ORIGINAL ARTICLE

Effect of Different Fiber Reinforcement Strategies on the Fracture Strength of Composite Resin Restored Endodontically Treated Premolars

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Abstract

Objective: To compare the effect of three different fiber reinforcement strategies on the fracture strength of composite resin restored endodontically treated premolars. **Material and Methods:** Seventy-two sound human premolars extracted for orthodontic reasons were divided into 6 groups (n=12) after endodontic treatment. Group 1: intact teeth (positive control); Group 2: endodontically treated teeth without restoration (negative control); Group 3: composite resin restoration; Group 4: placement of fibers at occlusal position; Group 5: splinting the buccal and palatal walls with horizontal fiber posts; Group 6: placement of fibers at the occlusal position after splinting the buccal and palatal walls with horizontal fiber posts. Then fracture strength was measured at a crosshead speed of 0.5 mm/min in a universal testing machine. Data were analyzed using one-way ANOVA and post hoc Tukey tests at α=0.05. **Results:** There were significant differences between the negative and positive control groups (p<0.001) and between the negative control group and all the other study groups (p<0.001). However, there were no statistically significant differences between the positive control group and all the experimental groups and between the experimental groups (p>0.05). **Conclusion:** Fiber insertion had no additional reinforcing effect on the fracture strength following composite resin restoration.

Keywords: Tooth, Nonvital; Composite Resins; Post and Core Technique.

Introduction

Endodontically treated teeth have low fracture resistance, compared to sound teeth, because of various reasons such as a decrease in dentin elasticity, a decrease in water content, and more importantly due to the extensive loss of tooth structures, including cusps, marginal ridges and the pulp chamber roof due to caries, previous restorations and endodontic access cavity preparation [1-3].

The success of endodontic treatment depends on the quality of final restoration and endodontic treatment is not considered complete without restoration of the crown. However, selection of the best final restoration for endodontically treated teeth is still a matter of controversy and so far, a wide range of amalgam, direct and indirect composite resin and full-coverage restorations have been suggested [4-6].

The risk of cusp fracture under occlusal forces is high in maxillary premolars due to their special anatomic configuration and their unique position in the dental arch [7,8]. Furthermore, because of their location in the appearance zone during smiling [7,8], the esthetic factor should be taken into account in these teeth in addition to fracture resistance.

At present, technological advances in the adhesive technology and introduction of fiber-reinforced composite resins (FRC) have led to an increase in the restoration of extensive cavities with composite resins. It has been shown that FRC has a successful function in the oral cavity and has so far been used in the manufacture of crowns, bridges and periodontal splints [9]. A finite element analysis has shown that FRC post-and-core systems are more appropriate than inflexible metallic post-and-core systems due to a coefficient of elasticity similar to that of dentin and better protection of remaining tooth structure [10].

Several studies have confirmed the efficacy of high molecular-weight polyethylene fibers for reinforcement of composite resins as stress breakers in extensive composite resin restorations, indicating that placement of these fibers increases the fracture resistance of endodontically treated teeth [11-17], with more occlusal fibers exerting greater effects [13,14]. In addition, horizontal transfixation of the remaining buccal and palatal walls of endodontically treated molars by glass fiber posts and restoration with composite resin significantly increase fracture resistance [15]. However, none of the restorative techniques used so far have been able to increase the fracture resistance of endodontically treated teeth to the level of intact teeth [12-15,17]. Furthermore, it is not clear which of the above-mentioned adhesive restorative techniques results in a greater increase in fracture resistance and whether a combination of these two techniques as a new restorative technique can result in a great increase in fracture strength to the level of an intact tooth.

Therefore, the aim of the present study was to compare the effect of three different fiber reinforcement strategies (placement of fibers in the occlusal position, splinting of the buccal and palatal walls with horizontal fiber posts, and placement of fibers at the occlusal position after splinting the buccal and palatal walls with horizontal fiber posts) on the fracture strength of composite resin restored endodontically treated premolars.

Material and Methods

Maxillary premolars with similar sizes in all the dimensions – with an approximate variation of ±1 mm – were used. All the teeth had been extracted for orthodontic reasons. Only teeth with no caries, previous restorations and cracks under sufficient illumination at a magnification of ×4 were included.

