Journal of
Dental Research, Dental Clinics, Dental Prospects

Original Article

Fracture Resistance of Endodontically-treated Maxillary Premolars Restored with Composite Resin along with Glass Fiber Insertion in Different Positions

Elmira Jafari Navimipour[1] • Mohammad Esmaeel Ebrahimi Chaharom[2] • Parnian Alizadeh Oskoee[1]* • Narmin Mohammadi[1] • Mahmoud Bahari[2] • Maryam Firouzmandi[3]

[1]*Associate Professor, Department of Operative Dentistry, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran*
[2]*Assistant Professor, Department of Operative Dentistry, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran*
[3]*Post-graduate Student, Department of Operative Dentistry, Faculty of Dentistry, Tabriz University of Medical Sciences, Tabriz, Iran*
**Corresponding Author; E-mail: parnianoskuee@yahoo.com*

Received: 26 May 2012; Accepted: 3 September 2012
J Dent Res Dent Clin Dent Prospect 2012; 6(4) :125-130 | doi: 10.5681/joddd.2012.026
This article is available from: http://dentistry.tbzmed.ac.ir/joddd

Abstract

Background and aims. The aim was to evaluate the effect of three methods of fiber insertion on fracture resistance of root-filled maxillary premolars *in vitro*.

Materials and methods. Sixty extracted human maxillary premolars received endodontic treatment followed by preparation of mesioocclusodistal (MOD) cavities, with gingival cavosurface margin 1.5 mm coronal to the cementoenamel junction (CEJ). Subsequently, the samples were randomly divided into four groups: no-fiber group; occlusal fiber group (fiber was placed in the occlusal third); circumferential fiber group (fiber was placed circumferentially in the cervical third); and dual-fiber group (occlusal and circumferential fibers). Subsequent to restoring with composite resin and thermocycling, a compressive force was applied until fracture. Data was analyzed using one-way ANOVA and Tukey test at significance levels of $P < 0.05$ and $P < 0.02$, respectively.

Results. Fiber placement significantly increased fracture resistance. Fracture resistance in the dual-fiber group was significantly higher than that in the circumferential fiber group ($P < 0.007$); however, there were no significant differences between the dual-fiber and occlusal fiber groups ($P = 0.706$). The highest favorable fracture rate was observed in the circumferential fiber group (60%).

Conclusion. Composite resin restoration along with glass fiber in the occlusal and gingival thirds can be an acceptable treatment option for restoring root-filled upper premolars.

Key words: **Endodontically treated teeth, fiber-reinforced composite resin, fracture resistance.**

Introduction

Endodontically treated teeth are more susceptible to fracture than teeth with vital pulps. This susceptibility has been attributed primarily to the structural defects due to caries and tooth preparation.[1] The loss of anatomic structures, such as pulp chamber roof and one or both marginal ridges, leads to a greater risk of fracture.[2] Considering the results of previous studies, the amount of residual coronal dentin appears to be the most important factor in the prognosis of an endodontically treated tooth.[3-6] Fracture resistance and the amount of remaining tooth structure after endodontic treatment are influenced by restorative procedures.[5] In spite of extensive studies on root-filled teeth, the optimal treatment planning for final restoration in endodontically-treated posterior teeth remains contentious.[1]

Root-filled upper premolars present specific challenges for the restorative dentist because in addition to esthetic considerations, cusp fracture is found to be more concentrated in these teeth.[7,8] Furthermore, longitudinal root fractures are more common in upper premolars with narrow roots in the mesiodistal dimension,[9] and post space preparation may expose the teeth to an increased risk of root perforation and root fracture; therefore, controversy over the use of posts is increasing.[5,10] In an attempt to avoid post placement horizontal pins were evaluated in a study; however, they failed to reinforce endodontically treated maxillary premolars.[11]

