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Fracture Resistance of Endodontically Treated Maxillary Premolars Restored by Various Direct Filling Materials: An In Vitro Study

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Abstract:
Aim: *Aim of this in vitro study was to compare cusp fracture resistance of root filled maxillary premolars restored with different composite resins using single step self etch and two step (etch & rinse) techniques after MOD preparations.*
Materials and Methods: *80 premolars with no restorations or cracks were selected. MOD cavities were prepared considering the buccolingual width to be equal to half of the intercuspal distance. The specimens were randomly divided into 8 groups, 10 specimens each: Group I did not receive cavity preparation or root canal treatment, group II remain unrestored after MOD cavity preparation. In group III, Xeno III was applied and then restoration was done with packable resin. Group IV were restored with packable resin after total-etched and Prime and Bond NT application. In group V, Xeno III was applied and then restoration was done with nano composite. Group VI were restored with Nano composite after total etched and Prime and Bond NT application. In group VII, Xeno III was applied and then restoration was done with ormocer resin. Group VIII were restored with Ormocer resin after total-etched and Prime and Bond NT application. The teeth were embedded in acrylic blocks, only anatomic crowns were exposed. The teeth were mounted on the lower platen of Universal testing machine and then a slowly increasing compressive force was applied occlusally until the teeth fractured.*
Results: *The mean value and standard deviation was calculated using Fisher's Test for each group. The mean values of other groups were compared and it was found to be significant. Inter-comparison of the different groups was done with Turkey's method. The mean value of each group was compared with all the other 7 groups.*
Conclusion: *The fracture resistance was found maximum in Group I, the positive control group. Group IV, VI, VIII had high fracture resistance compared to the other three groups III, V, VII which was followed by group II-negative control group.*
Keywords: *Fracture resistance; Xeno III; ormocer resin*

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I. Introduction:

Together with dental caries and periodontal disease, tooth fracture is the most common cause of tooth loss. Fractures are even more frequent in root-filled teeth. Excessive removal of coronal and radicular dentin during the root canal treatment (RCT) and lower residual moisture reduce the strength and increase tooth's fragility. Loss of axial walls, quite common in teeth that require RCT, also significantly weakens the hard dental tissues[1].

Study conducted by Joynt et al. claims that occlusal cavity preparation may reduce mechanical resistance of the remaining dental tissues by 20%.[2] A need for removal of the marginal ridges widens the cavity even further into the interproximal space. Resistance of dental structures reduces by 2.5 fold. This results in an overall 46% reduction in its mechanical resistance.

In case when both marginal ridges are affected, the resistance decreases by 63%. Dalpino et al.[3] showed that mesio-occluso-distal (MOD) cavity design measuring half of the intercuspal distance, rounded internal angles, and either convergent or divergent angulation of internal walls weakens the remaining tooth structure. Relatively wide MOD cavities restored with amalgam frequently develop cusp fractures due to continuous functional occlusal forces. This is mainly caused by the inability of amalgam to strengthen weakened cusps[4].

Studies investigating this matter raised hope for recognizing the elements that can reinforce the remaining tooth structure. This can be accomplished by the application of adhesive restorative materials. However, some questions still require more evidence in order to provide conclusive answers. What restorative

technique should be used to better reinforce the remaining tooth structure? How important the role of adhesive agents that bond the restorative material to the tooth? Is it possible to reproduce the initial resistance of the tooth after the preparation? Ever improving quality of advanced dental materials and progress in manufacturing of bonding agents make the reinforcement of tooth structures possible.[5,6]

The aim of our study is to compare the fracture resistance of endodontically treated maxillary premolars. These were restored by direct MOD fillings using various restorative materials and bonding agents.

II. Materials & Method:

The purpose of the study was to evaluate in vitro fracture resistance of different bonded restoration. Eighty freshly extracted human mature maxillary premolars with similar dimensions and without caries, abrasion cavities and injury from forceps or fractures were used. The teeth were cleaned of debris and soft tissue remnants and were stored in physiological saline at +4 ºC until required. The teeth were then randomly assigned into eight groups of 10 teeth each and were prepared as follows.

Root canal preparation

Endodontic access cavities were prepared using a water-cooled diamond bur in a high-speed handpiece and the pulp tissue was removed with barbed broaches. A size 15 K-file was introduced into each canal until it could be seen at the apical foramen. The working length was determined by subtracting 1 mm from this length.

The canals were prepared to a size 40 K-file at working length with a stepback technique. The coronal portion of each canal was enlarged with Gates Glidden burs sizes 1–3 in a slow speed contra-angle handpiece. The canals were irrigated with 3ml of 2.5% NaOCl solution using a 27-gauge endodontic needle after the use of each instrument. Following biomechanical preparation, the canals were irrigated with 3ml of 15% EDTA solution for 30 s to remove smear layer. Final canal irrigation was accomplished with 3 ml of 2.5% NaOCl solution.

