Fracture strength of endodontically treated premolars: An In-vitro evaluation

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ABSTRACT

Background: The aim of this study is to measure the invitro fracture strength of endodontically treated maxillary premolars restored with silver amalgam, composite resins and bonded amalgam.

Materials & Methods: Sixty mature maxillary premolars free of caries, restoration or fracture extracted for orthodontic purpose or periodontal reasons were selected. The teeth were randomly divided into six groups of 10 teeth each. Group I: Intact teeth, Group II: Access opening only, Group III: Standard MOD cavity preparation + superimposed endodontic access (Unrestored). In Group IV, Group V & Group VI preparation was done as in Group III and they were restored with amalgam, bonded amalgam and composite resins respectively. All the teeth were thermo cycled and were mounted on custom made rings and the fracture strength was calculated with an Instron testing machine and the results were analysed statistically.

Results: Group I showed the highest fracture resistance followed by Group II . The difference in the values between the two groups were not significant. Group III showed the lowest fracture resistance the decrease in fracture strength was highly statistically significant when compared to all other groups investigated in the present study. Fracture strength of teeth restored with Group IV, Group V, Group VI did not differ significantly from each other.

Conclusion: Fracture strength of intact natural teeth was superior to all the teeth tested in the study. Fracture strength of endodontically treated teeth restored with conventional amalgam, bonded amalgam and composite resin did not differ significantly from each other. Bonding of restorations to tooth structure has failed to bring about any improvement in the strength of the teeth tested.

Key Words: Amalgam restoration, bonded amalgam restoration, bonding agent, composite resin restoration, fracture resistance.

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Introduction

Unrestored endodontically treated teeth are structurally compromised. Caries, previous restorations fractures, wear, erosion and endodontic procedures, combine to necessitate careful and timely tooth reconstruction to ensure a favorable prognosis.[1] It is important to understand that changes occur in the dentin of endodontically treated teeth that may affect its function under stress. Endodontically treated teeth are not brittle because of loss of moisture content, changes that occur in the dentin of endodontically treated teeth may affect its function under stress, while the collagen bonds of dentin in these teeth are weakened and more likely to break.[2] Weakness is primarily caused by loss of tooth structure due to Caries, previous restorations, fractures, wear, erosion or preparation of root canal and access cavity.[3]

Posterior teeth present different restorative needs due to their structure and the occlusal forces placed on them during function. Many attempts have been made to replace the conventional cast restoration with various restorative materials but very few restorations have been evaluated objectively. If one could predictably restore an endodontically treated teeth to the original strength and fracture resistance without the placement of full coverage restorations, it could provide potential periodontal and economic benefits to the patients, as well as save time to the dentist.[4]

Amalgam is a restorative material that strengthens teeth only by distributing the stresses of mastication over a broad occlusal surface. Amalgam does not adhesively bond to the tooth structures and therefore has to be retained in cavity preparations by retentive features that often require the removal of sound tooth structure unrelated to the diseased or damaged aspect of tooth.

Introduction of newer adhesive bonding techniques and restorative materials have led some authors to suggest that endodontic ally treated teeth now can be restored in a more conservative manner than were previously considered.[5] It is known that the cusps of posterior teeth deflect under load. When a class II cavity preparation is made, the effective height of the cusps are increased, resulting in weakened cusps that deflect more under stress. When an endodontic access opening is superimposed on the Class II cavity preparation, there is removal of the intracoronal tooth structure which further weakens the tooth and the cusps deflect more.[6]

Improved composite resin materials bonded to the tooth using acid etch technique along with current dentin bonding agents which forms a hybrid layer of reinforced dentin and as potential to decrease deflection and fracture of the cusps under load by providing internal reinforcement of weekend tooth structure. This property of bonding provides internal reinforcement of weakened tooth and improved fracture resistance.

Similarly amalgam restorations can also be bonded to the cavity walls through a self cure or dual cure resin adhesive. The mechanism for bonding between the amalgam and the resin liner is micromechanical, by the penetration of the wet adhesive in to crystal phases of unset amalgam, where it polymerizes and gets locked in the set amalgam.[7] A dual cure or self cure adhesive is recommended to achieve polymerization of the adhesive with the amalgam. These bonded amalgam restorations improve not only marginal adaptability and retention, but it is also said to provide intracoronal support to weakened tooth structure and improve resistance to tooth fracture.

