A comparison of the effect of three direct composite resin restoration techniques on the fracture resistance of endodontically treated maxillary premolars

Haleh Kazemi Yazdi[1], Nazanine Aryan [2], Mahyar Shahbazi Moghdam [1]

[1]*Assistant Professor, Restorative Dentistry Dept, School of Dentistry, Islamic Azad University, Tehran, Iran*
[2] *Specialist in Restorative Dentistry*

ABSTRACT

Background and Aim: Failure of restored teeth after endodontic treatment is one of the challenges faced in restorative dentistry. Premolar teeth are more likely to fracture due to exposure to tensile stress and inappropriate anatomical shape. Therefore, the aim of this study was the comparison of the fracture resistance of maxillary premolars which were restored with composite resin, composite resin with glass ionomer lining and composite resin reinforced with fiber post.

Materials and Methods: In this experimental study, 60 extracted human maxillary premolars were randomly divided into 4 groups of 15: Composite resin without bonding (1), Composite resin+ glass ionomer lining (2), Composite resin+ single bond 2 (3) and Composite resin+ Fiber post (4). The teeth were prepared by MOD design with palatal cusp reduction. The samples were placed in a chewing simulator and went under a 30 N force for 1200000 cycles. The threshold of compressive resistance was measured in MPa. Also, fracture patterns were assessed divided by restorability and non-restorability. ANOVA test was used for statistical analysis of data in all groups and post-hoc TUKEY test was used for two by two comparisons.

Results: The threshold of fracture resistance significantly increased from group 1 to 4 and the difference among all groups was strongly significant (p = 0.000). Restorable fracture pattern followed an ascending order from group 1 to 4 which was reversed for unrestorable pattern with no significance. (P> 0.05)

Conclusion: Composite resin restoration reinforced with fiber post can increase the fracture resistance of endodontically treated premolars but the number of unrestorable fractures also increases with the use of these posts. Fracture strength and fracture patterns obtained through usage of composite resin restorations in endodontically treated teeth are appropriate.

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*Corresponding author: Haleh Kazemi Yazdi,
Assistant Professor, Restorative Dentistry Dept, School of Dentistry, Islamic Azad University, Tehran, Iran
Email: haleh1351@yahoo.com   Tel: 22564571

Introduction

Reduced fracture resistance and strength of premolar teeth after endodontic treatment and MOD preparation is among the most common challenges in dentistry.[1] Tooth fracture especially from the area below CEJ can lead to tooth loss in some cases or requires more complicated treatments such as crown lengthening, post & core and full cast crown placement in order to restore the tooth to the chewing system.[2] Fracture resistance of restored teeth is influenced by several factors which among them, the dimension of prepared cavity, cavity preparation design and type of restoration material are more important. [3,4] Extensive coronal restorations such as full cast crowns are also advised for prevention of fracture and also for minimizing the probability of microleakage in root-filled posterior teeth. [5] On the other hand, in most cases, esthetic crown restorations with suitable labial profile require a significant removal of dental structure of maxillary first premolars. It has been reported that during preparation for common full cast crowns, a significant amount of tooth structure (approximately %75) is removed[6]. In everyday clinical experience, remained coronal structure along with functional requirements are important factors to guide the dentist in choosing the appropriate type of restoration.[7] Studies have shown that preservative cavities (maximum of 50% of buccolingual width) do not have much effect on the reduction of fracture resistance in direct and indirect composite restorations resin.[8,9] While in most cases, dentists face more extensive cavities. Especially in these cases, despite the classic advice to restore the tooth with indirect restorations, inevitably other substituent treatment methods should be applied. Direct composite resin restorations are of interest due to low cost and suitable esthetics. [3, 4] For preservation of tooth structure, direct composite resin restorations are proposed after root canal treatment. [10] Similar levels of fracture resistance have been reported for endodontically treated teeth after restoration with direct and indirect composite resins.[11] Adhesive properties of composite resin restorations require minimum cavity preparations and reinforce the inner coronal areas. [12, 13] Nevertheless, caries formation, cavity preparation and common endodontic treatments, necessitate the reinforcement with posts. But in some studies it was concluded that dental posts do not necessarily increase the fracture resistance of endodontically treated teeth. [12] According to the results of some studies, cusp coverage with composite resin restorations can reduce the amount of tooth fracture.[13] As premolar teeth are exposed to shear forces in addition to tensile forces and their especial anatomy complicates their restoration, applying a uniform treatment protocol seems necessary. [8, 9]

Considering the importance of this issue and controversies in this regard [11, 12, 13] the present study was performed with the aim of comparing the effect of three direct composite resin restorative techniques on the fracture resistance of endodontically treated maxillary premolars.