The formula to estimate the differences between two means were used to determine the sample size, which was estimated to be 72 by considering α=0.05, power of 80% and a mean difference of 600 N, in 6 groups of 12. The selected teeth were stored in 0.5% chloramine T solution (Formula & Ação, São Paulo, SP, Brazil) for disinfection for 48 hours before the study. Then the teeth were immersed in distilled water at 4°C until used for the purpose of the study. The teeth were randomly divided into 6 groups of 12 after the tooth surfaces were cleaned with hand scalers (Figure 1).
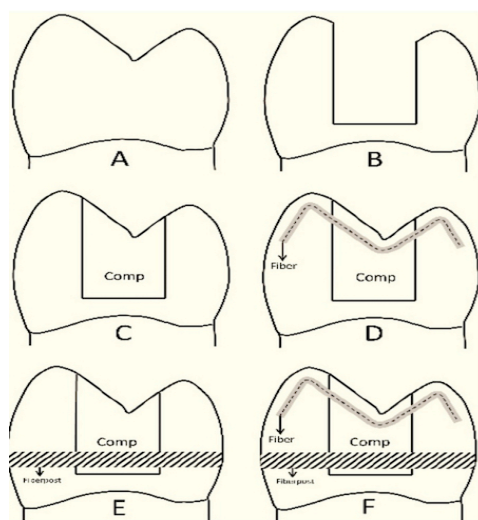

Figure 1. Schematic presentation of restorative procedures in study groups: A: Intact teeth, without root canal treatment and any restorations (positive control), B: Endodontically treated teeth without restoration (negative control), C: Endodontically treated teeth restored with composite resin, without fibers and/or horizontal fiber post, D: Endodontically treated teeth restored with placement of fibers at occlusal position, E: Endodontically treated teeth restored with the technique of splinting the buccal and palatal walls with horizontal fiber post, F: Endodontically treated teeth restored with placement of fibers at the occlusal position after splinting the buccal and palatal walls with horizontal fiber post.

- Group 1 (P-Crtl): Intact teeth, without root canal treatment and any restorations (positive control). The teeth did not undergo access cavity preparation and root canal treatment.
- Group 2 (RCT+MOD): Endodontically treated teeth without restoration (negative control). Standardized MOD cavities were prepared with a buccolingual dimension measuring 1/3 of the distance between the buccal and palatal cusp tips and a depth extending up to 1 mm from the CEJ. The width of the occlusal box was equal to the proximal width of the cavity. After pulpal debridement and irrigation with 1% sodium hypochlorite, each root canal was prepared with K-files (MANI Inc., Tochigi, Japan) #15 to #35 and #1 and #2 Gates-Glidden drills (MANI Inc., Tochigi, Japan). After irrigation with physiologic serum and drying with paper points, each root

canal was obturated with gutta-percha (GAPADent Co., LTD, Tianjin, China) and AH26 sealer (Dentsply DeTrey GMBH, Constance, Germany) using lateral condensation technique.

- Group 3 (RCT+MOD+CR): Endodontically treated teeth restored with composite resin, without fibers and/or horizontal fiber post. In this group, root canal treatment and access cavity preparation were similar to those of group 2. After etching the cavity for 15 seconds with 35% phosphoric acid (Scoltchbond Etchant, 3M Dental Products, St. Paul, MN, USA) and rinsing with water for 10 seconds, excess moisture was removed by cotton pellets and two layers of Single Bond (3M Dental Products, St. Paul, MN, USA) adhesive were applied according to manufacturer's instructions and light-cured for 10 seconds. Subsequently, the access cavities were restored with Valux Plus (3M Dental Products, St. Paul, MN, USA) composite resin using the incremental technique and each layer was cured by Litex 682 light-curing unit (Dentamerica Inc., Bedford circle, CA, USA) in soft start mode.

- Group 4 (RCT+MOD+OF+CR): Endodontically treated teeth restored with placement of fibers at occlusal position. In this group, root canal treatment, access cavity preparation and composite resin restoration procedures were similar to those of group 3. Then a groove measuring 2 mm in width and 1 mm in depth was prepared in the buccolingual direction toward the tips of the buccal and palatal cusps. After etching and bonding, flowable composite resin (Filtek Flow; 3M Dental Products, St. Paul, MN, USA) and fiberglass Interlig® (Angelus Ind. Prod. Odontológicos S/A, Londrina, PR, Brazil) were placed on the depth of the groove and light-cured for 40 seconds. Then the rest of the groove was restored with Valux Plus composite resin (3M Dental Products, St. Paul, MN, USA) to achieve anatomic form.