Restoration of a tooth with adhesive procedures and direct resin-bonded composites (RBC) eliminates the need for sacrificing any tooth structure and over-preparation. Following endodontic treatment and caries removal all the residual tooth structure would be a substrate for adhesion.[12] RBC restorations are also more economic and cheaper than indirect restorations that have additional laboratory costs. Furthermore, these procedures are less time-consuming. Fiber reinforcement systems are the most recent innovative techniques used to increase durability and damage tolerance of RBC materials.[13,14] Although some studies have investigated performance of fiber-reinforced composites (FRC) in diverse fields of dentistry, there is a limited amount of scientific literature on the use of FRC materials as single tooth restorations. According to the results of previous studies, insertion of a piece of polyethylene fiber into the cavity in the gingival and occlusal third increases fracture resistance in molars.[15-17] However, two layers of glass fiber placed at the bottom and at the former roof of the pulp chamber has no positive effect on fracture resistance.[18] In another study a ribbon of glass fiber in the occlusal third of the restoration was advantageous in relation to fracture resistance and fracture mode.[19] Considering the importance of fiber location in reinforcement of composite resin restorations in endodontically-treated upper premolars the present study was designed to evaluate this effect. The null hypotheses tested were the following: 1. There is no difference in fracture resistance of teeth restored with FRC with different fiber locations. 2. Fiber location does not affect the fracture pattern.

Materials and Methods

Sixty human maxillary premolars with approximately the same size (measured mesiodistally and faciolingually by means of a digital caliper) which were free of any caries, previous restorations, fractures and cracks were used for the purpose of this *in vitro* study. They were surveyed under a stereomicroscope (Nikon, Tokyo, Japan) at magnification of ×2. The teeth had been extracted for orthodontic reasons. The teeth were stored in 0.5% chloramine T trihydrate at 4ºC for no more than three month after debridement with a scalpel to remove remaining tissue tags. Subsequent to preparation of an endodontic access cavity, the root canals were instrumented 1 mm short of the apical foramen with K-files (Dentsply Maillefer, Simfra, Switzerland) to an apical size 35 using step-back technique. Coronal thirds of the root canals were flared using #1 through #3 Gates-Glidden drills (MANI, Nakaakusu, Japan) and obturated with gutta-percha (Diadent Group, Chongju, Korea) and AH26 root canal sealer (Dentsply, Konstanz, Germany) using lateral condensation technique. Each tooth was embedded in an acrylic resin cylinder up to 1.5 mm below the CEJ. Then MOD cavities were prepared in such a manner that the remaining lingual and buccal wall thicknesses measured 2.5±0.2 mm in the height of contour of each surface and the gingival cavosurface margin was 1.5 mm coronal to the CEJ. Subsequently, the teeth were randomly assigned to four groups of 15 teeth each.

In the no-fiber group, the teeth were etched with 35% phosphoric acid (Scotch Bond Etchant; 3M ESPE, St Paul, MN, USA) for 15 seconds. Then, the tooth surfaces were rinsed for 10 seconds and gently dried for 1-2 seconds in a way that the moist condition of the dentin was preserved. Subsequently, an adhesive resin (Single Bond; 3M ESPE) was used according to manufacturer’s instructions and cured by a light-curing unit (Astralis 7; Ivoclar Vivadent, Liechtenstein, Austria) for 10 seconds at a light intensity of 400 mW/cm^2. A metal matrix held by a retainer was placed around each tooth and the cavity was restored with composite resin (Filtek Z250; 3M ESPE) using the incremental technique. The layers were placed at thicknesses of 1.5 mm, and each layer was cured for 40 seconds with the pulse program of the light-curing unit from the occlusal aspect. In this curing program the initial intensity of 150 mW/cm^2 increases incrementally within 15 seconds up to 400 mW/cm^2 and then during the remaining time it oscillates between 400 mW/cm^2 and 750 mW/cm^2.

In the occlusal fiber group, after finishing restoration of the cavities as described for the no-fiber group, a groove measuring 2 mm in width and 1 mm in depth was prepared buccolingually on the cusp tips. The ends of the groove were on the occlusal third of the buccal and lingual surfaces. After etching and bonding, a piece of glass fiber (Interlig; Angelus, Londrina PR, Brazil) was adapted to the floor of the groove using flowable composite (Filtek Flow; 3M ESPE), and the combination was cured for 40 seconds using the pulse program. The exposed fiber surface was also filled with composite resin (Figure 1A). The glass fiber used in this study was a pre-impregnated intertwined tape measuring 2 mm in width and 0.2 mm in thickness.

In the circumferential fiber group, after etching and bonding as described in the no-fiber group, tooth restoration began by placing 1±0.5-mm-thick composite resin in the mesial and distal aspects to reconstruct proximal surfaces. Then the glass fiber was adapted inside the cavity walls in a circumferential manner using flowable composite resin; the rest of the cavity was incrementally restored with composite resin similar to the no-fiber group (Figure 1B). In the dual-fiber group, after placing the circumferential fiber, the rest of the cavity was restored in a manner similar to the occlusal fiber group.

