

Comparative Evaluation of Root Reinforcement Using MTA-based, Epoxy Resin-based, and Silicone-based Endodontic Sealers in Canals Instrumented with Single-file Rotary System: An *In Vitro* Study

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ABSTRACT

Aim: To evaluate root reinforcement by four different sealers, namely, AH Plus, MTA Fillapex, Dia-ProSeal, and GuttaFlow 2, on endodontically treated teeth.

Materials and methods: Sixty human mandibular premolars were randomly divided into four groups of 15 teeth each, according to the type of sealer used: Group I AH Plus, Group II MTA Fillapex, Group III Dia-ProSeal, and Group IV GuttaFlow 2. All samples were decoronated to a length of 13 mm from the apex. Root canals were prepared by OneShape, 25/0.06 taper file and obturated with a matching single cone gutta percha (25/0.06) using the above-mentioned sealers. All samples were subjected to load by universal testing machine until a point at which root fractured, which was recorded.

Results: Teeth obturated with GuttaFlow 2 showed the maximum fracture resistance followed by AH Plus, Dia-ProSeal, and MTA Fillapex. There was no significant difference in fracture resistance between AH Plus and Dia-ProSeal.

Conclusion: Teeth obturated with GuttaFlow 2 sealer, which has powdered gutta percha particles, showed the highest fracture resistance.

Clinical significance: According to the results obtained from this study, obturation of roots with GuttaFlow 2 increased the resistance of root canal-filled teeth to vertical root fracture.

Keywords: AH plus, Dia-ProSeal, Fracture resistance, GuttaFlow 2, MTA Fillapex, Single-cone obturation, Universal testing machine.

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INTRODUCTION

The main goal of endodontic treatment is to gain access into the root canal system and thoroughly debride it and obturate it three dimensionally. Endodontically treated teeth exhibit different structural and biomechanical behaviors than the vital teeth.^{1,2}

The biomechanical properties of the tooth are altered because of the loss of coronal tooth structure as a result of caries, fracture, and access cavity preparation. Additionally, the loss of radicular dentin results from biomechanical preparation of root canal.² Endodontically treated teeth are susceptible to fracture also because of loss of proprioception and an elevated pain threshold allowing higher masticatory force.³

Vertical root fracture (VRF) is the most common type of fracture seen in endodontically treated teeth. Very rarely, a tooth exhibiting VRF can be restored and often result in the extraction of teeth.⁴

The most commonly used method of obturation is the use of solid core like gutta percha along with a sealer. Gutta percha is the most popular solid core obturating material that does not adhere to the dentin and also has a low elastic modulus. Therefore, it does not reinforce the root to prevent VRF.^{5,6} Root canal obturating material in conjunction with sealer has an additional property of strengthening the root against fracture.⁷

The standard of seal obtained with gutta percha and conventional zinc oxide eugenol sealer is quite far from ideal. Hence, several new sealers have been developed to be used instead of zinc oxide eugenol. Resin-based sealer has the capacity to adhere to dentin, by infiltrating into the dentinal tubules.^{8,9} Silicone-based sealers are well tolerated by tissue and have a potential for forming

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monoblock, thus reinforcing root canal. Mineral trioxide-based sealers have a predilection toward mineralization by a controlled increase in the formation of inorganic nucleation on the dentin.¹⁰

Recently, a silicone-based endodontic sealer, GuttaFlow 2 (Coltene/Whaledent, Ohio, USA)—a cold flowable, self-curable obturating system, which contains poly-dimethyl siloxane, silver microparticles, and powdered gutta percha particles in less than 30 μm size—has been introduced. It does not shrink but expands by 0.2% and has a very good adhesion to gutta percha points and dentinal wall.¹¹

Dia-ProSeal (Diadent, Cheongju, Korea) is recently introduced epoxy resin-based sealer. It is available in a two-paste system as a base paste and a catalyst paste. It has acceptable biocompatibility, less solubility, and reduced microleakage, and has high pH due to the presence of calcium hydroxide, which helps in disinfection of the root canal.¹²

Single-cone obturation technique has become popular, because of the widespread use of Ni-Ti rotary instruments and the advent of tapered gutta percha cones, which closely match to the geometry of the prepared root canal walls. Obturation with these cones provides three-dimensional obturation in lesser time than conventional methods. Thus, a sealer that reinforces the tooth structure plays an important role in enhancing the fracture resistance of an endodontically treated tooth alongside gutta percha.