- Group 5 (RCT+MOD+GF+CR): Endodontically treated teeth restored with the technique of splinting the buccal and palatal walls with horizontal fiber post. In this group, the buccal and palatal walls were horizontally splinted with glass fiber post (Angelus Ind. Prod. Odontológicos S/A, Londrina, PR, Brazil). After root canal treatment and access cavity preparation in a manner similar to that of group 2, a #3145 diamond bur (KG Sorensen Ind. Com. Ltda., Barueri, SP, Brazil) was used to prepare a guide hole at the palatal surface height of contour and in the middle of the mesiodistal dimension of premolars until DEJ was reached. Placement of a hole at this location results in minimum weakening of the tooth structure because both enamel and dentin have the greatest thickness compared to other locations. The main holes were prepared in the buccal and palatal walls using the same high-speed bur under constant air and water spray using one motion so that both holes were placed in the same direction. The burs were replaced after making holes in 5 teeth. Before the cementation procedure, silane (Angelus Ind. Prod. Odontológicos S/A, Londrina, PR, Brazil) was applied to post surfaces. All the cavity surfaces were etched with 35% phosphoric acid and Single Bond adhesive system was applied according to manufacturer's instructions, followed by cementation of the post using flowable composite resin. Light-curing was carried out using Litex 682 light-curing unit (Dentamerica Inc., Bedford circle, CA, USA) for 30 seconds from the external surfaces of buccal and palatal surfaces. Before

placement of composite resin the pulp chamber was filled with flowable composite resin, the remainder of the cavity was restored with Values Plus composite resin using the incremental technique, and each layer was light-cured with Litex 682 light-curing unit (Dentamerica Inc., Bedford circle, CA, USA) in the soft-start curing mode. Subsequently, the teeth were incubated inside plastic containers containing distilled water at 37ºC for 24 hours. After incubation, excess post material was removed using the same diamond bur.

- Group 6 (RCT+MOD+OGF+CR): Endodontically treated teeth restored with placement of fibers at the occlusal position after splinting the buccal and palatal walls with horizontal fiber post. After root canal treatment and preparation of the access cavity similar to that in group 2, horizontal fiber post was placed and each tooth was restored with composite resin in a manner similar to that in group 5. Then glass fiber was placed at the most occlusal position similar to that in group 4 at the tip of the buccal and palatal cusps. Finally, the remainder of the cavity was restored with composite resin similar to group 5. After 24 hours of incubation in plastic containers containing distilled water at 37ºC, the excess post material was removed from the buccal and palatal cusps.

The teeth were mounted in plastic blocks made of self-curing acrylic resin up to 1.5 mm apical to the CEJ. Then a compressive force was applied at a crosshead speed of 0.5 mm/min by a steel spherical tip measuring 6.25 mm in diameter parallel to the tooth long axis, in a universal testing machine (H5K-S model/ Tinius Olsen, Ltd,. Surrey, England) until fracture occurred. The force at fracture was recorded in Newton.

In groups 4 and 6, in which it was necessary to place holes in the buccal and lingual walls with the use of a bur, cracks were possible to form on the walls. Therefore, all the specimens in these groups were evaluated under a stereomicroscope at ×4 after preparation of the holes; new specimens replaced specimens with cracks.

Evaluation of Fracture Patterns After Fracture Strength Test

Fracture patterns were divided into favorable (fractures extending up to 1 mm below CEJ), unfavorable (fractures extending more than 1 mm below the CEJ) fracture groups, and frequency percentages of fracture patterns were reported.

Data Analysis

Data were analyzed using IBM SPSS Statistics for Windows Software, version 20 (IBM Corp., Armonk, NY, USA). Descriptive statistics was used to calculate the mean and standard deviation. One-way ANOVA and post hoc Tukey tests were used. The significance level was set at 5%.

Ethical Aspects

This research was approved by the Ethics Research Committee of the Tabriz University of Medical Sciences (Protocol No. 271).

