

Original Article

The effect of different root canal sealers on the fracture resistance of endodontically treated teeth-*in vitro* study

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ABSTRACT

Background: The aim of this study was to compare the *in vitro* effects of four different root canal sealers on the fracture resistance of endodontically treated teeth.

Materials and Methods: Seventy-five freshly extracted human mandibular premolars were used for the study. Teeth were divided into five groups based on type of root canal sealers used. Gutta-percha was used for all the samples: Group I: AH Plus root canal sealer; Group II: MTA Fillapex root canal sealer; Group III: Apexit root canal sealer; Group IV: Conventional zinc oxide-eugenol (ZOE) sealer; Group V: Control (unobturated teeth). The teeth were embedded in acrylic resin blocks and fracture force was measured using a universal testing machine (Asian Test Equipments). Data obtained were statistically evaluated using one-way ANOVA and *post hoc* test (Tukey's test). All groups showed statistically significant result ($P < 0.05$).

Results: Group I and Group II showed higher resistance to fracture than other three groups. There was comparable difference in fracture force between Group I and Group II. Moreover, there was no statistically significant difference between Group III and Group IV and between Group IV and Group V.

Conclusion: Based on this *in vitro* study, resin-based sealer was more effective as compared to other sealers and the control group. However, no significant differences were observed between ZOE and control group.

Key Words: Sealer, fracture, resistance, MTA- Fillapex, zinc oxide-eugenol

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INTRODUCTION

The strength of endodontically treated teeth depends on the remaining amount of tooth structure after canal preparation. The factors affecting root fracture after endodontic therapy are over instrumentation, dehydration of dentine after endodontic therapy, and also uncontrolled pressure during obturation. All of these factors cumulatively and in addition to occlusal load increase the possibility of a root fracture.

Furthermore, synergetic actions of intracanal irrigants and medicaments may also influence the physical and mechanical properties of the root dentine, which leads to failure or fracture of endodontically treated teeth.^[1]

In endodontically treated teeth, the root canal system is reinforced by obturating the root canal in order to increase the resistance of the tooth to compressive strength.^[1] To provide a hermetic seal, the bonding

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of root canal sealer to the dentine is paramount in maintaining the integrity of the seal in a root canal filling.^[2] Thus, a root canal sealer with the property of strengthening the tooth against root fracture would be of obvious value. Various research methodologies have developed materials which facilitate adhesion to the root canal system as it is thought that adhesion and mechanical interlocking may strengthen the remaining tooth structure thus reduce the risk of fracture.^[1] Most commonly used root canal sealer is the zinc oxide-eugenol (ZOE) sealer (Kerr sealer-Rickert, California, USA) and has been used for several decades because of its satisfactory physicochemical properties.^[3] However, leakage and recontamination of the root canal system due to eugenol or zinc oxide loss through continuous hydrolysis which causes post treatment complication.^[4,5]

Apexit Plus (Ivoclar Vivadent, Schaan, Liechtenstein) is a calcium hydroxide (Ca(OH)₂)-based root canal sealer. It triggers healing by inducing hard tissue formation, has antibacterial activity, and mediates the degradation of bacterial lipopolysaccharides thereby controlling inflammatory root resorption.^[6] Ca(OH)₂-based root canal sealers have been found to have good biological apical sealing with deposition of calcified tissue at the apical foramen. The therapeutic property of this sealer depends on its ionized form, for which it must be partly soluble.^[7,8]

AH Plus (Dentsply, Konstanz, Germany) is an epoxy resin-based sealer with properties including easy handling, potential for better wettability of the dentine and Gutta-percha surfaces, and good sealing property. Resin-based root canal sealers are considering as the material of choice due to their ability to penetrate into dentinal tubule and the possibility of creating monoblocks between the root canal filling material and intraradicular dentin. These properties are considered to be of paramount importance among root canal sealers.^[5,6]

MTA Fillapex (Angelus, Londrina, Brazil) is a mineral trioxide aggregate (MTA)-based, salicylate resin root canal sealer containing 13% MTA and salicylate resin for their antimicrobial and biocompatibility properties.^[9] It has high radiopacity, low solubility, and low expansion during setting, cementum regeneration with good sealing property, bactericidal property, and biocompatibility.^[10,11] MTA Fillapex releases free calcium ions (Ca²⁺) which help in the healing process by stimulating tissue regeneration.^[12]

It has been well established that resin-based root canal sealer (AH-Plus) has a good retention to root dentine, leading to a good seal of the root. The MTA-based root canal sealer (MTA Fillapex) and the Ca(OH)₂-based root canal sealer (Apexit Plus) both have good biocompatibility and antibacterial activity. A root canal sealer which only helps in achieving a good hermetic seal but also has antibacterial property and would provide deposition of calcified tissue, and protection against root fracture would be considered as ideal.