After the matrix was removed, all the restorations were light-cured from the mesial and distal directions for 40 seconds using the pulse program, finished using flame-shaped fine diamond burs (MANI, Nakaakusu, Japan) and polished using Sof-Lex discs (3M ESPE). Subsequent to thermocycling (500 cycles at 5±2ºC/55±2ºC, a 30-second dwell time, and a 5-second transfer time), all the specimens were

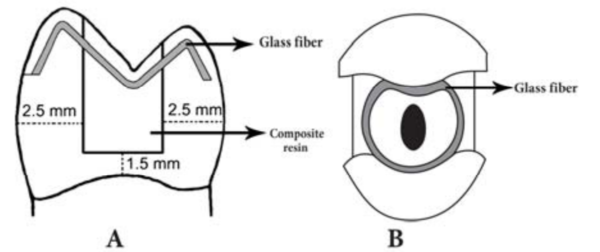

Figure 1. Schematic representation of groups. (A) Occlusal fiber; (B) Circumferential fiber.

stored in an incubator at 37ºC and 100% relative humidity for 24 hours.

Finally, a compressive force was applied at a strain rate of 0.5 mm/min using a universal testing machine (Hounsfield Test Equipment, H5K-S Model; Surrey, England). A 5-mm-diameter round bar was positioned parallel to the long axis of the teeth and centered over the teeth until the bar just contacted the occlusal surface of the restoration on the buccal and lingual cusp inclines. Then, the force necessary to fracture each tooth was measured in Newton (N). According to failure modes, the fractures were divided into two groups: favorable fractures in which the fractures stopped higher than 1 mm below the CEJ; unfavorable fractures in which the fractures stopped lower than 1 mm below the CEJ.[20] From another aspect, the failure mode classification was based on cusp detachment.[17]

Statistical analysis was performed using descriptive statistical methods (mean ± standard deviation, frequency [%]) and one-way ANOVA followed by a post hoc Tukey test. Statistical significance levels of ANOVA and post hoc test were defined as $P<0.05$ and $P<0.02$, respectively.

Results

The maximum, minimum and mean values of fracture resistance in each of the four experimental groups are presented in Table 1.

One-way ANOVA indicated statistically significant differences among the groups ($P<0.0001$). A post hoc Tukey test revealed significantly lower fracture resistance in the no-fiber group when compared to the other groups ($P<0.02$). Inserting a piece of

Table 1. Mean fracture resistance in the study groups

Group	No.	Mean ± SD	Minimum	Maximum
No fiber	15	885 ± 356	384	1580
Occlusal fiber	15	1593 ± 300	1081	2015
Circumferential fiber	15	1316 ± 406	578	2090
Dual-fiber [a]	15	1726 ± 246	1271	2170

SD: Standard Deviation.
[a] Occlusal and circumferential fiber

Table 2. The frequency (%) of different failure modes among the study groups

Group	Favorable fracture	Unfavorable fracture	Cusp detachment
No fiber	5 (33.3)	10 (66.7)	14 (93.3)
Occlusal fiber	2 (13.3)	13 (86.7)	13 (86.7)
Circumferential fiber	9 (60.0)	6 (40.0)	13 (86.7)
Dual-fiber	7 (46.7)	8 (53.3)	13 (86.7)

glass fiber from the buccal to the lingual aspect in the occlusal portion of the restoration or a circumferential fiber in the base of the restoration significantly increased fracture resistance when compared to the no-fiber group ($P<0.02$), but there were no significant differences between these two groups ($P=0.127$). When occlusal and circumferential fibers were used simultaneously, fracture resistance was significantly higher than that in the circumferential fiber group ($P=0.007$), but this did not mean significantly higher fracture resistance compared to the occlusal fiber group ($P=0.706$).

Regarding failure mode, the highest and the lowest rates of favorable fractures were observed in the circumferential and occlusal fiber groups, respectively, and most of the fractured cusps had been detached from the teeth (Table 2).

