority of fracture pattern was minimal tooth fracture in group A (intact structure), fracture of buccal or lingual cusps but intact restoration in groups B and C (biomimetic structure), and fracture of less than buccal or lingual one-half of crown in group D (bilayered structure). However, none of four groups showed severe crown fracture.

TABLE (1) Show means and standard deviations (SD) of fracture resistance expressed in N for 4 groups.

Groups	N	Mean ± SD (N) *	P value
Group A (Intact structure)	15	1831 ± 85.77 a	**0.000**
Group B (everX Posterior + G-aenial Posterior structure)	15	1626 ± 150.7 b	
Group C (everX Flow + G-aenial Posterior structure)	15	1648 ± 143.75 b	
Group D (Filtek Bulk Fill Flow + Filtek Z250 XT structure)	15	1509 ± 145.07 b	

Similar letters indicated no-significant difference(p>0.05)

TABLE (2) Show Number (N) and Percentage (%) of fractur patterns for 4 groups.

Groups	Type 1 N (%)	Type 2 N (%)	Type 3 N (%)	Type 4 N (%)	Type 5 N (%)
Group A (Intact structure)	11 (73%)	2(13.3%)	2(13.3%)	-	-
Group B (everX Posterior + G-aenial Posterior structure)	1(6.6%)	10 (66.6%)	2(13.3%)	2(13.3%)	-
Group C (everX Flow + G-aenial Posterior structure)	2(13.3%)	10 (66.6%)	2(13.3%)	1(6.6%)	-
Group D (Filtek Bulk Fill Flow+ Filtek Z250 XT structure)	-	1(6.6%)	11(73%)	3(20%)	-
Total	14(23.3%)	23(38.3%)	17(28.3%)	6(10%)	-

DISCUSSION

Functional occlusal forces generate uniformly distributed stress within teeth, but design of sound vital teeth is able to withstand these functional stresses. Besides vitality, presence of intact marginal ridges and roof of pulp chamber are considered sound teeth reinforcement structures [20,21]. Generally, pulpotomy procedures disrupt this design and functional stress become concentrated on walls of pulp chamber[3,9]. Thus, pulpotomy procedures negatively affect strength and critically expose pulpotomized molars to fracture under repetitive occlusal forces[1]. This highlights importance of restoring lost strength for pulpotomized primary molars[9].

Undoubtedly, composite restorations might preserve tooth structure, maintain natural contact, reduce chair time, and satisfy esthetic demand [3,6]. Bilayered biomimetic composite restoration restored fracture resistance for endodontically treated permanent teeth but its effect on pulpotomized primary molars was not investigated yet. Thus, current study investigated effect of biomimetic and bilayered composite restorations on fracture resistance and pattern of pulpotomized primary molars.

For current study, carious molars with certain inclusion criteria were selected to simulate compromised teeth and to some extent standardize cavity dimensions, so effect of restoration as variable could be tested. Also, the role of periodontal ligament and alveolar bone was replicated during sample preparation [19]. Moreover, strict adherence to manufacture instructions was followed during application of each restorative material to eliminate any variable during restoration process. Although loading force in current study did not replicate clinical situation, but at least simulated effect of normal occlusion on tooth -restoration complex.

Ghajari et al reported that bulk fill composite restoration enhanced fracture strength of pulpotomized primary molars and recommended its clinical use due to short chair time characteristic for pediatric patients[2]. Atalay et al found that difference between fracture resistance of restored root canal treated premolars with packable bulk-fill, flowable bulk-fill, and packable short glass-FRC resins was not significant but significantly lower than that of intact premolars [12]. Recently, Zareiyan et al investigated effect of short glass fibers addition to composite restoration on strength of pulpotomized primary molars [22]. They stated that fibers reinforced restoration could be practical cost-effective option even for pulpotomized molars with severe coronal destruction [22].

To my knowledge, no previous in vitro study addressed biomimetic restoration of pulpotomized primary molars, thus direct comparison of achieved results was not feasible. Also, comparison with their respective studies on endodontically treated permanent teeth was impossible due to morphological and anatomical differences between primary and permeant teeth, differences in design, and methodology of studies, difference in specimens' preparations and restorative procedures, and so forth. From results of current study, fracture resistance for group A (Intact structure) was higher and statistically significant than that for other restored groups. Regarding fracture pattern in group A, majority of its specimens showed minimal tooth fracture. These results demonstrated importance of tooth integrity and coincided with that of Atalay et al regrading intact premolars [12]. Also, it was in line with results from similar previous studies reporting detrimental effect of pulpotomy procedures on fracture resistance [3,8,9].

Also, results of current study revealed that mean fracture resistance of restored pulpotomized molars with biomimetic restoration (groups B and C) were higher than that with bilayered restoration (group D) but not statistically significant. However, majority of fracture pattern in biomimetic groups was fracture of buccal or lingual cusps but intact restoration. These results supported hypothesis of closest resemblance of everX Posterior and everX Flow to dentin [14,15]. In addition, protruding glass fibers from base to veneer surface layer might mimic to some extent mechanical interlock of dentin-enamel junction [16]. Favorable outcomes of everX Posterior and everX Flow could be attributed to multidirectional and isotropic reinforcement of randomly oriented glass fibers to polymeric matrix [14,16]. In addition, adhesion, and impregnation of glass fibers to semi-interpenetrating polymeric network matrix modify stress transmission inside cavity and improve stress-bearing capacity of tooth-restoration complex [15,16]. Furthermore, glass fibers conducting, and scattering-light effect enhance polymerization kinetics of polymeric matrix [17].

On other hand, tight adaptation of Filtek Bulk Fill Flow to cavity walls and mechanical retention of pulp chamber itself enhanced fracture resistance in group D (conventional bilayered structure) [16,32]. In spite of this, majority of its specimens showed fracture of less than buccal or lingual one-half of crown. It could be speculated that absence of unique polymeric resin matrix and its reinforcing and stress-distributing glass fibers in such restoration allowed fracture to be directed through bulk of whole structure [16,23]. Benefits from fracture pattern of biomimetic structure could be what is called dynamic concept of treatment or possibility of repairing restoration due to protruding fibers at surface [16]. It had been reported that short glass-FRC restorations preserved its strength after repair [14].

CONCLUSION

Based on results of current study, it could be concluded that:

1. Biomimetic structure enhanced resistance of pulpotomized molars to fracture and showed more repairable fracture than conventional bilayered structure.

2. Biomimetic structure showed ability to re-direct fracture away from bulk of restoration toward weak buccal or lingual cusps.
3. Biomimetic structure utilizing short glass-FRC could be recommended as conservative and time saving restoration for pulpotomized primary molars.

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