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Comparative evaluation of root fracture resistance using different root canal sealers

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Abstract--Background: Fracture resistance is a mechanical property that describes the resistance of brittle materials to the catastrophic propagation of flaws under an applied load. Therefore any material that can compensate for this weakening effect could be useful. Thus to reinforce the instrumented teeth against fracture; sealers are used in conjugation with a core filling material. Material and Methods: One hundred and twenty extracted caries-free and visually assessed fracture-free, human single rooted mandibular premolar teeth were selected for the study. The prepared teeth were randomly divided into four experimental groups and two control group of 20 teeth each. One control group of 20 teeth where access opened and left uninstrumented and unobturated. Group- I: Teeth obturated with gutta percha and

epoxy resin based sealer; Group- II: Teeth obturated with polymer based core and methacrylate based Sealer; Group- III: Teeth obturated with gutta percha and calcium silicate based sealer. ; Group IV: Teeth obturated with gutta percha and zinc oxide eugenol based sealer.; Group V: Teeth instrumented and obturated with gutta percha without use of sealer (Positive control).; Group VI – Teeth with no instrumentation or obturation (Negative control). Each specimen was subjected to a load at a crosshead speed of 1.0 mm/min until the root fractured using Universal testing machine. Results : Overall it can be said that Group II has best fracture resistances followed by Group I , Group VI -negative control , Group III and Group V- positive control is the least in order. As compared to Group V- positive control and Group VI -negative control (Root with no instrumentation and obturation). Conclusion : Among the root canal sealers; resin based root canal sealers showed higher resistance to fracture than non adhesive sealers. Methacrylate resin based sealer showed highest fracture resistance followed by the roots which are obturated with gutta percha along with epoxy resin sealer, zinc oxide eugenol sealer and least for calcium silicate based sealer.

Keywords--resin, fracture resistance, root canal treatment, premolar, gutta percha.

Introduction

Endodontically treated teeth are widely considered to be more susceptible to fracture than vital teeth. The reason most often reported have been the dehydration of dentin after endodontic therapy, excessive pressure during obturation, the removal of tooth structure during endodontic treatment i.e. excessive widening of root canals^{1,2} and loss of collagen cross-linking³. Also, the “loss of proprioception or an elevated pain threshold allows larger loads on endodontically treated teeth without triggering a protective response.⁴ The modulus of elasticity and, importantly, the fracture toughness of teeth might be reduced not only by incomplete root development and losses of hard tooth substance but also by changes in the moisture content of dentin with aging and with the loss of vital pulp tissue.⁵ Increased amounts of physiologic and pathologic translucent dentin also occur with aging, which is associated with loss of moisture and leads to an increased risk for brittle fracture^{5,6}. Tooth type, canal wall thickness and root canal diameter and cross-sectional shape, root canal preparation instruments, preparation methods and the size of the master apical file might all be involved in the increased risk for tooth fracture during and subsequent to endodontic therapy. Over instrumentation of root canals with excessive removal of dentin and the presence of noncircular canals and thin canal walls, particularly with certain tooth types, increase the risk for root fracture^{7,8}.

Until relatively recently, the choice of materials for root canal sealers and root canal filling was very limited. Stable adhesion to root canal dentin walls and an elastic modulus similar to dentin are two key factors for root filling material to improve fracture resistance of endodontically treated teeth⁷. The elasticity of

dentin plays a major role in the provision of successful bonding mechanism for root filling. So the knowledge of mechanical properties of dentin was important for understanding how masticatory strains were distributed throughout a tooth and predicting how stresses and strain were altered by dental restorative procedure, age and diseases⁶. It is suggested that materials that can adhere the root canal dentin surface will strengthen the remaining tooth structure. It is thought that the adhesion and mechanical interlocking between the material and the root canal dentin prevents microleakage and reduces the risk of fracture⁸.