Results

The means, standard deviations and standard errors of fracture strength values and distribution of fracture patterns are presented in Table 1. One-way ANOVA showed significant differences in fracture strength between the groups (p<0.001). Two-by-two comparisons of the groups with post hoc Tukey tests showed significant differences between the negative and positive control groups (p<0.001) and between the negative control group and all the other study groups (3, 4, 5 and 6) (p<0.001). However, there were no statistically significant differences between the positive control group and all the experimental groups and between the experimental groups with each other (p>0.05).

In relation to fracture patterns, the fracture patterns in groups 2 and 3 were predominantly unfavorable and in groups 5 and 6 they were predominantly favorable. In addition, the fracture patterns of group 4 were equally favorable and unfavorable (Table 1).

Table 1. Mean values (N) and standard deviations (SD) of fracture strength values.

	Bond Strength			Fracture Patterns	
Groups	Mean	SD	Std. Error	Favorable	Unfavorable
G1	1073.63[a]	245.18	70.77	5	0
G2	461.83[b]	136.26	39.33	0	5
G3	1103.50[a]	378.48	109.26	3	9
G4	1122.16[a]	231.61	66.86	6	6
G5	1023.33[a]	295.53	85.31	10	2
G6	1097.50[a]	256.05	73.91	3	9

Different superscript means statistically significant differences.

Discussion

Fracture resistance of endodontically treated teeth is an important factor in the longevity of teeth, which is under the influence of restorative procedures. Various techniques have been suggested in different studies for the restoration and strengthening of compromised endodontically treated teeth [14,15,18-22]. Advances in adhesive dentistry and chemical composition of composite resins have resulted in the ability to render direct restorations with an acceptable strength and esthetic appearance for posterior teeth [23]. Another technical advance is the introduction of flexible posts, including fiber posts, which provide greater protection for the remaining tooth structure against fractures compared to metallic posts because they have an elastic modulus comparable to that of dentin [4].

In the present study, the fracture strength of group 1 (sound teeth) was higher than that in group 2 (MOD+RCT). Therefore, the strength was significantly reduced after access cavity and MOD preparations similar to previous studies [11,24]. It has been shown the amount of lost dentin affects distribution of stress in the remaining tooth structure. In intact teeth, enamel is supported by the bulk of dentin, resulting in a higher fracture resistance [25]. Preparation of an MOD cavity decreases cusp stiffness up to 63%; however, preparation of an endodontic access cavity alone decreases cusp stiffness by approximately 5% [26]. In the present study, the fracture resistance of

endodontically treated teeth with MOD cavities (group 2) decreased by 58% compared to group 1 (sound teeth).

Considering the significant decrease in fracture resistance of endodontically treated teeth due to the loss of support by marginal ridges and the pulp chamber roof, it is necessary to apply proper restorative techniques to restore strength and reinforcement of the remaining tooth structure [15]. Some previous studies have shown that bonded composite resin restorations increase the strength of these teeth to a greater extent compared to unbounded amalgam restorations [8,27,28]; however, some other studies have reported no differences between these two restorative techniques [24,29].

Adhesive restorative techniques with the use of direct restorative materials contribute significantly to fracture resistance, by creating a bond to distribute compressive strength across the tooth–restorative material interface, which protects the tooth against fracture and restores the fracture resistance of the tooth to a level comparable to that of an intact tooth [22,30]. A previous study showed that the amount of tooth strength that is restored with the use of amalgam and Spectrum TPH, Surefil, Esthet-X and Esthet-X + Dyract Flow composite resins is 17%, 60%, 59%, 54% and 99%, respectively [27]. The important finding of the study above was the fact that the amount of strength restored with the use of Dyract Flow was higher than that with the use of other composite resins. The modulus of elasticity of this flowable compomer is almost comparable to that of dentin (approximately 18.5 GPa); however, the modulus of elasticity of hybrid composite resins is around 16.6 MPa, which is a little different from that of dentin. Therefore, as shown in some previous studies, strength and resistance to cuspal flexure after restorative procedures depend on the modulus of elasticity of the restorative material [15,27].