Thus, this study was undertaken to evaluate the fracture resistance of root canal sealers of different bases to root dentine of endodontically treated tooth when they are subjected to vertical loads from a universal testing machine.

MATERIALS AND METHODS

The present study was conducted in the Department of Pedodontics and Preventive Dentistry at ITS Centre for Dental Studies and Research (CDSR), Ghaziabad, India. For this study, 75 intact noncarious human mandibular premolars, extracted for orthodontic purposes were selected. The extracted teeth were cleaned and were stored in normal saline till the further period of the study. The teeth were prepared by the same operator, whereas the fracture resistance test was carried using a universal testing machine operator at Centre for Advanced Research (ITS CDSR). The teeth were decoronated using a wheel diamond bur to a standard length of 14 mm. Biomechanical preparation was done using ProTaper rotary system at a torque of 2.6 nm and speed of 250 rpm (Dentsply, Ballaigues, Switzerland) till F3. The canals were irrigated in three steps between the successive filings, initially with 5 ml of 3% sodium hypochlorite followed by 5 ml of 17% ethylenediaminetetraacetic acid. Final rinse was done with 5 ml of normal saline. The canals were dried using paper points. The specimens were then randomly divided into five experimental groups of 15 teeth each according to the root canal sealer used. Lateral compaction technique was used to obturate the samples with ProTaper Gutta-percha points.

- Group I: AH Plus root canal sealers (Dentsply, Konstanz, Germany) and Gutta-percha points
- Group II: MTA Fillapex (Angelus, Londrina, Brazil) and Gutta-percha points
- Group III: Apexit Plus (Ivoclar Vivadent, Schaan, Liechtenstein) and Gutta-percha points

- Group IV: ZOE in a thin consistency as a sealer and Gutta-percha points
- Group V: Control group (unobturated teeth).

The access cavity was sealed with temporary cement. Five-millimeter apical root end was embedded in acrylic resin and 9 mm length of the root exposed for vertically positioning the root at the time of testing. All the specimens were stored at 37°C in 100% relative humidity at Centre for Advanced Research (ITS CDSR) for 2 weeks. Fracture resistance testing was done using a universal testing machine (Asian Test Equipments, New Delhi, India). The blocks with the vertically aligned roots were mounted on the testing machine one at a time on the lower platform jig. A custom-made metal indenter of 3 mm diameter was tightened to the upper jig and force was applied vertically down the long axis of the root. The tip of the indenter was centered over the canal orifice. Each specimen was subjected to slowly increasing vertical force at a crosshead speed of 1 mm/min until the root fractured. The compressive load was applied at 0° to the long axis of the roots. It was determined by a drop in the force applied and also by the sound of the root cracking up [Figure 1]. The test was terminated at this point and the force required to fracture the root was measured in Newton. The data were compiled and subjected to statistical analysis using one-way ANOVA and least significant difference multiple comparison test. The level of significance was kept at $P \geq 0.05$. Statistical analysis was done using SPSS software version 20. (IBM-SPSS Inc. 233 South Wacker Drive, 11th Floor Chicago, IL 60606-6412).

RESULTS

The normality of data in the present study was tested using Shapiro–Wilk test and was found to be normally distributed ($P \geq 0.05$) [Figure 2].

Fracture force for various groups

The distribution of mean \pm standard deviation of fracture force of Group I (AH Plus) was 240.74 ± 23.98 N, Group II (MTA Fillapex) was 174.53 ± 48.07 N, Group III (Apexit) was 128.59 ± 41.34 N, Group IV (ZOE) was 125.54 ± 26.68 N, and Group V (Control) was 89.83 ± 25.62 N. Group I (AH Plus) exhibited the highest fracture force (240.74 ± 23.98 N), while Group V (Control) showed the lowest fracture force (89.83 ± 25.62 N) [Figure 3].