Canals were dried with absorbent paper points and filled with gutta-percha and AH plus sealer using cold lateral condensation. MOD cavities were prepared in the teeth down to the canal orifices so that the thickness of the buccal wall of the teeth measured 2 mm at the occlusal surface and 3 mm at the cemento-enamel junction. The dimensions of the cavities were measured with a calliper at 0.1 mm sensitivity.

Preparation of MOD Cavities

MOD (mesial-occlusal-distal) cavities were prepared with aerator ISO burrs and the cavities were refined with micro burs so that the buccolingual width of occlusal isthmus was one third the width between the Buccal and Lingual tips and the buccolingual width of the crown. The proximal boxes were prepared straight (non-undercut) and in the depth limited to 2mm coronally from the cemento-enamel junction.

Group 1; This group did not receive cavity preparation or root canal treatment and was used as the control.
Group 2; This group remained unrestored after MOD cavity preparation.
Group 3; The cavities were cleaned and dried. Two additional layers of Xeno III were applied onto the cavities according to the manufacturer's instructions and light-cured for 20 s. The cavities were then incrementally restored with Packable resin. Each increment was cured for 40 s from occlusal surface using a curing unit. To standardize the curing distance, the tip of the polymerization unit was applied to the occlusal surface of the teeth. The intensity of light was at least 500 mW/cm2. Verification of the unit light intensity output was checked with the digital read-out light meter available with the unit every 10 samples.
Group 4; The cavities were total-etched for 15 s, rinsed and air dried with a brief jet of compressed air leaving the surface moist. Prime & Bond NT was applied onto the cavity and light-cured for 20 s and the teeth then restored incrementally with packable resin and cured for 40 s.
Group 5; Two additional layers of Xeno III were applied onto the cavities in accordance with the manufacturer's instructions and light-cured for 20 s. The cavity surfaces were restored with Nano composite using an incremental technique and cured for 40 s.
Group 6; The cavities were total-etched for 15 s, rinsed and air dried with a brief jet of compressed air leaving the surface moist. Prime & Bond NT was applied onto the cavity and light-cured for 20 s and the teeth then restored incrementally with Nano composite and cured for 40 s.
Group 7; Two additional layers of Xeno III were applied onto the cavities in accordance with the manufacturer's instructions and light-cured for 20 s. The cavity surfaces were restored with Ormocer using an incremental technique and cured for 40 s.
Group 8; The cavities were total-etched for 15 s, rinsed and air dried with a brief jet of compressed air leaving the surface moist. Prime & Bond NT was applied onto the cavity and light-cured for 20 s and the teeth then restored incrementally with Ormocer and cured for 40 s.

Regular molds are using elastomeric impression material. Self cure acrylic resin was used to fill the mould and the teeth mounted to the level 1mm apical to cemento-enamel junction. Prepared specimens were then mounted on a holder slot which is fixed to the lower arm of the instron machine. The metal indenter of 4mm diameter was fixed to the upper arm of the universal testing machine which is set to deliver an increasing load until failure.

The cross head speed was 1mm per minute, and the load was applied to the tip of the buccal cusp vertically down the long axis of the tooth. The specimens were tested in random order and the operator of the machine was not informed of the group designation of the specimen being tested. The variable of interest was the load at failure measured in Newton.

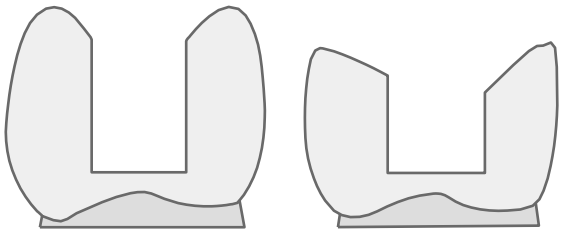
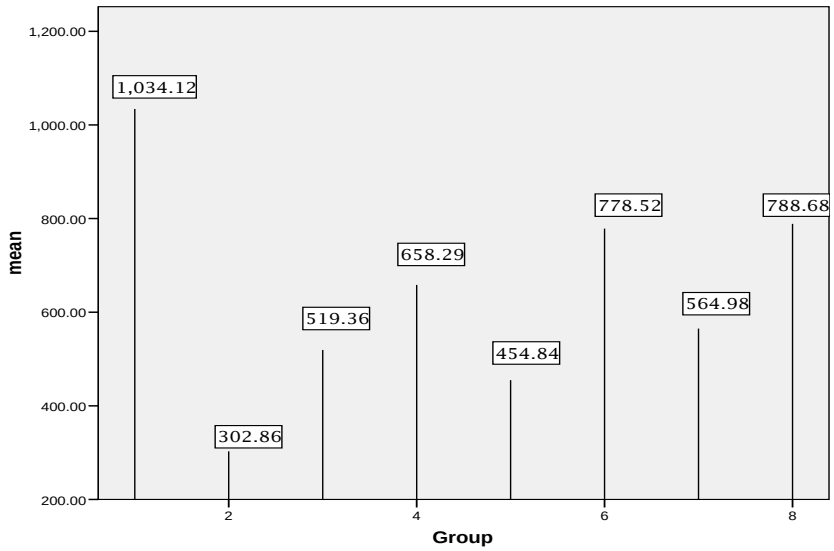