Furthermore, in the present study, there were no significant differences between the groups 4, 5 and 6 (reinforced with fiber) and a group restored with composite resin only (group 3: RCT+MOD+CR). This is in agreement with the results reported previously [11,31] and different from the results reported by Brazilian [15] and and Turkish authors [12]. It has been reported that von Mises stress distribution characteristics were similar at restorative material-tooth interface of sound teeth and in teeth restored with direct composite resins and fiber-reinforced composite resins [32]. The use of polyethylene ribbon fibers beneath composite resin restorations in endodontically treated teeth with MOD cavities gives rise to higher fracture resistance compared to composite resin restorations [13]. Based on their suggestion, polyethylene ribbon fibers modified stresses at restorative material-dentin interface; in this context, the bonding ability of fiber in association with resin might have increased the fracture resistance of the tooth by keeping the cusps close together. The discrepancies between the results of studies might be attributed to the absence of standardized preparation techniques and/or a standardized test model, and differences in position of fibers and the loading angle [13,14,18,21].

Apart from the discussion on fracture resistance, comparison of fracture patterns is very important. Generally, since fractures 1 mm coronal to the CEJ are easily restored by restorative techniques, they are considered favorable. However, fractures deeper than this are considered

unfavorable because they cannot be easily restored and might need further therapeutic interventions such as crown lengthening and orthodontic forced eruption, and in some cases the tooth might even be a candidate for extraction [18,21,33]. In the present study, although there were no significant differences in fracture resistance between the different groups, the fracture patterns were predominantly unfavorable in groups 2 and 3 and favorable in groups 5 and 6. In addition, fractures were equally favorable and unfavorable in group 4. One reason for more favorable fractures in groups reinforced with fibers, compared to the CR group, was the relative coverage of the cusps with composite resin during placement of fibers in the occlusal area and the relative ability of the fiber post in the cervical area to splint the buccal and lingual walls with no cuspal coverage. A higher rate of favorable fracture pattern in cervical fiber groups has been shown in at least two other studies, too [15,18].

It is possible that this has been achieved by producing a restorative material-dentin mono-block in the cervical area and much better distribution of stresses or through interconnection of the cavity walls and creation of a stronger and more resistant area in the cervical area of the tooth [18]. In addition, although the circumferential fiber did not significantly affect the overall stress concentration pattern, it gave rise to better distribution of stresses in the cervical area. Occlusal fibers decreased the mean stress in the whole structure, without decreasing cuspal movements [34]. Recently, the results of another FEA study demonstrated that reconnecting buccal and lingual walls of an endodontically treated lower molars with a 2 mm wide FRC band modeled as ring around the middle of the crown has a positive effect on stress distribution, reduces stress concentration at the cavity wall-restorative material interface and enhances fracture resistance [35].

The forces applied in the present study to evaluate fracture resistance were static forces. It has been claimed that dynamic fatigue test simulates the clinical situation better and is the gold standard for the evaluation of fatigue, due to the effect of oral movements on tooth restorations [36,37]. Therefore, it is suggested that dynamic fatigue testing be used in future studies in order to simulate clinical conditions.

Conclusion

Composite resin restoration restores fracture strength of endodontically treated maxillary premolars approximately to the level of sound teeth. Fiber reinforcement has no additional reinforcing effect on fracture strength of composite resin-restored endodontically treated maxillary premolars. Finally, fracture patterns in cervical fiber-reinforced samples are more favorable than occlusally oriented fiber and no-fiber groups.

Authors' Contributions: Each author made significant individual contributions to this manuscript. MB, NM, SK, and MAK conceived and designed the experiment. HV, MMT, and ASO performed the experiments. MB, SK and MAK analyzed and interpreted the data. All authors wrote the paper, read and confirmed publication of the paper.

References

[1]   Dietschi D, Duc O, Krejci I, Sadan A. Biomechanical considerations for the restoration of endodontically treated teeth: A systematic review of the literature - Part 1. Composition and micro-and macrostructure alterations. Quintessence Int 2007; 38(9):733-43.

[2]   Tang W, Wu Y, Smales RJ. Identifying and reducing risks for potential fractures in endodontically treated teeth. J Endod 2010; 36(4):609-17. https://doi.org/10.1016/j.joen.2009.12.002

[3]   Kishen A. Mechanisms and risk factors for fracture predilection in endodontically treated teeth. Endod Topics 2006; 13(1):57-83.

[4]   Bitter K, Kielbassa AM. Post-endodontic restorations with adhesively luted fiber-reinforced composite post systems: A review. Am J Dent 2007; 20(6):353-60.