Discussion

Premolars are more likely than molars to be subjected to lateral forces with more detrimental nature.[21] Bearing in mind their position in the esthetic zone, esthetic requirements should be fully achieved when restoring upper premolars. Cusp elongation in maxillary premolars due to pulp chamber roof removal in the process of endodontic access cavity preparation tends to separate the buccal and palatal cusps under occlusal load,[22] and post placement in restoration of these teeth should better be avoided because of their anatomic root form.[9] In addition, the width of tooth preparation influences cusp fracture of these teeth in such a way that MOD cavity is considered the worst case in terms of fracture resistance.[23,24] Therefore, in the current study preparation of MOD cavity was considered for simulation of the worst clinical situation. Clinically, the normal biting force is 222–445 N (average 322.5 N) for the maxillary premolar area and during clenching, the occlusal force is as high as 520–800 N (average 660 N).[25,26] Therefore, it seems that all the experimental groups in the present study could withstand the functional and parafunctional loads generated in the mouth; however, it should be taken into account that some clinical situations such as thermal changes, chemical agents, and fatigue phenomena as a result of repeated stresses may lead to the failure of restorations far below the ultimate fracture resistance; therefore, this kind of *in vitro* static loading, may overestimate the fracture resistance of the tested specimens. Further clinical trials should be conducted to validate the results of this *in vitro* study.

Polymerization shrinkage and consequent stresses generated in the tooth-tissue and the tooth-restoration interfaces are the main drawbacks of composite resin restorations. Incremental placement of composite resins, which is supposed to reduce this effect,[27] was used in this study to achieve maximum curing and minimum polymerization shrinkage.

Based on the results of this study, incorporation of pre-impregnated glass fiber into composite restorations increases fracture resistance of teeth. Some studies have reached the same conclusion that FRC restorations can significantly increase fracture resistance through an increase in the flexural strength of the whole structure.[19,28] The special orientation of the fiber network efficiently transfers stresses. It is practically supple and thus can be easily formed to the arbitrary configuration. Its optical properties make it an excellent esthetic material. The reinforcing capacity of fibers depends on their adhesion properties, orientation of the fibers, and impregnation with the resin.[29,30] Other desirable physical properties of the fiber are good flexural strength and no need for mechanical retention within the restoration.[31]

In the present study placing fibers in the occlusal third of the cavities significantly increased fracture resistance, which is consistent with the results of some previous studies.[17,19] The anchorage promoted by occlusal fiber in the most approximate position to the applied load leads to a shorter working arm according to levers principle in addition to keeping the buccal and lingual cusps together through splinting mechanism, recovering the fracture resistance. Orientation of occlusal fibers following cusp inclines allows a greater fiber volume fraction and it has been shown that use of a higher volume of fibers results in a higher fracture resistance.[32] In a previous study there was no significant difference between FRC restoration and conventional composite restoration of maxillary premolars in relation to fracture strength. Although location and orientation of fibers was similar to the occlusal fiber group in the present study, the simulated load was at an angle of 45º to the long axis of the tooth in that study.[33] Direction of load would affect reinforcing capacity of fibers since it has been shown that directional orientation of the fiber's long axis perpendicular to an applied force will result in strength reinforcement.[34]

In the present study circumferential fibers in the gingival portion also increased fracture resistance. As with previous studies, the increase in fracture resistance might be explained by elastic properties of fiber assemblies and their stress-modifying ability.[15,16,35] Elastic modulus of fiber is similar to that of dentin[36] and is supposed to create a mono-block dentin-restoration system through intimate and simultaneous contact with the four walls of the cavity; therefore, it can better distribute forces. This method of fiber placement might have protected the cusps by shortening their heights, avoiding the separation of cusps as a result of the wedging effect. In the present study reconstruction of proximal walls with 2 mm of occlusogingival layers of composite resin might have increased C-factor and consequently the negative effect of polymerization shrinkage stress; the use of a low-viscosity flowable composite resin in combination with a bonding agent can counteract this effect.[37]

In this study application of circumferential and occlusal fibers led to fracture resistance higher than that of circumferential fiber alone, but it was not significantly higher than that in the occlusal fiber group, which can be explained from two aspects. First, according to levers principle the anchorage created by occlusal fibers leads to a shorter working arm than circumferential fibers in the gingival portion. Second, in these biaxially braided fibers, the fiber orientation can change after cutting during adaptation to tooth contours. The fibers in the ribbon spread out and separate from each other. Not being perpendicular to the applied force results in little actual reinforcement as with the circumferential fibers.[34]