Figure 1: Specimens without (a) and with (b) cusp reduction as described by Lia Mondelli et al.

Figure 2: Mounted tooth in the acrylic cylinder under the LR5k testing machine.

III. Results:

The results of fracture strength in each group were summarized. The control groups and teeth with two step adhesive restorations were more resistance to fracture followed by teeth with single step adhesive restorations. Statistical analysis of variance was done by Fisher's F test followed by Turkey's method to evaluate the pair wise difference between the means.



The mean value and standard deviation was calculated using Fisher's Test for each group. The mean values of other groups were compared and it was found to be significant.

Descriptives

Observations

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
1	10	1034.1200	232.94117	73.66247	867.4839	1200.7561	672.00	1371.10
2	10	302.8600	108.95612	34.45495	224.9175	380.8025	187.70	511.80
3	10	519.3600	114.16487	36.10210	437.6914	601.0286	342.70	728.30
4	10	658.2900	127.15347	40.20946	567.3299	749.2501	452.50	850.20
5	10	454.8400	154.83529	48.96322	344.0775	565.6025	200.50	669.90
6	10	778.5200	122.97528	38.88820	690.5488	866.4912	593.90	958.80
7	10	564.9800	208.76035	66.01582	415.6418	714.3182	312.30	974.60
8	10	788.6800	176.65973	55.86471	662.3052	915.0548	575.10	1208.70
Total	80	637.7063	264.65768	29.58963	578.8096	696.6029	187.70	1371.10

Inter-comparison of the different groups was done with Turkey's method. The mean value of each group was compared with all the other 7 groups.

The teeth were embedded in acrylic blocks, with only their anatomic crowns exposed. The teeth were then placed on the lower platen of the Universal testing machine and a slowly increasing compressive force was applied on the occlusal surface until the fracture occurred. The force at which the teeth fractured was recorded in Newton.

The mean values and standard deviation was calculated using Fisher's F test for each group of 10 specimens. The mean value was found to be maximum in case of group 1(positive control) and minimum in case of group 2 (negative control) with of 1034.50 N and 302.91 N, respectively.

Group 8(Two step adhesive with ormocer resin) had mean fracture strength of 788.68 N followed by group 6 (Two step adhesive with nano composite resin) and group 4 (Two step adhesive with packable resin) with of 778.52 N and 658.29 N, respectively.

Group 7(single step adhesive with ormocer resin) had mean fracture strength of 564.98 N followed by group 3(single step adhesive with packable resin) and group 5(single step adhesive with nano composite resin) with of 519.36 N and 455.44 N, respectively.

IV. Discussion:

Restoration of teeth is an important final step of root canal treatment. Studies demonstrated that endodontic access cavity preparation in an otherwise intact tooth had a minimal effect on the strength of the tooth and also reported that the mean fracture strength for unrestored teeth with MOD preparations was 50% less than that of unaltered premolar teeth.[7,8]

Several factors have been reported to affect the fracture resistance of teeth including: the amount of tissue lost and its location, the magnitude and duration of the load, tooth type, direction of applied load, and slope of the cuspal inclines. Therefore, the measurement of crown deformation associated with caries removal and cavity preparation procedures is important in operative dentistry to optimize cavity designs and subsequent restoration.[9,10] Lower speeds are accompanied by greater plastic deformation and, thus higher fracture resistance measurements will be recorded. [11]

In the mouth, the load capability of root filled teeth is influenced by the number of adjacent teeth, the number of occlusal contacts, tooth position in the dental arch, crown placement, type of abutment, apical status, collagen degradation, intermolecular cross-linking of the root dentine by the amount of lost tissue. [12]

Endodontically treated teeth are usually weak because of loss of tooth structure due to caries, access cavity preparation and instrumentation of the root canal. Loss of moisture in the dentin of these teeth results in a decreased resilience with increased likelihood of fracture. The endodontically treated tooth also has a lowered resistance to decay because of the loss of neural stimuli. [7,13]