In restorative dentistry, numerous studies have demonstrated coronal reinforcement of tooth through bonded restorations. Bonded amalgams, composites and glass ionomer all have been shown to reinforce remaining tooth structure by bonding to dentin and enamel^{9,10}. Similarly, bonding endodontic obturation materials could enhance the ability of endodontically treated teeth to resist fracture. Therefore any material that can compensate for this weakening effect could be useful. Thus to reinforce the instrumented teeth against fracture; sealers are used in conjugation with a core filling material¹¹. In the present study an attempt has been made to measure and compare the fracture resistance of root canals obturated with four different endodontic sealers namely zinc oxide eugenol based, epoxy resin based, calcium silicate based root canal sealer along with gutta percha and methacrylate resin based along with polymer as core using lateral condensation technique.

Materials and Methods

One hundred and twenty extracted caries-free and visually assessed fracture-free, human single rooted mandibular premolar teeth were selected for the study. Teeth were cleaned of calculus, deposits and soft tissue debris with ultrasonic scaler. The teeth were examined under an operating microscope at 25 X magnification and those with microcracks were excluded. The radiographs of all the teeth were taken with Radio Visio Graphy unit. Two radiographs were taken, one in a bucco-lingual and the other in a mesio-distal plane for studying the root canal anatomy. These radiographs were performed to eliminate teeth with irregularly shaped canals, to confirm that each tooth had a single canal, no previous root canal treatment and no resorption. The teeth were stored in 0.9% normal saline solution for twenty four hours.

Sample preparation

Each tooth was sectioned with a diamond disc and straight handpiece under constant irrigation by syringe needle, 1mm coronal to the cemento-enamel junction, measuring root specimens of 14 mm in length using digital vernier caliper. The pulpal tissue was removed using barbed broach. The patency of the canal was checked with a No. 10 K file. The working length was determined visually by subtracting 1 mm from the length of a size 10 K file at the apical foramen. The root canals were instrumented with crown down technique with endodontic rotary handpiece and NiTi rotary file i.e. HERO Shaper instruments as follows: A #30 file with 0.06 taper was initially introduced in two thirds of the working length followed by #30 file with 0.04 taper at the working length and final shaping with #30 file with 0.06 taper performed till working length .

A root canal lubricant was used throughout the cleaning and shaping of the root canal. Throughout instrumentation, irrigation was performed using 1 ml of 5% sodium hypochlorite and with 1 ml of 17% EDTA to remove smear layer. The canals were recapitulated with a No. 10 K file to ensure patency of the canal terminus. Final irrigation was done with 5ml of 5.25 % sodium hypochlorite solution followed by 10 ml of saline to remove any remaining sodium hypochlorite residue with a 27-gauge needle. The root canals were dried using sterile paper points. The prepared teeth were randomly divided into four experimental groups and two control group of 20 teeth each. One control group of 20 teeth where access opened and left uninstrumented and unobturated.

- Group- I: Teeth obturated with gutta percha and epoxy resin based sealer.
- Group- II: Teeth obturated with polymer based core and methacrylate based Sealer.
- Group- III: Teeth obturated with gutta percha and calcium silicate based sealer.
- Group IV: Teeth obturated with gutta percha and zinc oxide eugenol based sealer.
- Group V: Teeth instrumented and obturated with gutta percha without use of sealer (Positive control).
- Group VI – Teeth with no instrumentation or obturation (Negative control).

Storage of samples

All samples were stored in 100 % humidity at 25°C for one week in incubator to simulate *in vivo* conditions ensuring correct and complete setting of sealing material. After one week, preparation of the root specimens was done for mechanical testing (Instron.). The entire root samples were mounted vertically in self curing acrylic resin blocks in custom made iron mould (Length= 20 mm, height =20 mm, width=20 m). The samples of each group were color coded according to acrylic resin base used to fix the root samples. Root samples were mounted in acrylic resin keeping 9mm of root exposed and 4-5 mm of root was embedded in resin. Then resin block samples were removed from the iron mould when the first sign of polymerization occurred. The temporary material (cavitemp) was removed and the root canal access was shaped with the help of carbide bur to accept the loading fixture.