In the present study the failure modes were classified as favorable and unfavorable according to the position of fracture line in relation to the cementoenamel junction, which is useful in predicting the prognosis of a restored tooth in case of failure. In fact, fractures that extend not more than 1 mm below the CEJ can be restored successfully.[20] According to the results, restoration of teeth only with composite resin results in relatively low fracture resistance and the majority of failures (66.7%) were unfavorable. Application of occlusal fibers was advantageous in relation to fracture resistance but most of the failures (86.7%) were catastrophic in nature. This kind of fracture pattern was attributed to the morphology of the MOD preparations, leaving limited amounts of residual tooth structure in the cervical region. Although circumferential fiber at the base of the cavity restored fracture resistance less than the occlusal fibers, it resulted in more favorable fracture patterns (60%). This might have been achieved through production of a restoration-dentin mono-block in the cervical region and favorable stress distribution pattern or interconnecting the cavity walls and creating a more strong and resistant region in the cervical third of the tooth.

Considering the conditions of the oral cavity, including the moisture and accessibility, placing such laborious and technique-sensitive restorations may be a difficult and demanding procedure. Since visualization of stress distribution within restored teeth provides an insight into the optimum treatment planning for endodontically-treated teeth, stress distribution analysis using finite element method is suggested for future studies.

Within the limitations of this *in vitro* study, incorporation of occlusal and circumferential glass fibers simultaneously in direct composite resin restorations might be an acceptable conservative treatment option for post-endodontic MOD cavities in maxillary premolars.

Acknowledgements

This project was carried out by the financial support from the Deputy Dean of Research at Tabriz University of Medical Sciences. The authors thank Dr. Morteza Ghojazadeh for statistical analysis of the data and Dr. Majid Abdolrahimi for editing the English manuscript.

References

1. Faria AC, Rodrigues RC, de Almeida Antunes RP, de Mattos Mda G, Ribeiro RF. Endodontically treated teeth: characteristics and considerations to restore them. *J Prosthodont Res* 2011;55:69-74.
2. Burke FJ. Tooth fracture in vivo and in vitro. *J Dent* 1992;20:131-9.
3. Bitter K, Noetzel J, Stamm O, Vaudt J, Meyer-Lueckel H, Neumann K, et al. Randomized clinical trial comparing the effects of post placement on failure rate of postendodontic restorations: preliminary results of a mean period of 32 months. *J Endod* 2009;35:1477-82.
4. Stockton L, Lavelle CL, Suzuki M. Are posts mandatory for the restoration of endodontically treated teeth? *Endod Dent Traumatol* 1998;14:59-63.
5. Peroz I, Blankenstein F, Lange KP, Naumann M. Restoring endodontically treated teeth with posts and cores—a review. *Quintessence Int* 2005;36:737-46.
6. Seow LL, Toh CG, Wilson NH. Remaining tooth structure associated with various preparation designs for the endodontically treated maxillary second premolar. *Eur J Prosthodont Restor Dent* 2005;13:57-64.