The current study was aimed at evaluating the fracture resistance of teeth obturated using novel endodontic sealers GuttaFlow 2 and Dia-ProSeal with conventional AH plus and MTA Fillapex.

MATERIALS AND METHODS

This study was approved by the institutional review board with the reference number AECS/MDC/ 215/2016-17.

The sample size has been estimated using the software GPower v. 3.1.9.2, the total sample size needed was 60, and each study group comprised 15 samples.

Teeth Specimens

Sixty human single-rooted mandibular premolars extracted for orthodontic or periodontal reasons from the patients of age group 15–30 years were collected. Prior consent from the patients were obtained. Inclusion criteria include intact teeth with a minimum root length of 14 mm. Tooth with dental caries, developmental anomalies, internal or external resorption, attrition or deep cervical abrasion, calcified canals, and curved roots were excluded. Both buccolingual and mesiodistal radiographs were taken to confirm single canal.

Preparation of Samples

Teeth were cleaned using ultrasonic scaler to remove any soft tissue remnants and calculus, and they were disinfected in autoclave according to Occupational Safety and Health Administration regulations (OSHA). The root surface was observed under stereomicroscope at the magnification of 20 \times for any cracks or resorption. The selected teeth were stored in normal saline until further preparation to prevent dehydration.

The crowns were sectioned below the cemento-enamel junction using a slow speed diamond disc (Horico, Berlin, Germany) under water coolant to obtain a standardized length of 13 mm (Fig. 1A). Roots of approximately similar dimensions were chosen (Fig. 1B).

A glide path was obtained with a size 10K-file (Mani, Tochigi Ken, Japan). RC-Prep (Premier dental products, Philadelphia, USA) was used as lubricant during canal preparation. The working length

was determined by inserting a No.10K file into the root canal until it just exited the apical foramen and 1 mm was subtracted from the obtained length (Fig. 1C). Biomechanical preparation of all the roots was done using OneShape single-file rotary system (MicroMega, Besancon, France) to a master apical size of 25/0.06 (Fig. 1D).

The root canals were irrigated with 5 mL of 5.25% sodium hypochlorite solution (Prime dental, Maharashtra, India) using 27-gauge needle between the instrumentation. Later, the root canals were irrigated with 5 mL of 17% EDTA (Prime dental, Maharashtra, India) for 1 minute for removing the smear layer. A final irrigation with 10 mL of distilled water was done to remove any traces of previous irrigants used. The canal was then dried with paper points (Dentsply-Maillefer, Ballaigues, Switzerland).

Teeth were then randomly divided into four groups of 15 teeth each, based on the endodontic sealer used for obturation (Fig. 2A).

Grouping Method

Sample size: $n = 15$

- GROUP 1 (Control) AH Plus (Dentsply, Konstanz, Germany) with single-cone gutta percha (25/0.06)
- GROUP 2 MTA Fillapex (Angelus, Londrina, Brazil) with single-cone gutta percha (25/0.06)
- GROUP 3 Dia-ProSeal (Diadent, Cheongju, Korea) with single-cone gutta percha (25/0.06)
- GROUP 4 GuttaFlow 2 (Coltene/Whaledent, Ohio, USA) with single-cone gutta percha (25/0.06)