Materials and Methods

This experimental study was performed in vitro on human single rooted maxillary premolars which were endodontically treated and restored with different methods. In this study, 60 human single rooted maxillary premolars which were extracted due to periodontal diseases or orthodontic treatment plans were selected and soft tissue of periodontium and dental calculus were detached from coronal and radicular surfaces with use of hand scaling instruments. Teeth were extracted from individuals with 18 to 25 years of age. (With completely formed roots) All teeth were inspected under stereomicroscope with magnification of 25× to ensure the absence of fracture and caries on coronal and radicular surfaces .Intact teeth with complete roots were selected for the study. The anatomical shape of the samples was also assessed to have normal anatomy without any anomalies. Root lengths and mesiodistal width of teeth were measured with Vernier caliper and similar dimensions were selected. Teeth were disinfected in 0.5% chloramine T solution at 23 ºC and were kept in this solution till the beginning of the experiment (3 months at most).[14]

Grouping of teeth

The selected teeth were divided based on their size and were randomly assigned to 4 groups of 15. For calculation of tooth size, based on Eakle's proposal, in the one third occlusal area of the tooth maximum buccolingual and mesiodistal di-

mensions were measured with caliper and these two obtained values were multiplied and were regarded as a factor for size of each sample.[15] The samples were divided to 4 groups of 15 based on this factor, in a way that in each group a homogenized distribution of teeth based on their size was achieved. In this way, the differences in tooth size and morphology as confounding factors are eliminated as possible. For homogenization of inter cuspal angle and morphology of restored teeth, an over-impression was fabricated from a premolar tooth with standard size with use of especial tooth whitening sheaths (Easy Vac gasket,Korea) and a vacuum machine. These molds were used as a uniform template of outer shape of real intact premolars for all restorations. The prepared mold in each group was trimmed for the designated tooth.[15]

Study groups

Group 1- single rooted endodontically treated maxillary premolars with MOD cavity design and reduced palatal cusp with unbonded composite resin restoration (negative control)

Group 2- single rooted endodontically treated maxillary premolars with MOD cavity design and reduced palatal cusp (palatal or functional cusps were 2mm reduced.), restored with glass ionomer cement Fuji IX (GC Dental) and P60 composite resin (3M ESPE)

Group 3- single rooted endodontically treated maxillary premolars with MOD cavity design and reduced palatal cusp (palatal or functional cusps were 2mm reduced.), restored with P60 composite resin (3M ESPE)

Group 4- single rooted endodontically treated maxillary premolars with MOD cavity design and reduced palatal cusp (palatal or functional cusps were 2mm reduced.), restored with fiber post and P60 composite resin (3M ESPE)

Before fracture resistance test, the roots of teeth were covered with 0.2 mm of an elastic impression material and were embedded in acrylic resin up to 2mm below CEJ to simulate the periodontal ligament.[16,17]

Endodontic treatment of samples

First, access cavity was prepared with a diamond fissure bur with 3×2 mm dimension. [18] Then, k file number 15 was entered in each canal till the tip of the file was seen through the root apex. 1mm was reduced from its length and the obtained value was considered as working length. Canal shaping was done with step back method to k file master file number 30. Root canals were widened with number 1, 2, 3 Gates-Glidden drills (Mani, stainless steel, Japan) and physiologic serum was used for rinsing between all filing stages. After shaping, the canals were dried with paper point and gutta percha number 30 impregnated with AH26 sealer was placed in the canal. The canals were filled by lateral condensation method with number 2 spreader and number 20 lateral cones and excessive gutta percha was cut from 0.5 mm below CEJ and the remained gutta percha was condensed with a plugger.[19]

Restorative cavity preparation

The cavity was prepared in all groups with a high speed hand piece with cooling air and water system with diamond bur of 1.0 mm diameter and the bur was replaced after preparation of each 3 teeth. In preparation of MOD cavity, buccolingual width of the cavity in occlusal surface was 3 mm, the height of the axial wall of proximal boxes was 2 to 4mm in a way that the gingival floor of proximal box was 1mm above CEJ. Width and depth of gingival floor were respectively 4 and 1.5 mm. [18]

Cusp reduction

After MOD cavity preparation, palatal cusps of all 4 groups were 2mm reduced with fissure bur of 1.0 mm diameter in accordance to the cuspal inclination .Diameter of the bur was used as a guide for the depth of cusp reduction, in a way that on two sides of the cusp tip, two depth guide grooves were placed and then the cusps were reduced by connecting these grooves. [11, 12, 19, 20]

Tooth restoration

Group 2:

Gutta percha was removed from pulp chamber to 2mm below canal orifice. As a cavity conditioner, Poly acrylic acid 20% was placed for 10 seconds over all areas that must be filled with glass ionomer. Then glass ionomer cement Fuji IX (GC) was placed as a liner over gutta percha to restore the floor of MOD cavity.[16] After setting

of glass ionomer (3.5 minutes) entire cavity was etched with phosphoric acid 37% for 20 seconds and rinsed for 10 seconds. After drying the area, 2 step etch-and-rinse single bond2 adhesive (3M ESPE) was applied in cavities and was cured for 20 seconds with LED device (Star Lightpro, mectron, Italy) with intensity of 600 mw/cm2. Composite resin P60 (3M ESPE) was used for tooth restoration with incremental method. The last layer on the occlusal surface was restored with the especial template fabricated with bleaching shield from a premolar tooth with appropriate size and was cured.

Group 3:

Gutta percha was removed to 2mm depth below canal orifice.[21] Entire cavity was etched with phosphoric acid 37% for 20 seconds and rinsed for 10 seconds. After drying the area, etch-and-rinse single bond2 adhesive (3M ESPE) was used in the cavity of samples and was cured for 20 seconds. Composite resin P60 (3M ESPE) was used for tooth restoration with incremental method. The first composite resin layer was placed at 2mm below canal orifice. The last layer on the occlusal surface was restored with the especial template fabricated with bleaching shield from a premolar tooth with appropriate size and was cured.

Group 4:

Gutta percha was removed from palatal canal in a way that 4 mm of it remained in the apical area. Removing of gutta percha and final preparation of the canal was performed with especial fiber post drills. After rinsing and drying, glass fiber post with appropriate size was cemented in the canal with self-adhesive resin cement (Clearfill SA cement, Kuraray).[22] After 2 seconds of initial curing , excessive resin cement was removed and then final curing was done for 20 seconds with a light cure device. Entire cavity was etched with phosphoric acid 37% for 20 seconds and rinsed for 10 seconds. After drying the area, two step etch-and-rinse single bond2 adhesive (3M ESPE) was used in cavities and was cured. Composite resin P60 (3M ESPE) was used for tooth restoration with incremental method. The last layer on the occlusal surface was restored with the

especial template fabricated with bleaching shield from a premolar tooth with appropriate size and was cured.

After finishing and polishing, all samples were kept in distilled water for one week for proper setting of endodontic sealer.

Fracture test
Mounting of the samples

A two-step fixing method was applied for mounting the samples: in the first stage, roots were placed in hot wax up to 2mm below CEJ so that a thin layer (approximately 0.2 mm) of wax covered the roots. Then, the teeth were placed and mounted in 3×3 cylindrical molds containing self-cure red acrylic resin up to 2mm below CEJ. After that the samples were removed from molds and root surfaces were cleared from wax. Dental roots were covered with a thin layer of an elastic silicon material for simulation of periodontal ligament. To do this, the hole inside mold was filled with silicon impression material and the roots covered with silicon material were remounted in acrylic resin. Samples were moistened with distilled water during acrylic resin setting to reduce the polymerization temperature.

Then, the samples were placed in a chewing simulator machine (SD Mechatronic, CS-4, Germany) and went under a 30 N force for 1200000 cycles in a moist environment so that a condition similar to the oral environment in the form of horizontal and vertical movements during chewing can be simulated. [19, 23] After cyclic loading, the specimens went under a compressive load at 150 degrees angle to the long axis of the tooth and at 45 degrees angle on the palatal inclination of palatal cusp in contact with the buccal inclination of palatal cusp with speed of 1 mm/min in Universal testing machine (Walter+bai, k-21046, Switzerland) with use of a conic steel cylinder. The load was increased until the samples were fractured. The loading steps were recorded as a Stress (N)-strain (µm) curve with the software of Universal testing machine and the maximum force applied for tooth fracture was recorded in MPa.

Fracture pattern assessment

Fractured teeth were inspected under stereomicroscope to assess their fracture pattern

(restorable or unrestorable)

Statistical analysis method

The amount of fracture strength in different study groups was reported with use of central dispersion indices including mean, standard deviation, min and max. In addition, for statistical test selection, distribution of data was assessed with Kolmogorov-Smirnov test and due to the normal distribution, ANOVA test was selected. Due to statistically significant differences in all groups, multiple comparisons Post-hoc TUKEY test was used for two by two comparisons of groups. Level of type one error was considered 0.05 in this study.