The search for an ideal and universally acceptable system to restore pulpless teeth is still a goal of dental material research. The system should have enough strength and retention to support masticatory force, yet should preserve as much tooth structure as possible. The objectives of restoration are form and function as well as prevention of fracture of the residual roots. Other considerations are esthetics, prevention of caries and retention of a final restoration. With new equipments and techniques for cavity preparation and new or improved restorative materials, preservation of tooth structure has become an important trend in modern dentistry.[14,15]

The restoration for the pulpless tooth should increase the resistance to horizontal and vertical fracture. Coverage of the entire occlusal surface of the tooth with a restoration decreases the incidence of vertical fracture. Internal reinforcement using the residual root for anchorage will resist horizontal fractures. [16]

The resistance to fracture of endodontically treated teeth following different methods of treatment compared access restoration with and without acid etching, and with or without post. Acid etching of the access cavity before inserting the composite did not alter the teeth. The preparation of the post space significantly weakened the resistance of the teeth to fracture and the force required to fracture them were lower than the force required to fracture a similarly restored teeth without a prepared post. [17,18]

Studies were done to evaluate the cuspal stiffness on the following sequentially performed procedures; unaltered teeth, completion of all endodontic procedures, appropriate restorative preparations and restorations. The restorative procedures evaluated were amalgam, cast gold onlay, composite restoration with enamel etch and composite restoration with enamel and dentin etch. When loaded to fracture cast gold was found to be the strongest material tested and amalgam was the weakest. Composite restoration and enamel and dentin etch were almost as strong as the unaltered teeth, while enamel only yielded lower stiffness. [19,20]

Studies compared the fracture resistance of endodontically treated premolars with modified types of cavity preparation and restoration with either amalgam or composite resin. When different restorative materials were compared the results indicated that the type of restorations in teeth with small preparations contributed minimally to the compressive strength of the cusps.[21] When the influence of remaining tooth structure on fracture resistance was compared, there was significant drop in the strength of the teeth restored with amalgam but not with dentin verifying the effectiveness of acid etch bonding in reinforcing the teeth. [22]

The comparative effects of acid etched light cured composite restorations on resistance to fracture of structurally compromised posterior teeth was compared, the results revealed that intact teeth are more resistant to fracture than prepared teeth and that restored teeth are more resistant to fracture than prepared unrestored teeth. No significant difference in fracture resistance was found between teeth restored with amalgam and those restored with composite or between composite groups with and without bevels. [23]

Study compared the cuspal fracture resistance of posterior teeth restored with four different adhesive restorations. The difference between the mean cuspal fracture resistance of unprepared control group and those restored with amalgam groups was found to be statistically significant. No significant difference in resistance to cuspal fracture was found among the restoration groups, the unprepared control group and those teeth restored with hybrid composite, packable composite and Ormocer groups.[24]

Studies evaluated the significance of retaining intact marginal ridges in maintaining tooth stiffness and the significance of selective cusp coverage during restoration on recovery of tooth stiffness. They found that MOD preparation produced the greatest loss of stiffness for both mesial and distal cusps. [25]

Study reported that prepared teeth showed a significant decrease in fracture strength. Restoring with amalgam did not increase the fracture strength of the prepared teeth. Posterior composite material with and without dentin adhesive and acid etching as well as with dentin adhesive with no acid etching significantly increased the fracture strength. [26]

A study compared the resistance to fracture of endodontically treated premolars after different methods of restoration. A class II MOD cavity was prepared in the teeth of each group tested. The mean force of fracture when cavities were acid etched and restored with composite resin was significantly higher than the groups in which cavities were filled with amalgam or a composite resin without prior acid etching. [24,25]

According to the study done on the teeth restored with amalgam showed a significant decrease in fracture strength as compared with unprepared teeth and teeth with composite resin indicating a possibility that composite resin contributed to the reinforcement of the remaining tooth structure.[15]

Based on the result of this study, it can be inferred that endodontically treated premolars restored with two step total etch adhesive system better reinforces the tooth structure and required more force to fracture than single step self etch adhesive system. Fracture resistance of group 1 was highest and group 2 was lowest. The fracture resistance of group 4, group 6, and group 8 was very highly significant than group 3, group 5, and group 7.

V. Conclusion:

Study concluded that, when a total etch two-step adhesive was used, increase in fracture resistance was significantly greater than a one-step adhesive. All three packable, nano and ormocer are equal in strength and fracture resistance in the MOD cavity of endodontically treated maxillary premolar teeth.

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