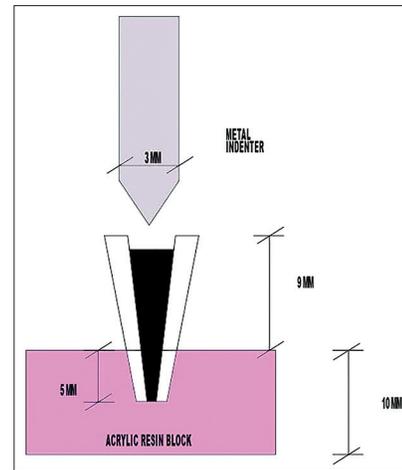


Figure 1: Schematic figure representing root segment for load to fracture test. The tooth was mounted vertically in 10 mm of cold cure acrylic block exposing 9 mm of the coronal portion. 5 mm of the root is embedded in the acrylic block. A 3 mm diameter metal indenter is used at a crosshead speed of 1 mm/min to fracture test the endodontically treated root.

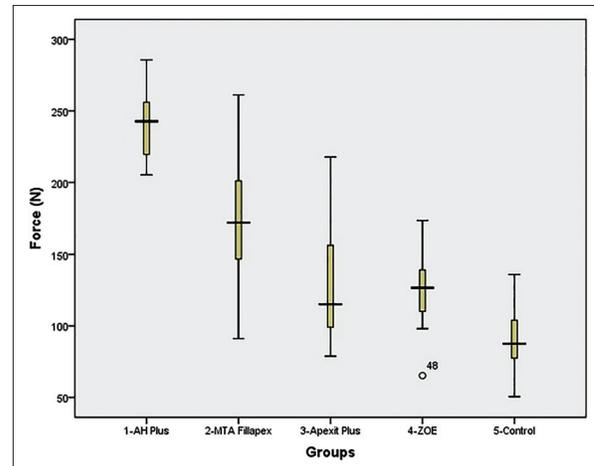


Figure 2: Box plot diagram representing distribution pattern of the measured fracture force values in different groups. (n: Newton)

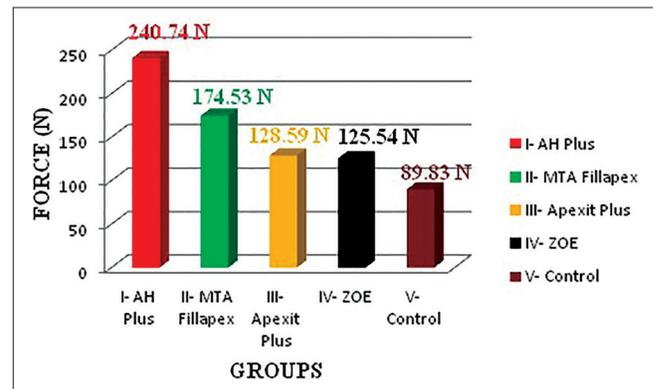


Figure 3: Mean values of fracture force of obturated and unobturated root canals. (n: Newton)

Intergroup comparison using one-way ANOVA and *post hoc* tests (Tukey's test)

On applying *post hoc* tests and setting a level of significance at 0.05, it was seen that Group I (AH Plus) showed statistically significant difference when compared with other four groups. Group II (MTA Fillapex) showed statistically significant difference when compared with Group III (Apexit Plus) and Group IV (ZOE). However, Group III (Apexit Plus) showed no statistically significant difference when compared with Group IV (ZOE). Moreover, Group IV (ZOE) and Group V (Control) also showed no statistically significant difference when comparison was made between the two groups ($P \geq 0.05$) [Table 1].