The aim of this study is to measure the invitro fracture strength of endodontically treated maxillary premolars restored with silver amalgam, composite resins and bonded amalgam

Material and Methods:

Materials Used

1) Dental amalgam alloy (Solila nova)
2) Mercury.
3) Composite restorative resin (Z100 3M Co.).
4) Guttapercha cones (Dentsply) & Zinc oxide eugenol based sealer (Tubliseal)
5) Dentin bonding agents.
   a) Scotch bond multipurpose plus.
   b) Scotch bond multipurpose.

Selection of teeth

Sixty mature maxillary premolars free of caries, restoration or fracture extracted for orthodontic purpose or periodontal reasons were selected. The teeth were inspected to ensure that they were free of caries, restoration or fractures. The teeth were immersed in 0.5% sodium hypochlorite for one week to remove soft tissue debris and were then stored in water at room temperature until ready for use.

Grouping

The teeth were randomly divided into six groups of 10 teeth each.
Group I: Unaltered teeth
Group II: Standard endotonic access + obturation.
Group III: Standard MOD cavity preparation + superimposed endodontic access + obturation.
Group IV: Standard MOD cavity + superimposed endodontic access + obturation + Cavity varnish + restoration with a sliver amalgam.
Group V: Standard MOD cavity + superimposed endodontic access + obturation + bonded amalgam restoration.
Group VI: Standard MOD cavity + super imposed endodontic access + obturation + bonding agent + composite resin restoration.

Tooth preparation and Restorative procedure

Group I: The teeth were left unaltered.
Group II: A standard endodontic access was prepared and the biomechanical preparation was carried out with step back technique using 2.5% NaOCI as irrigant. Apical enlargement upto the size 30 files was achieved and the root canals were obturated using laterally condensed Guttapercha and Zinc oxide eugenol sealer.
Group III: A Standard MOD cavity preparation was done with super imposed endodontic access opening. The dimensions of the MOD cavity were as follows :
Occlusal width: 2mm of intercuspal distance
Occlusal depth : 2mm at the central groove area
Proximal box: 3mm of the facio-lingual distance Width:
at the gingival floor level Gingival depth : 4mm from the marginal ridge Axial depth: 1mm at the gingival seat & 1.5mm at the contact area.The biomechanical preparation and obturation was carried out with step back preparation using 2.5 % NaOCL. Apical enlargement up to size 30 file was achieved and root canals were obturated using laterally condensed gutta-percha and Zinc Oxide eugenol sealer.
Group IV: A standard MOD cavity preparation with a superimposed endodontic access opening, root canal preparation and obturation was done as in Group III. Cavity varnish was applied to the cavity walls of the cavity and pulp chamber. A matrix band was secured by Toffelmire retainer around the tooth and amalgam was condensed into the pulp chamber as well as and the prepared MOD cavity incrementally.
Group V: A standard MOD cavity preparation with a superimposed endodontic access opening, root canal preparation and obturation was done as in Group III. Surface of the MOD cavity including the pulp chamber were acid etched with Scotch bond etchant (10% maleic acid) for 15 seconds and the cavity was rinsed and blotted. One drop of primer was mixed with one drop of activator and applied to the prepared cavity. later on one drop of adhesive was mixed with one drop of catalyst and was applied over the primed tooth surface. Matrix band was applied and amalgam was condensed incrementally.
Group VI: A standard MOD cavity preparation with superimposed endodontic access opening root canal preparation and obturation was done as in Group III. Surface of the MOD cavity including the pulp chamber were acid etched with Scotch bond etchant (10% maleic acid) for 15 seconds. The cavity was then rinsed and blotted dry. The scotch bond primer was applied on to the cavity and gently dried for 5 seconds. Adhesive was then applied over the primed surface and light cured for 10 senconds. The cavity was restored with Z – 100 restorative composite resin.
All the specimens were stored at 37^0 C in umidifier maintaining 100% humidity for one week prior to testing. The specimens were then subjected to themocycling in water bath for one thousand cycles form 6^0 C – 60^0 C with 30 seconds dwell time.

Testing for fracture resistance

The restored teeth were handled with moist gauge to prevent dehydration. Casting rings were filled with acrylic resin and the teeth were mounted to a level 1 mm apical to the cementoenamel junction. The

Instron dynamic testing system is specifically for testing the strength and measuring the physical properties of materials and components.

Each specimen was subjected to a compressive force using an specially designed metal bar that was aligned between the buccal and lingual cusps of the prepared teeth. The diameter of the bar was large enough so that the bar contacted the inclined planes of the tooth rather than the restoration. A 500 kg load cell with gross head speed of 0.50 cm/min was used and the load at which the teeth fractured were recorded in kilograms.