Root Canal Obturation

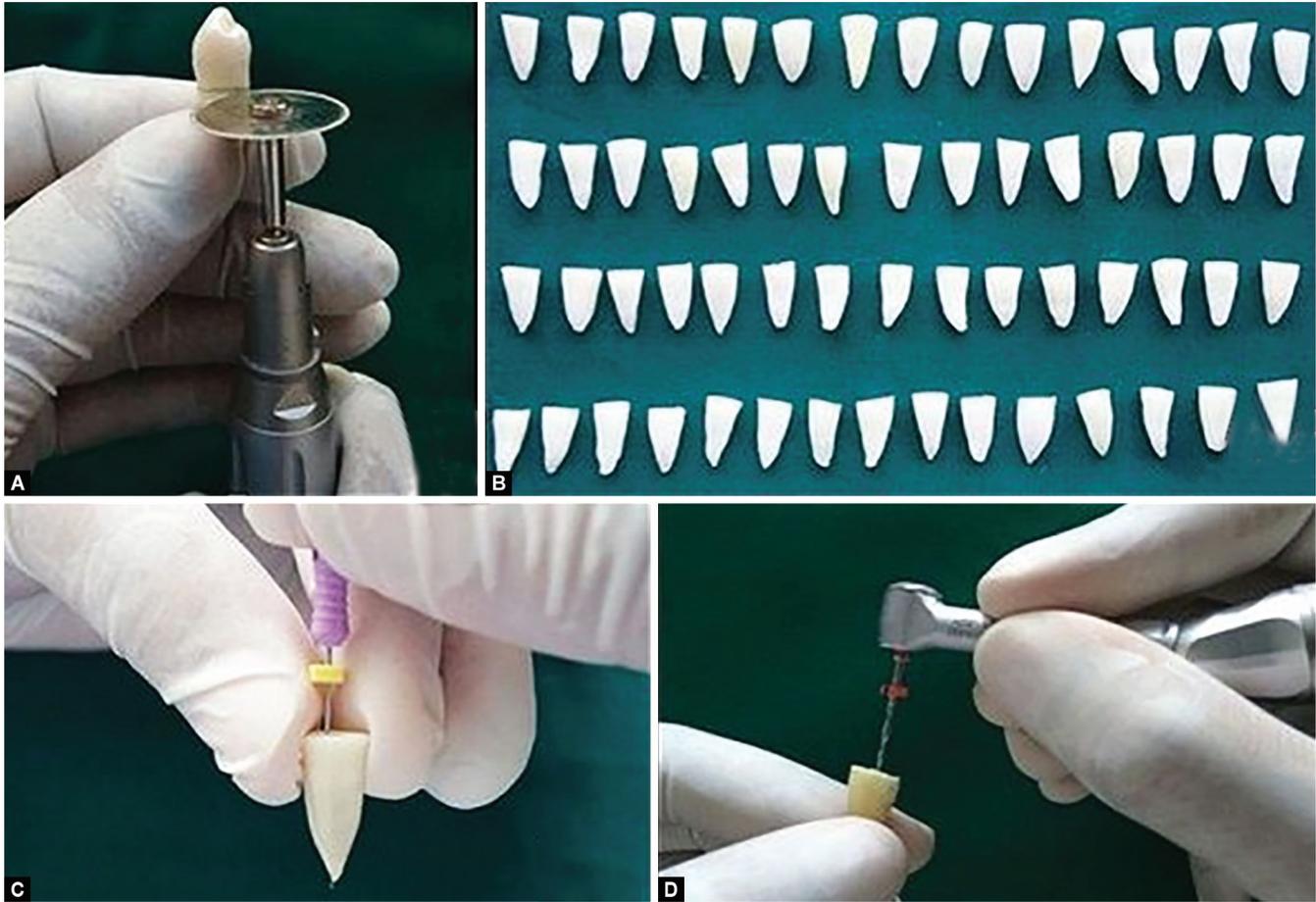
The apical fit of master gutta percha cone was confirmed using digital radiograph. Sealers were mixed according to the manufacturer's instructions, and root canals were coated with sealer using lentulospiral and obturated using single-cone gutta percha size 25/0.06 (Dentsply-Maillefer, Ballaigues, Switzerland). Heated ball burnisher was used to remove the coronal excess of gutta percha, with no further vertical compaction and sealed with a temporary restoration, Cavit (3M ESPE, Seefeld, Germany). Radiographs were taken in buccolingual and mesiodistal directions to check the quality of obturation. All the specimens were then stored at 37°C at 100% relative humidity for 2 weeks to allow the sealers to set before being subjected to the fracture resistance test.

Test Assembly

Samples from all groups were prepared for test assembly. Metal molds of dimensions 1.5 \times 1.5 \times 2 cm were used. Autopolymerizing acrylic resin powder and liquid were mixed and placed into these metal molds. The roots were covered by a layer of aluminum foil and positioned at the center of the acrylic resin such that 12 mm of the root is extending inside the mold, exposing the remaining coronal 1 mm. After the acrylic resin underwent setting, the root was removed and foil taken off. A thin layer of light body polyvinyl siloxane impression material (Flexceed, GC, Japan) was applied into the resin mold and the root returned to the same position, thus simulating periodontal ligament (Fig. 2B).