DISCUSSION

A sealer is conceived as a joint created between radicular dentine and filling material. For a root canal sealer, the ability to resist break in the accomplished seal through micromechanical retention or friction is extremely desirable during intraoral tooth flexure^[13] or preparation of cores or posts along the coronal and middle thirds of canal walls.^[14] The purpose of the sealer is to obliterate discrepancies such as grooves and lateral depressions^[15] that cannot be filled with Gutta-percha, to improve the marginal adaptation to the dentinal walls,^[16] and to fill lateral canals.^[17] The final root filling should prevent microleakage and bacterial contamination.^[18]

Adhesion of root canal sealer to radicular dentine is important for two main reasons. first is the superior

Table 1: Intercomparison of fracture force between test groups

Group	Fracture force (newton) HSD (Tukey's test)				
	Mean difference	SE	Significant	95% CI	
				Lower bound	Upper bound
I versus II	66.21	12.61	0.000**	29.66	102.77
I versus III	112.15	12.61	0.000**	75.59	148.71
I versus IV	115.20	12.61	0.000**	78.65	151.76
I versus V	150.91	12.61	0.000**	114.36	187.47
II versus III	45.93	12.61	0.005*	9.38	82.49
II versus IV	48.99	12.61	0.002*	12.43	85.54
II versus V	84.70	12.61	0.000**	48.14	121.25
III versus IV	3.05	12.61	1.000 (NS)	-33.50	39.60
III versus V	38.76	12.61	0.030*	2.20	75.31
IV versus V	35.71	12.61	0.060 (NS)	-0.84	72.26

The mean difference is significant at the 0.05 level. **Highly significant ($P < 0.001$), *Significant ($P < 0.05$). NS: Not significant ($P > 0.05$); CI: Confidence interval; SE: Standard error; HSD: Honestly significant difference

seal which in turn results in less coronal and apical leakage^[19] and second is preventing the displacement of filling material during restorative procedures.^[20]

The wide range of sealers have been used over the years, namely, ZOE, Ca(OH)_2 sealer, glass ionomer sealer, resin sealers (epoxy-based, urethane dimethacrylate-based) and most recently Bioceramic and MTA-based root canal sealers.

A prime requisite for a sealer to be ideal is having a high fracture resistance and forming a successful monoblock in conjunction with the obturating material. Thus, assessment of fracture resistance of sealers needs to be judged. Therefore, this study was undertaken to test the fracture resistance of the roots receiving different canal sealer materials using the universal testing machine. Here, vertical force with a compressive load was used which is similar to the technique used by Sedgley and Messer to test the brittleness of endodontically treated teeth.^[21] In this study, the force was used in 0° angle, resulting in splitting stress applied over the access opening. This resulted in smaller stresses because of decreased bending movements and maximum stresses located more cervically. This design was found to be more clinically relevant as it better stimulates the support given to healthy tooth by alveolar bone and results in less catastrophic stress build-up caused by unrealistic bending movements.^[22] The fracture was found to occur parallel to the dentin bonding surface.

The results of the present study showed that AH Plus had significantly high resistance ($P < 0.001$) to fracture than all other tested root canal sealers. These results are in accordance with the previous study of Fisher *et al.*,^[23] where they found that AH Plus showed a significantly ($P < 0.05$) greater bond strength compared with all other groups.

They related the higher fracture resistance of AH Plus to formation of a covalent bond by an open epoxide ring to any exposed amino groups in the collagen. AH Plus has a better penetration into the micro-irregularities because of its creeping property and long polymerization period, which increases the mechanical interlocking between the sealer and root dentine.^[24]

In another study by Gesi *et al.*,^[25] AH 26 gave the highest bond strength values. In both cases, the epoxy resin-based sealer showed highest bond strength to dentine and Gutta-percha than ZOE-based and Ca(OH)_2 -based sealer.

Nagas *et al.*^[26] related high fracture resistance of AH Plus to its low shrinkage while setting and long-term dimensional stability. It is resilient, and in combination to Gutta-percha, it forms a perfect seal with dentinal walls giving it a good strength and resistance to fracture. McMichen *et al.*^[8] in their study showed that AH Plus had low solubility and greater film thickness than other sealers which might play a role in its better bond strength.^[8]

In our study, MTA Fillapex showed significantly higher fracture resistance ($P < 0.05$) as compared to Apexit, conventional ZOE, and the unobturated canals (control) but lower bond strength than AH Plus.