[5]   Shu X, Mai QQ, Blatz M, Price R, Wang XD, Zhao K. Direct and indirect restorations for endodontically treated teeth: A systematic review and meta-analysis, IAAD 2017 Consensus Conference Paper. J Adhes Dent 2018; 20(3):183-94. https://doi.org/10.3290/j.jad.a40762

[6]   Zarow M, Ramírez-Sebastià A, Paolone G, de Ribot Porta J, Mora J, Espona J, et al. A new classification system for the restoration of root filled teeth. Int Endod J 2018; 51(3):318-34. https://doi.org/10.1111/iej.12847

[7]   Smales R, Hawthorne W. Long-term survival of extensive amalgams and posterior crowns. J Dent 1997; 25(3-4):225-7.

[8]   Hürmüzlü F, Kiremitci A, Serper A, Altundaşar E, Siso SH. Fracture resistance of endodontically treated premolars restored with ormocer and packable composite. J Endod 2003; 29(12):838-40.
https://doi.org/10.1097/00004770-200312000-00014

[9]   Meiers JC, Duncan JP, Freilich MA, Goldberg AJ. Preimpregnated, fiber-reinforced prostheses. Part II. Direct applications: Splints and fixed partial dentures. Quintessence Int 1998; 29(12):761-8.

[10]   Eskitaşcıoğlu G, Belli S, Kalkan M. Evaluation of two post core systems using two different methods (fracture strength test and a finite elemental stress analysis). J Endod 2002; 28(9):629-33.
https://doi.org/10.1097/00004770-200209000-00001

[11]   Sengun A, Cobankara FK, Orucoglu H. Effect of a new restoration technique on fracture resistance of endodontically treated teeth. Dent Traumatol 2008; 24(2):214-9.
https://doi.org/10.1111/j.1600-9657.2007.00538.x

[12]   Belli S, Erdemir A, Yildirim C. Reinforcement effect of polyethylene fibre in root-filled teeth: Comparison of two restoration techniques. Int Endod J 2006; 39(2):136-42. https://doi.org/10.1111/j.1365-2591.2006.01057.x

[13]   Belli S, Erdemir A, Ozcopur M, Eskitascioglu G. The effect of fibre insertion on fracture resistance of root filled molar teeth with MOD preparations restored with composite. Int Endod J 2005; 38(2):73-80.
https://doi.org/10.1111/j.1365-2591.2004.00892.x

[14]   Oskoee PA, Ajami AA, Navimipour EJ, Oskoee SS, Sadjadi J. The effect of three composite fiber insertion techniques on fracture resistance of root-filled teeth. J Endod 2009; 35(3):413-6.
https://doi.org/10.1016/j.joen.2008.11.027

[15]   Beltrão MC, Spohr AM, Oshima H, Mota EG, Burnett LH Jr. Fracture strength of endodontically treated molars transfixed horizontally by a fiber glass post. Am J Dent 2009; 22(1):9-13.

[16]   Sungur DD, Ersu B, Tezvergil-Mutluy A, Canay S. The fracture resistance of composite core materials reinforced by varying fiber orientations. J Int Prosthodont 2017; 30(1):25-6. https://doi.org/10.11607/ijp.4899

[17]   Hshad ME, Dalkilic EE, Ozturk GC, Dogruer I, Koray F. Influence of different restoration techniques on fracture resistance of root-filled teeth: In vitro investigation. Oper Dent 2018; 43(2):162-9.
https://doi.org/10.2341/17-040-l

[18]   Navimipour EJ, Chaharom MEE, Oskoee PA, Mohammadi N, Bahari M, Firouzmandi M. Fracture resistance of endodontically-treated maxillary premolars restored with composite resin along with glass fiber insertion in different positions. J Dent Res Dent Clin Dent Prospects 2012; 6(4):125-30.
https://doi.org/10.5681/joddd.2012.026

[19]   Oskoee SS, Bahari M, Daneshpooy M, Ajami AA, Rahbar M. Effect of different intraorifice barriers and bleaching agents on the fracture resistance of endodontically treated anterior teeth. J Endod 2018; 44(11):1731-5.
https://doi.org/10.1016/j.joen.2018.07.025

[20]   Oskoee SS, Bahari M, Kimyai S, Asgary S, Katebi K. Push-out bond strength of fiber posts to intraradicular dentin using multimode adhesive system. J Endod 2016; 42(12):1794-8. https://doi.org/10.1016/j.joen.2016.08.025

[21] Oskoee SS, Oskoee PA, Navimipour EJ, Ajami AA, Zonuz GA, Bahari M, et al. The effect of composite fiber insertion along with low-shrinking composite resin on cuspal deflection of root-filled maxillary premolars. J Contemp Dent Pract 2012; 13(5):595-601.