Fracture Resistance Testing

Fracture resistance of the specimens was tested using a universal testing machine (Instron Corp., Canton, Massachusetts, USA). A custom-made stainless steel indenter with a spherical tip ($d = 3$ mm) was mounted on the universal testing machine to apply vertical forces at the center of specimen (Fig. 2C). The specimen was



Figs 1A to D: (A) Decoronation using diamond disk; (B) Decoronated samples; (C) Working length determination; (D) Biomechanical preparation using OneShape rotary file

centered under the metal indenter with its coronal cut surface parallel to lower plate. The indenter was driven toward the canal orifice and directed along the long axis of tooth. The load was increased at 1 mm/minute until fracture occurred. The fracture was indicated by audible crack and/or sudden fall in load as seen on the graph. The force necessary to fracture was recorded in newton (N).

RESULTS

The data obtained were statistically analyzed using one-way ANOVA test followed by Tukey's HSD *post hoc* analysis. According to this study, the mean load required to fracture the samples was 1347.93N, 1097.07N, 1303.00N, and 1569.93N for AH Plus, MTA Fillapex, Dia-ProSeal, and GuttaFlow 2, respectively. Comparison of mean fracture resistance of endodontically treated teeth between different groups is summarized in Table 1 and represented in bar chart in Figure 3. Endodontically treated teeth with GuttaFlow 2 as sealer showed the highest fracture resistance and MTA Fillapex showed the least among the groups and the results obtained were statistically significant. Dia-ProSeal showed lower fracture resistance when compared to AH Plus sealer but the result was not statistically significant. Multiple comparison of mean difference in fracture resistance (newton) between different sealers using Tukey's *post hoc* analysis is summarized in Table 2. Mean fracture resistance

between the different groups of endodontic sealer in descending order is represented in Figure 4.

DISCUSSION

Root canal therapy is an established clinical treatment to preserve a tooth when the dental pulp has become irreversibly inflamed, necrotic, or infected. When compared to vital teeth, endodontically treated teeth have significantly different physical and mechanical properties. Therefore, the resistance of treated root canal to functional loads may be decreased, thus leading to a reduction in fracture resistance.¹³ Shafer et al. have confirmed that enlarged but unfilled roots are notably weaker than filled roots and thus more prone to fracture.¹⁴ Root canal instrumentation is a critical step in endodontic therapy. Therefore, the endodontically treated teeth need to be restored to reinforce against fracture. Several factors should be considered when selecting a material or a combination of materials to fill a root canal.

An ideal root canal-filling material has to strengthen the root structure and increase the tooth fracture resistance. Root canal sealers not only provide adhesion to both root dentin and gutta percha, but also fill the voids, patent lateral canals and multiple foramina, and minor discrepancies between gutta percha cones and root canal wall.¹⁵



Figs 2A to C: (A) Sample grouping based on sealer used; (B) Tooth embedded in acrylic blocks using metal molds; (C) Fracture resistance of sample tested using universal testing machine

Table 1: Comparison of mean fracture resistance (Newton) between different sealers using one-way ANOVA test

| Groups | N | Mean | SD | 95% CI for mean | | p value |
|---------------------------------|----|---------|--------|-----------------|-------|---------|
| | | | | Min | Max | |
| Group I AH Plus | 15 | 1097.07 | 131.30 | 846 | 1,375 | <0.001* |
| Group II MTA Fillapex | 15 | 1347.03 | 182.96 | 930 | 1,671 | |
| Group III Dia-ProSeal | 15 | 1303.00 | 119.42 | 1,145 | 1,510 | |
| Group IV GuttaFlow2 | 15 | 1569.93 | 168.86 | 1,075 | 1,782 | |

*Statistically significant

In order to standardize, roots with similar size, length, and dimensions were used in the current study. Further, standardized instrumentation, irrigation, and obturation procedures were used in all the experimental groups.

For the apical preparation of root canals, size 25/0.06 taper OneShape rotary file was used in all groups. The use of single-file system simplifies the instrumentation protocol. The unique design of OneShape instrument incorporates a variety of cross section along the active length of the file.