Sarkar *et al.*^[27] showed that release of calcium and hydroxyl ions from set sealer results in formation of apatite which comes into contact with fluids containing phosphate. Reyes-Carmona *et al.*^[28] also showed that the apatite formed by MTA and phosphate salts is deposited among collagen fibrils, resulting in a controlled increase in the formation of inorganic nucleations on the dentin, which are seen as an interfacial layer with tag-like features. The low fracture resistance of MTA Fillapex than AH Plus might be due to the lower adhesion capacity of these tag-like structures as related by Nagas *et al.*^[26] and Amin *et al.*^[29]

In the present study, Apexit Plus showed lower fracture resistance than AH Plus and MTA Fillapex, which may be due to its greater solubility which leads to substantial breakdown in its seal, thereby hampering the sealing capability of the root canal sealer. In a study by McMichen *et al.*,^[8] it was seen that the solubility values for Apexit Plus were approximately 200 times greater than that of AH Plus, which suggested that there may be a substantial breakdown. Grossman also reported that epoxy resin sealers have least weight loss.^[30]

In the present study, Apexit Plus and conventional ZOE did not show statistically significant difference. This is in accordance with the studies of Rothier *et al.*,^[31] Siqueira *et al.*,^[32] and Limkangwalmongkol *et al.*,^[33] which stated that the physicochemical properties of $\text{Ca}(\text{OH})_2$ -based root canal sealers were equal to or slightly superior than that of ZOE sealer.

The bonding of ZOE is by chelating reaction which takes place during setting. The zinc ion may react with mineral component of dentine as well as with

the zinc oxide in Gutta-percha cone which creates an interlocking meshwork that increases adhesion between the two materials.^[34]

The results of the present study demonstrated that ZOE sealer showed the lowest fracture resistance of the four sealers studied. These results are in accordance with the previous studies of McComb and Smith,^[35] who reported that ZOE sealer showed no adhesive properties. Furthermore, a study done by Gopikrishna *et al.* showed that it had negligible adhesive as well as cohesive strength.^[36]

In the present study, Apexit Plus showed higher fracture resistance values as compared to ZOE though the results were statistically not significant. The slightly higher fracture resistance values for Apexit Plus may be due to the fact that $\text{Ca}(\text{OH})_2$ -based sealers have lower microleakage values that ZOE as reported by Siqueira *et al.*^[32]

In addition, initial solubilization of sealer with release of hydroxyl ions might induce a biological closing of apical foramen by formation of hard tissue, thus minimizing long-term dissolution.^[32]

ZOE and control groups which comprised unobturated root canals showed no significant difference in the fracture resistance. This is in accordance with the previous studies of Bhat *et al.*^[11] and Chadha *et al.*^[24] However, it is not advisable to leave the root canals unobturated. In addition, the main prerequisite of a root canal therapy is to fill the biomechanically prepared root canal space, which is accomplished with root canal sealers and Gutta-percha forming a monoblock with root dentin. Thus, as compared in our study, the intergroup comparison of ZOE and nonobturated group holds significance only in laboratory and not in the clinical setup.

Recently, AH Plus has been widely accepted as a sealer in root canal filling with Gutta-percha due to its better adhesion MTA Fillapex and Apexit Plus are both therapeutic sealers having capability to heal apical tissues and to regenerate the tissues. The results of our study showed that MTA Fillapex had a better bond strength than Apexit Plus, thus to obtain a good hermetic seal with good adhesion MTA Fillapex can be considered in selected cases. However, to obtain a better adhesion with root canal and obtain a good secondary monoblock, AH Plus should be used as it shows better adhesion than most of the root canal sealers.

CONCLUSION

Conclusions that were drawn from the results of the present study are as follows:

- AH Plus (240.74 ± 23.98 N) showed the highest push-out bond strength values amongst the groups followed by MTA Fillapex (174.53 ± 48.07 N)
- Both AH Plus and MTA Fillapex showed better push-out bond strength than the other root canal sealers used
- AH Plus exhibited the highest push-out bond strength (240.74 ± 23.98 N) while non-obtured root canals showed the lowest push-out bond strength (89.83 ± 25.62 N).

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Conflicts of interest

The authors of this manuscript declare that they have no conflicts of interest, real or perceived, financial or non-financial in this article.

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