Table 1: Mean load (Kgs) of the group with respective Standard Deviation

Groups	No. Of specimens	Mean	SD
Group I	10	113.956	20.98
Group II	10	100.39	16.23
Group III	10	56.517	16.77
Group IV	10	81.897	13.091
Group V	10	84.657	14.38
Group VI	10	77.849	22.013

Results

All the specimens were subjected to a compressive force using instron testing machine. The mean load (Kgs) of the group with respective Standard Deviation at which fracture occurred as shown in Table 1

To carry out a test of equality of mean fracture strength for the six groups, one way analysis of variance (ANOVA) was carried out. This gave a value of $p < 0.05$ and hence the hypothesis of equality of mean fracture strength for the six groups was rejected based on the sample data at 5% level of significance.

Duncan's multiple range test was used to test the significance of difference between specific means (Table 2). If the difference between two means exceeds the corresponding critical value we conclude that two means differ significantly.

The mean fracture resistance value of all the group are compared, plotted on a Graph 1 and has been depicted on the bar diagram.

Group I has the highest fracture resistance in value (113.95 Kg) when compared to any other group tested in this study followed by Group II with just a marginal decrease in value (100.39kg). However there was no statistically difference between Group I & II.

Group III showed the lowest values (56.517 Kg) amongst all the group tested and the difference was shown to be highly statistically significant.

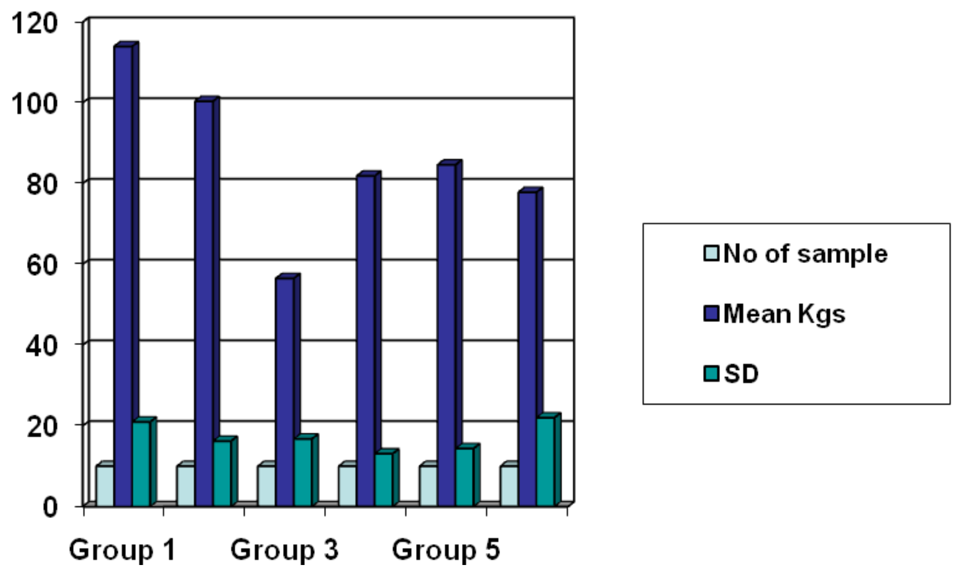
Fracture resistance of Group IV, Group I and is significantly lower when compared to Group I & Group II but higher then Group III which was again shown to be statistically significant.

On analyzing the mean fracture resistance value of Group IV, Group V and Group VI, it appears that

Table 2: Pair wise comparison

	Groups compared	Absolute difference in sample mean (AD)	Least Significant difference	Conclusion
1.	I vs III	57.493	17.75	Significant
2.	I vs VI	30.107	17.42	Significant
3.	I vs IV	32.059	17.09	Significant
4.	I vs V	29.29	16.53	Significant
5.	I vs II	13.56	15.70	Insignificant
6.	II vs III	43.873	17.42	Significant
7.	II vs VI	22.54	17.09	Significant
8.	II vs IV	18.49	16.53	Significant
9.	II vs V	15.733	15.103	Significant
10.	V vs III	28.14	17.09	Significant
11.	V vs VI	6.808	16.536	Insignificant
12.	V vs IV	2.76	15.703	Insignificant
13.	IV vs III	25.38	16.532	Significant
14.	IV vs VI	4.048	15.703	Insignificant
15.	VI vs III	21.232	15.703	Significant

Group V shows the higher value followed by Group IV and then Group VI. But this variation was not found to be statistically significant.