7. Cavel WT, Kelsey WP, Blankenau RJ. An in vivo study of cuspal fracture. *J Prosthet Dent* 1985;53:38-42.
8. Lagouvardos P, Sourai P, Douvitsas G. Coronal fractures in posterior teeth. *Oper Dent* 1989;14:28-32.
9. Tamse A, Zilburg I, Halpern J. Vertical root fractures in adjacent maxillary premolars: an endodontic-prosthetic perplexity. *Int Endod J* 1998;31:127-32.
10. Youngson C. Posts and the root-filled tooth. *Br Dent J* 2005;198:379.
11. Oskoee SS, Oskoee PA, Navimipour EJ, Shahi S. *In vitro* fracture resistance of endodontically-treated maxillary premolars. *Oper Dent* 2007;32:510-4.
12. Grandini S, Goracci C, Tay FR, Grandini R, Ferrari M. Clinical evaluation of the use of fiber posts and direct resin restorations for endodontically treated teeth. *Int J Prosthodont* 2005;18:399-404.
13. Abdulmajeed AA, Narhi TO, Vallittu PK, Lassila LV. The effect of high fiber fraction on some mechanical properties of unidirectional glass fiber-reinforced composite. *Dent Mater* 2011;27:313-21.
14. van Heumen CC, Kreulen CM, Bronkhorst EM, Lesaffre E, Creugers NH. Fiber-reinforced dental composites in beam testing. *Dent Mater* 2008;24:1435-43.
15. Belli S, Cobankara FK, Eraslan O, Eskitascioglu G, Karbhari V. The effect of fiber insertion on fracture resistance of endodontically treated molars with MOD cavity and reattached fractured lingual cusps. *J Biomed Mater Res B Appl Biomater* 2006;79:35-41.
16. 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;38:73-80.
17. Belli S, Erdemir A, Yildirim C. Reinforcement effect of polyethylene fibre in root-filled teeth: comparison of two restoration techniques. *Int Endod J* 2006;39:136-42.
18. Hitz T, Ozcan M, Gohring TN. Marginal adaptation and fracture resistance of root-canal treated mandibular molars with intracoronal restorations: effect of thermocycling and mechanical loading. *J Adhes Dent* 2010;12:279-86.
19. 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;35:413-6.
20. Uyehara MY, Davis RD, Overton JD. Cuspal reinforcement in endodontically treated molars. *Oper Dent* 1999;24:364-70.
21. Schwartz RS, Robbins JW. Post placement and restoration of endodontically treated teeth: a literature review. *J Endod* 2004;30:289-301.
22. Mondelli RF, Ishikiriama SK, de Oliveira Filho O, Mondelli J. Fracture resistance of weakened teeth restored with condensable resin with and without cusp coverage. *J Appl Oral Sci* 2009;17:161-5.
23. Panitvisai P, Messer HH. Cuspal deflection in molars in relation to endodontic and restorative procedures. *J Endod* 1995;21:57-61.
24. Steele A, Johnson BR. In vitro fracture strength of endodontically treated premolars. *J Endod* 1999;25:6-8.
25. Hidaka O, Iwasaki M, Saito M, Morimoto T. Influence of clenching intensity on bite force balance, occlusal contact area, and average bite pressure. *J Dent Res* 1999;78:1336-44.
26. Widmalm SE, Ericsson SG. Maximal bite force with centric and eccentric load. *J Oral Rehabil* 1982;9:445-50.
27. Wilson EG, Mandradjieff M, Brindock T. Controversies in posterior composite resin restorations. *Dent Clin North Am* 1990;34:27-44.
28. Garoushi S, Lassila LV, Tezvergil A, Vallittu PK. Load bearing capacity of fibre-reinforced and particulate filler composite resin combination. *J Dent* 2006;34:179-84.
29. Karbhari VM, Strassler H. Effect of fiber architecture on flexural characteristics and fracture of fiber-reinforced dental composites. *Dent Mater* 2007;23:960-8.
30. 30.Miettinen VM, Vallittu PK, Docent DT. Water sorption and solubility of glass fiber-reinforced denture polymethyl methacrylate resin. *J Prosthet Dent* 1997;77:531-4.
31. 31.Feinman RA, Smidt A. A combination porcelain/fiber-reinforced composite bridge: a case report. *Pract Periodontics Aesthet Dent* 1997;9:925-9; quiz 30.
32. Rashidan N, Esmaeili V, Alikhasi M, Yasini S. Model system for measuring the effects of position and curvature of fiber reinforcement within a dental composite. *J Prosthodont* 2010;19:274-8.
33. Sengun A, Cobankara FK, Orucoglu H. Effect of a new restoration technique on fracture resistance of endodontically treated teeth. *Dent Traumatol* 2008;24:214-9.
34. DeBoer J, Vermilyea SG, Brady RE. The effect of carbon fiber orientation on the fatigue resistance and bending properties of two denture resins. *J Prosthet Dent* 1984;51:119-21.
35. 35.Eraslan O, Eskitascioglu G, Belli S. Conservative restoration of severely damaged endodontically treated premolar teeth: a FEM study. *Clin Oral Investig* 2011;15:403-8.
36. Vitale MC, Caprioglio C, Martignone A, Marchesi U, Botticelli AR. Combined technique with polyethylene fibers and composite resins in restoration of traumatized anterior teeth. *Dent Traumatol* 2004;20:172-7.
37. Kemp-Scholte CM, Davidson CL. Marginal integrity related to bond strength and strain capacity of composite resin restorative systems. *J Prosthet Dent* 1990;64:658-64.