Preparation for Mechanical Testing

The blocks were mounted with the vertically aligned roots in the testing machine one at a time. A loading fixture with a spherical tip was mounted and aligned with the center of the canal opening of each specimen. Each specimen was subjected to a load at a crosshead speed of 1.0 mm/min until the root fractured. This is the point at which a sharp and instantaneous drop greater than 25% of the applied load was observed. The test was terminated at this point and the force required to fracture the roots was recorded in Newton's.

Statistical Analysis

The statistical analysis was performed using a commercially available software program SPSS version 20.0.0. One way ANOVA test was carried out for comparing the groups and to determine whether significant differences existed among the tested groups. Further, Independent 't' tests were carried out to determine whether significant differences existed among the individual groups and also among each pair of groups. Significance for all statistical tests was predetermined at $p < 0.05$. For all the tests p value was considered for statistical analysis.

Results

The mean fracture resistance values (in N) for Group were depicted in Figure 1.

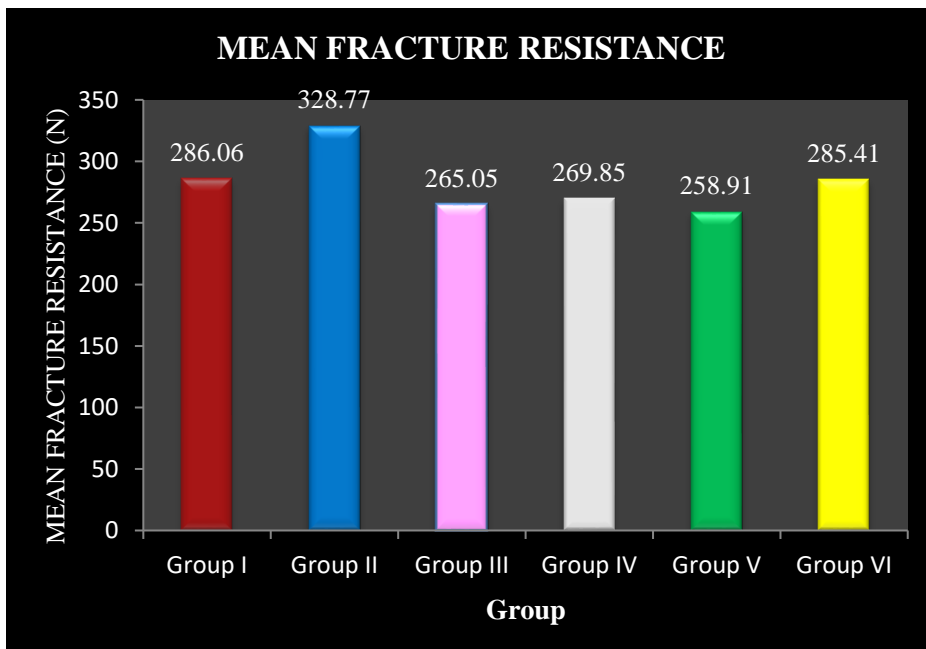


Figure 1. Bar graph showing fracture resistance amongst the groups

Table no. 1 shows that there is significant difference between mean fracture resistances of all the groups.

Table 1. ANOVA test for variance among the Test Groups and Control Group						
Source of variation	Sum of Squares	Degree of freedom (df)	Mean sum of Square	F - value	p - value	Remark
Between Groups	63644.552	5	12728.910		.018	

Within Groups	509515.24	114	4470.134	2.848	(P <0.05)	Significant
Total	573239.71	119				