Graph 1: Mean Values (Kgs) with respective standard deviation

Discussion

The disease process and the restorative procedure that create the need for endodontic therapy affect much more than the pulp vitality. The tooth structure that remains after endodontic therapy has been undermined and weakened by previous episodes of caries, fracture, tooth preparation. Endodontic manipulation further removes intra – coronal dentin and the decreased strength, this is primarily caused by the loss of coronal tooth structure and is not a direct result of endodontic treatment.

The adhesive bonding system used in this study contains methacrylates that contain both hydrophobic groups on the ester molecule. These groups improve the adhesive capability and bond strength of resin to tooth structure by promoting penetration, impregnation and entanglement of the methacrylate based monomers into exposed collagen and also encapsulating the HA crystals dentinal substrates where they polymerise in situ and creates zones of acid resistant, insoluble transitional zone of resin reinforced dentin or hybrid layer. When the acid conditioners is applied, it removes the smear layer and demineralises intertubular and peritubular dentin and leave hydroxyl apatite depleted dentin surface exposing the collagen fibers. The hydrophilic primer HEMA, infiltrates the collagen network when placed on the somewhat moist dentin. The primer allows subsequent resin layer to flow or "wet" the etched surface. Adhesive is placed on the primed region of conditioned tooth surface and cured.

For bonding of amalgam, Scotch bond multipurpose plus kit is used, in addition to the etchant, primer and adhesive, additional catalyst and activator components are supplied, when the activators and catalyst are added to the above components we get the dual cure mode needed for bonded amalgam restoration which will set in approximately 4 to 5 minutes at room temperature. When amalgam is condensed prior to polymerization, a micro-mechanical bond is formed between the amalgam and the adhesive resin. The wet adhesive resin interferes the unset amalgam and the resin penetrates between the amalgam crystal phases where it polymerizes and is locked in by setting of amalgam (Warren S. et all).

The results of the present study demonstrated that there was no significant difference in the fracture resistance between Group-I and Group-II these observations are in agreement with that of E.S. Reeh et al[8] and J.G. Bell et al[9]. Gutmann J.L[10]., E.S.Reeh et al[8] has conclusively shown that endodontic procedure reduces tooth stiffness by only 5% which is mostly contributed by the access opening and further states that MOD cavity preparation reduces the tooth strength to an extent of 60% or more. Therefore loss of marginal integrity was the greatest contributor to the reduced fracture resistance of endodontically treated teeth. This finding is very clearly depicted in our study where fracture resistance value of Group III was significantly low (50% less), when compared to Group I and Group II. Marginal decrease in values of Group II in comparison to Group I, although insignificant could be attributed to this 5% decrease which E.S.Reech et al[8] has noticed in his study.

Further studies by A.R. Helfer et al[3] has carried out a study on the moisture content of vital and pulpless teeth to show that there was only 9 % loss of moisture in pulpless teeth which is likely to play a insignificant role in contributing to the reduced strength of endodontically treated teeth.

Amongst MOD cavity preparation with superimposed access cavity, it was noticed that Group III had statistically significant lower values when compared to Group IV, Group V and Group VI. The above finding goes to say that restoring a prepared cavity resulted in an improvement in the fracture resistance of the teeth (by 25%) irrespective of the type of material used in this study. The mean values for endodontically treated MOD cavities which were left unrestored (Group III) is about 50% less than an intact sound tooth (Group I) or teeth with just an access opening (Group II). Restoring these teeth has resulted in 25% increase in the tooth strength, which is significantly higher when compared to Group III. The increase in fracture resistance of teeth restored with silver amalgam (Group IV) has been discussed by Goel et al[11] It was interesting to note that fracture resistance of Group IV was similar to that of Group V and Group VI. This was an unanticipated finding as it has been claimed by many authors that bonded restoration brings about cuspal reinforcement with a resultant increase in tooth strength.