Results

The present study was performed on 60 samples and in 4 groups of 15 including unbonded composite resin (control), composite resin+ glass ionomer cement, composite resin+ bonding and composite resin + fiber post. The amount of fracture resistance in MPa and divided by study groups (different methods of composite resin restoration) is presented in table 1 and shows thatThe least amount of fracture resistance was related to unbonded composite resin which equaled 315.8. In next place was composite resin with glass ionomer which equaled 477.7 and then composite resin with bonding which equaled 545.2 and the highest amount of fracture resistance was related to composite resin reinforced with fiber post which equaled 703.6.

Table 1- Fracture resistance based on different direct composite resin restoration techniques

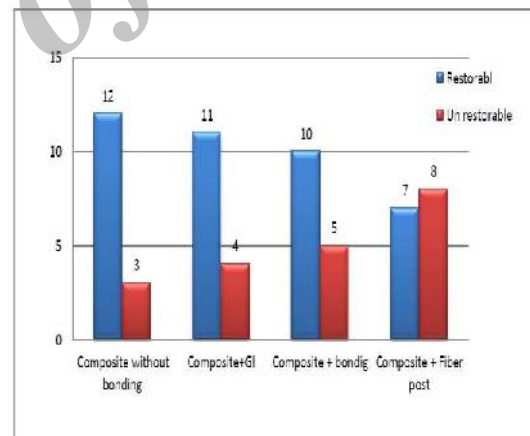| Fracture resistance	MPa	CV
Unbonded composite resin	315.8±71.7	22.7
Composite resin+ glass ionomer	477.7±25.1	5.2
Composite resin+ bonding	545.2±38.4	7
Composite resin+ fiber post	703.6±53.4	7.6
Test result	P<0.001	

ANOVA test showed that a difference exists among the amount of fracture resistance of these direct composite resin restorative methods. (p<0.001)

Post-hoc TUKEY test showed that a significant difference exists tow by two among all these direct composite restorative methods. (p<0.001)

Regarding homogeneity (CV), the highest variation coefficient was related to unbonded composite resin method which equaled 22 and almost similar homogeneity was present in other three methods.

In addition, as a component test, 5 intact maxillary premolars had also gone under cyclic loading and fracture test so that the results can be compared to them. None of the direct restorative techniques could restore the fracture resistance of natural and intact teeth.

The distribution of samples based on fracture pattern and restorability divided by restorative method is presented in diagram 1.

Diagram 1 – Distribution of samples based on fracture pattern and restorability divided by study groups

Discussion

The results showed that fracture resistance followed an ascending order from group 1 to 4 in a way that according to TUKEY test the differences among all groups were strongly significant. (p=0.000) In addition, the unrestorable fracture pattern followed an ascending order from group 1 to 4 and restorable fracture pattern followed a

descending path from group 1 to 4 but the difference among groups was not significant.(p=1.0)

In the present study maxillary premolars were used for assessment of different restorative techniques in cavities with remained buccal cusp .It seems that the anatomic position influences the fracture resistance of the tooth in a way that in a report the incidence of fracture was higher in maxillary restored premolars compared to mandibular premolars. [23] Clinically, the high incidence of fracture in maxillary premolars is reported to be due to their especial anatomic position. [26] These teeth are exposed to fracture due to occlusal loading more than any other posterior tooth due to unusual anatomic shape, coronal bulk and inappropriate crown to root ratio. [27] Fracture analyses have shown that probability of palatal cusp fracture of maxillary premolars is higher under compressive load.[28] Also in an in vivo study by Eakle et al. the prevalence of palatal cusp fracture was reported to be higher than buccal cusp fracture. [8, 9, 29]

The effect of adhesive restorations on increased fracture resistance of such teeth has been frequently studied. Many studies have shown the successful application of composite resin restoration in pulpless teeth with extensive cavities and have shown that the fracture resistance of weakened teeth due to endodontic treatments and extensive cavities can be improved with use of composite resin with bonding.[4] In some studies, including a three-year clinical trial by Monnossi et al. no significant difference was seen between the survival rate of maxillary premolars restored with composite resin and fiber post and teeth restored with crown. [30] In other words, for endodontically treated premolars with remained buccal cusp, direct adhesive technique without any coverage with crown can be a suitable, preservative and economic substitute for other more expensive and time consuming treatments. Our findings, also showed that the best restorative technique for increasing the threshold of facture load was the restoration with composite resin P60 reinforced with fiber post.