Overall it can be said that Group II (methacrylate resin) has best fracture resistances followed by Group I (Epoxy Resin), Group VI -negative control (Root with no instrumentation and obturation), Group IV (Zinc Oxide eugenol), Group III (Calcium silicate), and Group V- positive control (Root obturated without root canal sealer) is the least in order. As compared to Group V- positive control (Root obturated without root canal sealer) and Group VI -negative control (Root with no instrumentation and obturation) Group II showed best results i.e. the sealer is effective in getting better fracture resistance. Table 2

Pair	Mean (in N)	Standard Deviation	t - value	p - value	Remark	Percent change %	
Group I	286.0675	73.4629	-2.023	.050	Significant	14.93	↑
Group II	328.7765	59.2975					
Group I	286.0675	73.4629	1.091	.046	Significant	7.347	↓
Group III	265.0505	43.7498					
Group I	286.0675	73.4629	.715	.479	Not Significant	5.67	↓
Group IV	269.8520	69.9220					
Group I	286.0675	73.4629	1.123	.268	Not Significant	9.49	↓
Group V	258.9160	79.2959					
Group I	286.0675	73.4629	.029	.977	Not Significant	0.0023	↓
Group VI	285.4160	69.4052					
Group II	328.7765	59.2975	3.867	.000	Significant	19.38	↑
Group III	265.0505	43.7498					
Group II	328.7765	59.2975	2.874	.007	Significant	17.92	↓
Group IV	269.8520	69.9220					
Group II	328.7765	59.2975	3.155	.003	Significant	21.25	↓
Group V	258.9160	79.2959					
Group II	328.7765	59.2975	2.124	.040	Significant	13.19	↓
Group III	265.0505	43.7498	-0.260	.796	Not significant	1.77	↑
Group IV	269.8520	69.9220					
Group III	265.0505	43.7498	.303	.764	Not significant	2.34	↓
Group V	258.9160	79.2959					
Group III	265.0505	43.7498	-1.110	.274	Not significant	7.13	↓

Group IV	269.8520	69.9220	.463	.646	Not significant	4.05 ↓
Group V	258.9160	79.2959				
Group IV	269.8520	69.9220	-.707	.484	Not significant	5,77 ↑
Group V	258.9160	79.2959	-1.125	.268	Not significant	1.24 ↑
Group VI	285.4160	69.4052				

Discussion

Fracture resistance is a mechanical property that describes the resistance of brittle materials to the catastrophic propagation of flaws under an applied load. It is proportional to the energy required to create new surfaces via crack propagation. Typical fracture resistance values of dental tissues are in the range of 0.6-1.8 MNm^{-3/2} for enamel and 3.1 MNm^{-3/2} for dentin¹². In our study according to results obtained resin based sealer i.e. methacrylate based sealer and epoxy resin sealer had shown high fracture resistance as compared to other non adhesive root canal sealer¹³. The advantage of resin sealer can be because of greater adhesion of this sealer to root dentin as well as less volumetric shrinkage and high dimensional stability as compared to the two other root canal sealers.^{12,13}

The results of our study is in accordance with study performed by Hammad et al who had showed that two resin based obturating material i.e. Resilon and EndoRez had a mean force to fracture higher than zinc oxide eugenol and gutta flow group¹⁴. Another study performed by Ulusoy O I et al also had stated that resin based sealer had showed better resistance to fracture than the non adhesive sealer¹⁵. In the present study Group II i.e. roots filled with methacrylate resin based sealer showed highest mean fracture resistance as compared to all other test and control group. The findings of this study are in agreement with Teixeira et al⁸. The group with resin based sealers displayed significantly higher fracture resistance than the non adhesive sealers group. This can be explained by the fact that core filling material consist of synthetic polymer and as resin based sealer which attaches to polymer core as well as to dentin wall by the use of bonding agents or primer in order to penetrate into dentinal tubules . As result, a monoblock is formed consisting of self etch methacrylate resin sealer, polymer core and dentin⁸. Another reason for better fracture resistance could be that the removal of smear layer by EDTA after biomechanical preparation may have allowed the root canal filling material and root canal sealer to contact the canal wall and penetrate in the dentinal tubules which may increase the strength of roots¹⁶.