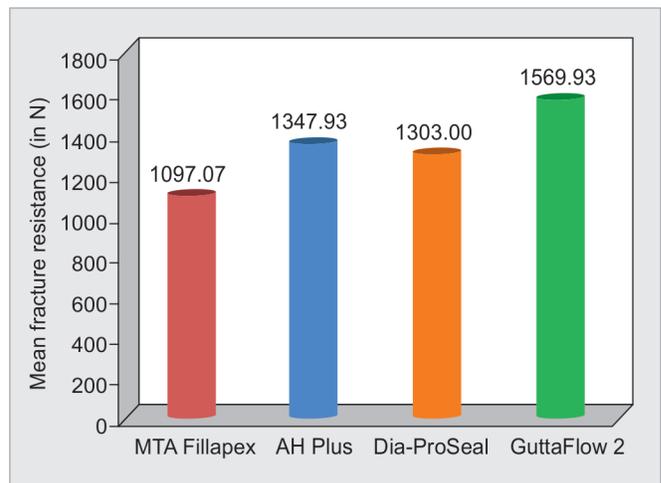


Fig. 3: Bar chat representing mean fracture resistance between different groups

Sodium hypochlorite and 17% EDTA were used as irrigants. Irrigation using EDTA removes the smear layer. Smear layer removal has many advantages such as improved adhesion and adaptation of the root canal sealer to the root canal wall and thereby increased

Table 2: Tukey's *post hoc* analysis for pairwise comparison

| Groups | Groups | Mean diff | 95% CI of the diff | | p value |
|-------------|-------------|-----------|--------------------|---------|---------|
| | | | Lower | Upper | |
| MTA | AH Plus | -250.87 | -398.68 | -103.05 | <0.001* |
| Fillapex | Dia-ProSeal | -205.93 | -353.75 | -58.12 | 0.003* |
| | GuttaFlow2 | -472.87 | -620.68 | -325.05 | <0.001* |
| AH Plus | Dia-ProSeal | 44.93 | -102.88 | 192.75 | 0.85 |
| | GuttaFlow2 | -222.00 | -369.82 | -74.18 | 0.001* |
| Dia-ProSeal | GuttaFlow2 | -266.93 | -414.75 | -119.12 | <0.001* |

*Statistically significant

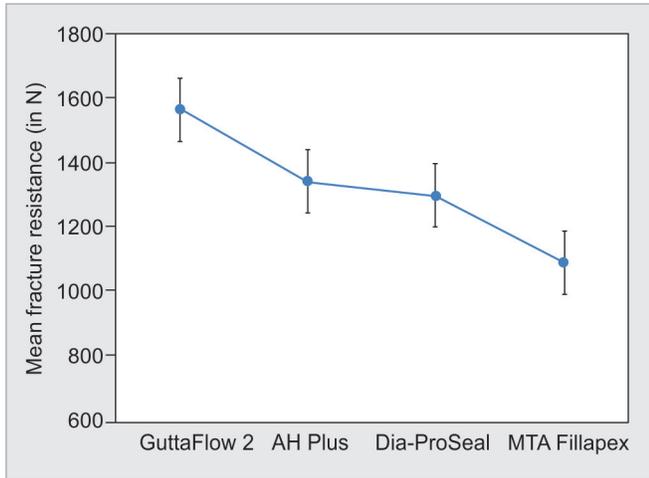


Fig. 4: Fracture resistance in descending order

sealing efficiency.^{16,17} A final rinse using distilled water was carried out to neutralize the effects of root canal irrigants.

Among the new materials for root obturation, the single-cone method and application of sealer as the only obturating material are increasingly advocated procedures.¹⁸ In the present study, single-cone obturation was used because it excludes the wedging forces of spreader during lateral compaction, plugger insertion during vertical compaction, and the need for accessory points.^{15,19}

Today, the commercially available sealers are categorized on the basis of chemical components as zinc-oxide eugenol, calcium hydroxide, epoxy resin, glass ionomer, and silicone-based and bioceramic sealers. Zinc oxide-containing sealers have been the most popular and widely used sealers for many years. This combination has its own disadvantages, such as its inability to strengthen roots; as it does not bond to dentin, the solubility of sealer and its inability to control microleakage make its prognosis questionable.

In many studies, epoxy resin-based sealers showed higher adhesion to root canal dentin and deeper penetration into the dentinal tubules than glass ionomer- and ZnOE-based sealers.^{8,9} In the present study, AH plus sealer was kept as control group. AH Plus is a two-component sealer comprising base and catalyst in which a polymerization reaction of epoxy-resin amine with a high molecular weight, including bisphenol A and bisphenol B, occurs. It has been well documented in the literature that when used for obturation, it improves the resistance to fracture of the teeth similar to that of sound dentin.^{8,9}

MTA Fillapex is a two-paste system of salicylate resin-based root canal sealer with automix syringe or tubes containing MTA

component. The rapid hydration of tricalcium silicate is responsible for the early strength and hardening of material. The bioactivity has also been reported to be due to the release of calcium hydroxide during the hydration process.²⁰