[22] Monaco C, Arena A, Scotti R, Krejci I. Fracture strength of endodontically treated teeth restored with composite overlays with and without glass-fiber reinforcement. J Adhes Dent 2016; 18(2):143-9. https://doi.org/10.3290/j.jad.a35908

[23] Bohaty BS, Ye Q, Misra A, Sene F, Spencer P. Posterior composite restoration update: Focus on factors influencing form and function. Clin Cosmet Investig Dent 2013; 5:33-42. https://doi.org/10.2147/CCIDE.S42044

[24] Joynt R, Wieczkowski G, Klockowski R, Davis E. Effects of composite restorations on resistance to cuspal fracture in posterior teeth. J Prosthet Dent 1987; 57(4):431-5.

[25] Lin CL, Chang CH, Wang CH, Ko CC, Lee HE. Numerical investigation of the factors affecting interfacial stresses in an MOD restored tooth by auto-meshed finite element method. J Oral Rehabil 2001; 28(6):517-25. https://doi.org/10.1046/j.1365-2842.2001.00689.x

[26] Reeh ES, Messer HH, Douglas WH. Reduction in tooth stiffness as a result of endodontic and restorative procedures. J Endod 1989; 15(11):512-6. https://doi.org/10.1016/S0099-2399(89)80191-8

[27] Cerutti A, Flocchini P, Madini L, Mangani F, Putignano A, Docchio F. Effects of bonded composites vs. amalgam on resistance to cuspal deflection for endodontically-treated premolar teeth. Am J Dent 2004; 17(4):295-300.

[28] Reeh E, Douglas W, Messer H. Stiffness of endodontically-treated teeth related to restoration technique. J Dent Res 1989; 68(11):1540-4. https://doi.org/10.1177/00220345890680111401

[29] Steele A, Johnson BR. In vitro fracture strength of endodontically treated premolars. J Endod 1999; 25(1):6-8. https://doi.org/10.1016/S0099-2399(99)80389-6

[30] Scotti N, Forniglia A, Tempesta RM, Comba A, Saratti CM, Pasqualini D, et al. Effects of fiber-glass-reinforced composite restorations on fracture resistance and failure mode of endodontically treated molars. J Dent 2016; 53:82-7. https://doi.org/10.1016/j.jdent.2016.08.001

[31] Cobankara F, Unlu N, Cetin A, Ozkan H. The effect of different restoration techniques on the fracture resistance of endodontically-treated molars. Oper Dent 2008; 33(5):526-33. https://doi.org/10.2341/07-132

[32] Eraslan Ö, Eraslan O, Eskitaşcıoğlu G, Belli S. Conservative restoration of severely damaged endodontically treated premolar teeth: A FEM study. Clin Oral Investig 2011; 15(3):403-8. https://doi.org/10.1007/s00784-010-0397-7

[33] Uyehara MY, Davis RD, Overton JD. Cuspal reinforcement in endodontically treated molars. Oper Dent 1999; 24(6):364-70.

[34] Navimipour E, Firouzmandi M, Mirhashemi F. Finite element analysis of the endodontically-treated maxillary premolars restored with composite resin along with glass fiber insertion in various positions. J Contemp Dent Pract 2015; 16(4):284-90.

[35] Daher R, Feilzer AJ, Krejci I. Novel non-invasive reinforcement of MOD cavities on endodontically treated teeth. J Dent 2016; 54:77-85. https://doi.org/10.1016/j.jdent.2016.09.008

[36] Kim Y-H, Lee J-H. Influence of modification in core building procedure on fracture strength and failure patterns of premolars restored with fiber post and composite core. J Adv Prosthodont 2012; 4(1):37-42. https://doi.org/10.4047/jap.2012.4.1.37

[37] Sterzenbach G, Rosentritt M, Frankenberger R, Paris S, Naumann M. Loading standardization of postendodontic restorations in vitro: impact of restorative stage, static loading, and dynamic loading. Oper Dent 2012; 37(1):71-9. https://doi.org/10.2341/10-355-L