The bonding ability of Resilon to methacrylate resin based root canal sealers is supposed to be derived from the inclusion of the urethane dimethacrylate resin. Tay FR and Pashley DH had reported that it contains two interfaces one between the sealer and primed dentin, another between the sealer and Resilon, hence may

be classified as a secondary type monoblock¹⁷. Secondary monoblock are those that have two circumferential interfaces, one between the cement and dentin and the other between the cement and the core material. With an understanding of these principles, it is appropriate to examine the ability of some classic secondary monoblock described in the restorative and endodontic literature to function as mechanically homogeneous units¹⁷. In the present study control group i.e. roots obturated without sealer (Positive) and uninstrumented or obturated roots (Negative) had showed lower fracture resistance as compared to root filled with methacrylate sealer. These results are in accordance to the study performed by Teixeira FB et al⁸.

Vishwanathan K et al had also stated similar results in his study by comparing fracture resistance of teeth prepared with rotary instrument and filled with gutta percha-zinc oxide eugenol sealer, gutta percha-epoxy resin sealer and Resilon obturating materials¹⁸. The Group I i.e. epoxy resin based sealer showed better fracture resistance than other experimental (except Group II) and control group. The advantage of resin sealer can be because of greater adhesion of this sealer to root dentin as well as less volumetric shrinkage and high dimensional stability as compared to the two other root canal sealers. These results were in agreement with study of Conbankara FK et al⁹ and Sagsen B et al¹⁹. Epoxy resin sealer also shows better penetration into micro irregularities because of its creep capacity and long polymerization time, which increases the mechanical interlocking between the sealer and root dentin. Those properties facilitate the interlocking between sealer and dentin, which allied to the cohesion among molecules, promotes larger adhesion and higher resistance to dislodgement from dentin surface²⁰.

The findings of this study are in agreement with Sagsen B et al who found that an epoxy resin based sealer demonstrated a better fracture resistance to calcium silicate based sealer¹⁹. Similar observation was made by Bhat SS et al who compared epoxy resin based sealer, silicone based sealer and zinc oxide eugenol sealer²¹. Fisher et al theorized the explanation for the superior adhesiveness to root dentin shown by epoxy resin based sealer (AH Plus) can be based on the creation of a covalent bond by an epoxide ring to amino groups in collagen network. However, the bonding capacity is not able to totally reduce the susceptibility of the roots to fracture^{22,23}.

They observed that roots obturated with epoxy resin based sealers with lateral condensation technique were significantly stronger than other sealer such as zinc oxide eugenol, calcium silicate and root filled without sealer²⁰. In addition, epoxy resin based sealer also exhibits low solubility, good dimensional stability, low expansion, adhesion to dentin, good flow and hence coats the canal walls meticulously²⁴. In the present study epoxy resin based sealer had more fracture resistance than calcium silicate based sealer. The result is in accordance with a study done by Topcuoglu HS et al. They compared resistance to fracture of roots obturated with epoxy resin-based, mineral trioxide aggregate-based, and bioceramic root canal sealers²⁵.

The Group III i.e. calcium silicate based sealer showed lowest mean fracture resistance values. These finding is according to study of Sagsen et al (2012); who

compared fracture resistance of roots filled with gutta percha and epoxy resin-based sealer (AH Plus) and with a calcium silicate-based sealer (iRoot SP and Fillapex)²⁶. The chemical composition of the MTA-based sealer could also influence its bonding behaviour. In a recent study, the reason for the low bond strength of MTA Fillapex was claimed to be the low adhesion capacity of tag-like structures because of apatite formation by MTA²⁷. The Group IV i.e. zinc oxide eugenol based sealer showed mean fracture resistance lower than epoxy resin sealer and methacrylate resin sealer. This can be explained by their sudden setting reaction (transition from paste to solid mass) i.e. it shrinks upon setting and dissolve over period of time. This may be responsible for debonding from dentinal walls or cohesive fracture caused by shrinkage of setting stresses. Zinc oxide eugenol based sealers have less penetrating ability and less flow, are more viscous and had a tendency to produce more frequent and larger pores and vacuoles. The vacuoles in particular the larger ones, would allow the bubbles to open up to the exterior, thus leaving gap between root canal walls and obturating materials. Also many studies have proved that no zinc oxide eugenol based sealer bond to root dentin and prevent apical leakage.²⁸