Recently, a silicone-based sealer GuttaFlow 2 and epoxy resin-based sealer Dia-ProSeal were introduced. GuttaFlow 2 is a silicone-based sealer. It is an original sealer/gutta percha combination, which is flowable at room temperature that can be used as a sealer as well as an obturating paste without a solid master cone.^{11,21}

Dia-ProSeal contains zirconium oxide, calcium hydroxide, and calcium tungstate. The presence of calcium hydroxide results in higher pH value, and this is significant as it disinfects the root canal. It has an excellent flow, which allows it to reach and seal lateral canals. It has low risk of cytotoxicity with better biocompatibility.¹²

In this study, the four sealers evaluated were AH plus, MTA Fillapex, Dia-ProSeal, and GuttaFlow 2.

The root surfaces were covered with the addition of silicone impression paste to simulate the periodontal ligament. Bone support and the periodontal ligament are important for the mechanisms of stress distribution over teeth. During *in vitro* tests, the root embedment material should reproduce bone capacity to absorb masticatory load and thus support the compressive and tangential force in a fracture resistance test.⁹

For fracture strength measurement in many studies, loading force was applied in a vertical direction. This was done with the view that a vertical force applied parallel to the long axis of a tooth produced more uniform stress distributions.²² Therefore, in the present study, a 3-mm-diameter intender at a cross-head speed of 1 mm/minute was applied using a universal testing machine.

The result of the present study shows that root canal sealers reinforced the endodontically treated teeth. GuttaFlow 2 showed the highest fracture resistance, and the result was statistically significant. The increased fracture resistance by GuttaFlow 2 may be attributed to its greater adhesion with gutta percha as well with root dentin with minimal sealer-dentin interface and homogenous obturation; high viscosity of the material allows for adequate condensation of obturating material with minimum stress generation, resulting in a dense mass that effectively reduces fracture. Additionally, the presence of zirconium oxide might play a role in increasing fracture toughness and tensile strength.²³

The result of this study is in accordance with the previous study by Punjabi et al.²⁴ However, a study by Mohammed et al.²⁵ showed that GuttaFlow 2 did not exhibit favorable results, as it was compared with a bioceramic sealer. Bioceramic sealers are known to produce chemical bond with radicular dentin due to the formation of hydroxyapatite crystals.

Roots filled with gutta percha and AH Plus sealer showed increased fracture resistance. The result was statistically significant. This may be due to its adhesive properties as the epoxy resin-based sealer is found to have good adhesion to dentin and gutta percha. This finding agrees with the results obtained by Upadhyay et al., Mandava et al., and Fisher et al.²⁶⁻²⁸

Dia-ProSeal showed statistically significant lower fracture resistance than GuttaFlow 2. In comparison with AH Plus, it showed lower fracture resistance but the results were not statistically significant. The comparable fracture resistance of Dia-ProSeal can be attributed to it being a resin-based sealer. The better adhesion of epoxy resin-based sealers is attributed to the epoxide ring reacting with exposed amino group in collagen, thus resulting in increased bonding to dentin.¹²

Numerous studies have concluded that MTA Fillapex did not strengthen the endodontically treated teeth significantly when compared with positive controls.²⁹ MTA Fillapex contains MTA as one of its ingredients. The lowest fracture resistance of MTA Fillapex in the present study might be due to the decreased adhesion capacity of the tag-like structure to dentin. Contradictory findings were reported by Mohammed et al.²⁵

There are very few studies that have compared the fracture resistance of GuttaFlow 2 and Dia-ProSeal sealer with that of other conventional sealers.

The major limitation of the current research was its small sample size. And this being an *in vitro* study will not give an exact correlation with the oral environmental conditions. Therefore, future studies should include randomized clinical trials with larger samples. Additionally, a single vertical load was delivered parallel to the long axis of the tooth to evaluate the fracture resistance. However, in real oral conditions, load and forces were in different directions. Therefore, further studies need to consider the application of cyclic loading. There are limited studies on GuttaFlow 2 and Diaproseal sealer, so more researches and comparative studies are warranted to assess other physical properties.

CONCLUSION

Within the limitations of this study, it can be concluded that root canal sealers enhanced the fracture resistance of endodontically treated teeth. Teeth obturated using GuttaFlow 2 sealer showed the highest fracture resistance. MTA Fillapex sealer showed the least fracture resistance of all the tested groups and AH Plus sealer showed a greater root reinforcement than Dia-ProSeal, but the results were not statistically significant.

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