Numerous studies have investigated the fracture resistance of direct restorations reinforced with post. Many researchers have reported that high fracture resistance is seen when modulus of elasticity of post and dentin are compatible with each other. It seems that with creating a monoblock of dentin-post-core with use of bonding agents, force distribution in root is improved. [31] Post can stabilize the restorative composite resin and consequently can reduce the stress in composite –adhesive interface. Insertion of post in endodontic restoration retains the restorative material and creates a better force distribution in tooth and can reduce the probability of tooth fracture. [28] It seems that post insertion in restoration of weakened teeth is necessary for increasing the strength but considering the type of post, this additive effect can be controversial. [12, 19] Preservation of dental tissue during preparation and post placement increases the resistance of tooth. Also, type of post has an important role in increasing the compressive resistance.

Fiber post is more flexible and requires less removal of dental tissue compared to the rigid type thus is a suitable choice for restoration. [32] In a study by Mohammadi et al. composite resin restoration with and without fiber post showed similar results regarding dental strength. [20] The reason could be attributed tot the use of different composite resin and fiber post materials. Steele et al. found no significant difference among different restorative materials in increasing the threshold of fracture load in mandibular premolars. Although, in the mentioned study fracture resistance of composite resin restoration with fiber post was less than composite resin restoration without fiber post which contradicts our results.[24] Torabzadeh et al. found no significant difference in fracture resistance of composite resin Z250 with and without reinforcement with fiber post. [29] The reason for controversy among above findings in addition to the type of restorative materials, can be due to the different conditions of these studies and the method of fracture force application. For instance, according to the findings by Xie et al. different preparation techniques cause significant variations in the threshold of fracture force in a way that in their study with different techniques of composite resin restoration fracture

force varied from 924 to 1131 N. [19]

overall, according to the systematic study by Schwarts et al. composite resin reinforced with fiber post shows satisfactory restorative results. Clinical trials cannot completely detect the fracture resistance due to assessment limitations. Therefore, laboratory studies are a valuable aid in recognition of superior and more effective restorative materials and techniques. Although the best restorative technique has not yet been introduced, nevertheless according to the finding of the above systematic review study, composite resin restorative method with or without fiber post shows suitable fracture resistance in restoration and seems to be the best choice.[27] Glass ionomer cement was the other material used in our study along with composite resin which was in the third place of fracture resistance among four groups. Nowadays, glass ionomer cement is an important restorative material especially in restorative interventions in children. This material has a suitable bio compatibility and can absorb and release fluoride ion which will be absorbed by enamel and dentin. [33]In laboratory studies, glass ionomer has shown a protective role in dental restoration and impedes secondary caries .Nevertheless, no adequate clinical evidence is yet available for or against this protective role for dental walls. Glass ionomer has been advised in many studies for improving marginal adaptation and decreasing microleakage. Despite weak mechanical properties of glass ionomer, placing this material beneath composite resin in a study by Taha et al. had no mal effect on the fracture resistance of teeth compared to composite resin group which is not in line with our study. This could be due to differences in research conditions.

Despite all its limitations, fracture test is still a common method for evaluation of the different restorative techniques for endodontically treated tooth. the limitations of this method include application of non-physiological fracture force, differences among evaluated teeth and differences in study conditions, direction and shape and location of force applying instrument, speed of applied force, method of stabilizing the sample and mechanical or thermal fatigue tests which

can vary the results of different studies. In the present study, premolar teeth went under an axial force at 45 degrees angle to the palatal cusp and at 150 degrees angle to the long axis of the tooth. These angles were selected to simulate the angle between mandibular and maxillary premolars during chewing. [20, 31]

Simulation of periodontal ligament was also attempted in order to simulate clinical condition. Hence, the teeth were not directly embedded in acrylic resin and roots were covered with a thin layer of an elastic silicon material. Elastic properties of this material create an area in the cervical area of the tooth with no concentration of tension and consequently tension distributes mere evenly from crown to root.[20] Teeth are under cyclic loading during chewing in the oral environment and dental restorations are usually lost due to fatigue caused by these cycles.[32] Therefore, in the present study for simulation of this clinical situation, cyclic fatigue test was used prior to the application of static force. Cyclic loading is necessary for the evaluation of adhesive restorations because the cyclic pattern of this loading is highly similar to the physiologic conditions in the mouth during chewing. Nevertheless, in vitro studies cannot fully simulate the intraoral conditions. Loading cycles in the mouth during chewing occur while teeth are in a moistened environment under numerous thermal and chemical challenges.

Conclusions

Composite resin restoration reinforced with fiber post can increase the fracture resistance of endodontically treated premolars but the number of unrestorable fractures also increases with the use of these posts. Fracture strength and fracture patterns obtained through usage of composite resin restorations in endodontically treated teeth are appropriate.

acknowledgment

Conflict of interests

Authors report no conflict of interest related to this study.

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