Also there is a slight increase in the fracture resistance of zinc oxide eugenol based sealer when compared to Group III i.e. Calcium silicate based sealer and Group V i.e. roots obturated without sealer. As they contain particle such as wax, polymerised resins and zinc oxide in them which may provide a better flow and was able to penetrate dentinal tubule partially thus creating adhesion resulting in reinforcement of weakened root¹³. In our study zinc oxide eugenol group has shown increased fracture resistance than group where obturation with no sealer which may be explained by a chelating reaction that occur while eugenol and zinc oxide in the gutta percha to form chelate bond. Eugenol also has softening effect on gutta percha, thus creating an interlocking meshwork that will increase adhesion between two materials²⁹.

These properties impart a shock reduction mechanism and add more resistance to fracture when obturated with gutta percha core but there was no significant difference between Group V (Obturated without root canal sealer) and Group III (Calcium silicate based root canal sealer). In the present study gutta percha with Zinc oxide eugenol based sealer (Group IV) showed lower mean value of fracture resistance compared to resin based root canal sealers (i.e. Group I and Group II) which are in accordance with the study of Lertchirakarn et al¹. These results are in accordance with the study performed by Wadhvani and Gurung, who compared the fracture resistance of roots filled with Resilon/epiphany, epoxy resin sealer/gutta percha and zinc oxide eugenol based root canal sealer³⁰.

The low fracture resistance values observed in the present study compared to previous studies may be due to the variations between structures of root dentine of the tested samples related to age or dentinal sclerosis¹⁹. When the results of this group is compared to Group V i.e. roots filled without sealer; it had shown less fracture resistance to that of roots filled with zinc oxide eugenol which are similar to finding obtained in the study performed by Nagpal et al²⁹. The specimens in the negative control i.e. with no instrumentation and obturation showed better fracture resistance than teeth which obturated with calcium silicate based sealer, zinc oxide eugenol based sealer and positive control i.e.

without root canal sealer and less compared to teeth methacrylate resin based sealer, epoxy resin based sealer. The fracture resistance study performed by Chadha et al also showed similar results³¹.

The specimens in the positive control showed least fracture resistance than roots with zinc oxide eugenol based sealer, methacrylate resin based sealer, epoxy resin based sealer and calcium silicate based sealer. This suggest that root canal sealers are necessary to seal the space between the dentinal wall and the obturating core interface, to fill voids and irregularities in the root canal, to fill lateral and accessory canals, and spaces between gutta-percha points used in lateral condensation. This confirmed that gutta percha should be used along with a sealer. These results are in agreement with results obtained by study performed by Shetty R et al³².

Conclusion

Based on the results obtained and discussed, the following conclusions were drawn from the present study:-

- Among the root canal sealers; resin based root canal sealers showed higher resistance to fracture than non adhesive sealers. Methacrylate resin based sealer showed highest fracture resistance followed by the roots which are obturated with gutta percha along with epoxy resin sealer, zinc oxide eugenol sealer and least for calcium silicate based sealer.
- The fracture resistance of roots with no instrumentation and obturation had higher fracture resistance than roots which are obturated with Calcium silicate based sealer, Zinc oxide eugenol based sealer and roots obturated without the use of root canal sealer and lesser than roots obturated with resin sealers.
- The fracture resistance of roots which were instrumented and obturated with gutta percha without the use of root canal sealer showed least fracture resistance when compared with the other groups.

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