Zidan and Abdel Kereim[12] compared the stiffness of teeth resorted with amalgam, amalgam bonded with amalgam bond plus with HPA powder and composite bonded with Scotch bond multipurpose plus adhesive. The researchers concluded that bonded restorations significantly recovered the lost tooth stiffness than non-bonded restorations. Several other authors are of the similar opinion that bonded amalgam restorations show increased fracture resistance than non-bonded restorations.[5-7,13-19] Though our observations in the present study is contrary to the findings of the above authors, but is in conformity with the findings of Andrew Steele et al[1], who has found no significant difference in fracture resistance of silver-amalgam, bonded amalgam and composite resin restoration in an endodontically treated premolar with MOD cavities. Antonio J et al[2], Santos et al[20], have studied the effect of aging and thermo cycling of MOD restoration and have revealed that after thermo cycling there was no increase in fracture resistance of bonded amalgam when compared to conventional amalgam restorations. Thermocycling intereferes with the tooth strengthening effect of bonded amalgam restoration, this was due to the fact that there is hydrolysis of the adhesive. However, there is no general agreement on such a process. According to Nelson J[21], polymers like 4 – meta based adhesive resin, when once polymerized or cured, form a plastic material that does not break down in the presence of water, they are not degraded by hydrolysis. Nakahayashi et al[22] have determined that, silver amalgam restoration bonded to human dentin in vivo, might be subjected to failure in a zone of exposed collagen that can occur between resin collagen hybrid layer and the underlying unaltered normal dentin. This zone undergoes demineralization during pretreatment for smear removal but the adhesive monomer failed to completely penetrate it leaving a zone of collagen only exposed to possible degradation after long term water immersion.

When the adhesive resin liner is still wet and amalgam is condensed with pressure, the viscous resin adhesive may get incorporated into the incremental amalgam interface and this incorporation of resin adhesive may affect the mechanical properties of amalgam and may affect the clinical performance.[23-25] With regard to Group VI it is again an unanticipated finding because bonding agents capable of bonding restorative material and tooth structure theoretically should provide tooth strengthening effect. Several authors have studied the effect of bonded composite restorations on the reinforcement of the endoontically treated as well as non-endodontically treated teeth and have confirmed the above said effect.[26-29] Wendit et al[30] on investigation goes even to the extent of stating that bonded composite restoration in endodontically treated teeth improves fracture resistance to a degree, that exceeds that of sound natural teeth. Interestingly, the present study has obtained contrasting results. The mean value obtained for Group VI (77.849kg) is marginally lesser than that of even amalgam (81.897) or bonded amalgam (84.657) restoration although, statistically not of significance.. Studies by Joynt et al[31] are in line with the observation made in the present study.

De-C-Oliveria et al[32] has studied the tooth strengthe-ning effect of various restorative materials in endod-ontically treated teeth and has related the cavity dimensions of MOD cavity preparations with that of reinforcing effect of the restorative materials. The type of tooth preparation investigated in this study was a standard MOD preparation which was of the same dimension as that of De-C-Oliveria et al [32]

On visually observing the fractured specimens after testing it was noticed that the teeth in the group I, II & III fractured at the base near the CEJ or split through the pulpal floor. In Group IV specimens the fracture of the cusps either facial or lingual occurred at the base of the preparation in variably at the tooth restoration interface. In Group V & VI although the fracture occurred at the interface on could notice that small portions of the restoration was adhering on the fractured cusps indicating bonding. One should also agree that many differences exists between fracture occurring clinically and those induced by a testing machine. Forces generated intra-orally during function vary in magnitude, speed of application and direction, where as force applied to tooth in this study were at a constant direction and speed, increased continuously until fracture occurred. Therefore the results obtained in the controlled lab study cannot be directly interpolated with the clinical performance. Therefore further in vivo and in vitro studies are required before these materials could be recommended for routine use in restoring endodontically treated teeth.

Certainly most teeth that require endodontic therapy would have lost more tooth structure than just an access preparation. The results of present study as well as the various theoretical implications would suggest a need to further evaluate the restorative technique for endodontically treated teeth. It is imperative that tooth structure should be preserved wherever possible consistent with good endodontic access Marginal ridges should be preserved unless their removal is unavoidable for the purpose of restoration irrespective of the restorative material or the technique used.

Conclusion

On analyzing the results obtained in the present study following conclusions were drawn.

1) Fracture strength of intact natural teeth was superior to all the teeth tested in the study.
2) Endodontic procedure by itself has not affected the tooth strength significantly.
3) Loss of marginal ridge integrity was the major contributor in reducing the Fracture strength of endodontically treated tooth (approximately 50%)
4) Restoration of teeth after endodontic therapy improved the fracture resistance by about 25% with all the three type of restorations investigated in the study.
5) Fracture strength of endodontically treated teeth restored with conventional amalgam, bonded amalgam and composite resin did not differ significantly from each other.
6) Bonding of restorations to tooth structure has failed to bring about any improvement in the strength of the teeth tested.

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