ORIGINAL RESEARCH

Fracture Resistance of Endodontically Treated Teeth Obturated with Different Root Canal Sealers (A Comparative Study)

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Abstract

Aim: The aim of this study is to compare the effect of different root canal sealers on the fracture resistance of endodontically treated teeth using AH Plus, GuttaFlow 2, MTA-Fillapex, and TotalFill® BC™ sealers.

Materials and methods: Sixty single-rooted mandibular premolar teeth were used in the study. After the decoronation of the crowns of the teeth, we got a 13 mm root length. All samples instrumented using ProTaper Next system reaching file size ×4 as the final master apical file. Gutta-percha (GP) with single cone as obturation technique was carried out to all experimental teeth. Then, the teeth was divided into five groups ($n = 12$) based on the type of sealer to be used. Group I: AH Plus sealer + GP, Group II: GuttaFlow 2 sealer + GP, Group III: MTA-Fillapex sealer + GP, Group IV: TotalFill BC sealer + GP, and Group V: control (instrumented but unobturated teeth). Embedding all teeth in acrylic resin blocks was carried out and fracture force was measured using a universal testing machine (Instron Corp., Canton, MA, USA) by using metal-like spreader tip on 0.5 mm/m speed. Then, the data were statistically evaluated using one-way analysis of variance (ANOVA) and *post hoc* test (Tukey's test).

Results: Group IV showed higher resistance to fracture than other groups significantly. There was a nonsignificant difference in fracture force between Group I, Group II, and Group III. Group V showed the least fracture resistance than other groups.

Conclusion: Based on this *in vitro* study, TotalFill bioceramic-based sealer was more effective when compared with other sealers and the unobturated group showed the lowest mean fracture resistance.

Clinical significance: The use of bioceramic sealer with BC cones enhanced the fracture resistance of endodontically treated teeth.

Keywords: AH Plus, Bioceramic, Fracture resistance, GuttaFlow 2, MTA-Fillapex, Root.

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Introduction

Endodontically treated teeth strength obviously depends on the remaining amount of tooth structure after canal preparation.[1] The factors affecting root fracture after endodontic therapy are over-instrumentation, dehydration of dentin after endodontic therapy, and also uncontrolled pressure during obturation.[2–4] All of these factors in addition to occlusal load may 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 dentin, which leads to failure or fracture of endodontically treated teeth.[5] Obturation materials are considered the key elements in supporting strength of the endodontically treated teeth. Gutta-percha, in combination with a sealer, is among the most commonly used root canal filling material;[6] however, GP has a low elastic modulus than dentin, therefore has a little effect in reinforcing roots after root canal treatment.[7] Hence, the use of sealer with the ability to bond to the root canal dentin surface will strengthen the remaining tooth structure, thus increasing resistance to fracture.[8] The 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 reducing the risk of fracture.[9] AH Plus sealer (Dentsply, Konstanz, Germany) is an epoxy resin-based sealer with properties including easy handling, potential for better wettability of the dentin and GP surfaces, and good sealing property. Resin-based root canal sealers are considered as the material of choice due to their ability to penetrate dentinal tubule. These properties are of paramount importance among root canal sealers.[10]

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.[11] It has high radiopacity, low solubility, and low expansion during setting, cementum regeneration with good sealing property, bactericidal property, and biocompatibility. MTA-Fillapex releases free calcium ions (Ca^{2+}) which help in the healing process by stimulating tissue regeneration.[12]

TotalFill (FKG Swiss Endo) sealer is a premixed bioceramic obturation material. It is dispensed using a syringe in cases of root canal obturation, and with either a syringe or as a putty when doing root repair and retrograde fillings, TotalFill BC sealer forms hydroxyapatite upon setting and chemically bonds to both dentin and to bioceramic points (TotalFill BC Points). BC sealer is

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antibacterial during setting due to its highly alkaline pH and unlike traditional sealers and exhibits absolutely zero shrinkage.[13]

GuttaFlow 2 (Coltène/Whaledent) is a filling system for root canals that combines two products in one: GP in powdered form with a particle size of less than 30 µm and sealer. This filling system works with cold free-flow GP. ROEKO GuttaFlow 2 shows a slight expansion, and it adheres very well to the GP point (master point) as well as to the dentin. Therefore, no time-consuming condensation is necessary.[14] The aim of this study was to evaluate the ability of (AH Plus, GuttaFlow 2, MTA-Fillapex, and TotalFill BC) sealers in terms of reinforcing endodontically treated teeth.

Materials and Methods

In the current study, 60 single-rooted mandibular premolar teeth used were extracted for orthodontic demands from patient age ranged from 18 to 25 years. Soft periodontal tissue removed from the teeth using periodontal curette was then stored in 0.1% thymol. The collected teeth were checked for cracks, fractures, and external resorption using dental microscope 24× (Koolertron, Shenzhen, China). During their selection, care was taken to ensure that the teeth had comparable buccolingual and mesiodistal dimensions. Crowns were sectioned using diamond disk mounted on straight hand-piece under water coolant to obtain a standardized root length of 13 mm. Correct working length was confirmed by placing a k-file size #15 into the canal until the tip of file observed the apical foramen and then decreasing the file length by 1 mm. Cleaning and shaping of the root canals were done using ProTaper Next rotary NiTi files (Dentsply Maillefer, Switzerland) using an Electric Motor Endo-Mate (Eighteeth-E-Connect Pro, China) at a speed of 300 rpm, canal instrumented to ×4 master apical file. The canals were irrigated by using 5 mL 3% NaOCl solution, and as soon as the instrumentation is completed, the smear layer was removed by flushing the root canals with 5 mL 17% ethylenediaminetetraacetic acid solution then irrigated again with NaOCl. The canals finally rinsed with 10 mL distilled water in all test samples. Samples were divided into five groups based on the type of root canal sealers used.

Grouping Samples

Group I: Obturation with GP and AH Plus sealer.

Group II: Obturation with GP and GuttaFlow 2 sealer.

Group III: Obturation with GP and MTA-Fillapex sealer.

Group IV: Obturation with BC GP and TotalFill BC sealer.

Group V: Samples were instrumented and left unobturated.

For all obturated groups, mixing of sealers was done according to the manufacturer's instructions, and all canals were obturated with single-cone obturation technique.

To permit the sealers to fully set, the specimens were kept in incubator for 7 days (at 37°C and 100% relative humidity). To simulate a periodontal ligament, the root surface was covered with a thin-layer polyvinylsiloxane impression material to 2 mm apical to the coronal end of the root. Each tooth was then mounted vertically into acrylic resin exposing only 2 mm from the root using a plastic ring as a mold for packing acrylic. Fracture resistance testing was done using a universal testing machine (Instron Corp.). The blocks with mounted samples were placed on the lower part of testing machine. A custom-made metal-like spreader of 0.8 mm tip diameter was tightened to the upper part, and force was applied vertically to the long axis of the root. The metal tip was centered over the canal orifice. Each sample was subjected to slowly increasing vertical force at a crosshead speed of 0.5 mm/minute until the root fractured. The fracture can be defined as the point at which a sharp and sudden drop >25% of the applied force was observed. For most samples, an audible sound can be heard at fracture time, amount of force required for fracture was recorded in Newton.

The fracture load data were subjected to statistical analysis using SPSS V.25 (IBM, New York, USA) to examine the forces of root fracture, one-way ANOVA, was used. Then, Tukey's multiple *post hoc* test was used to compare between groups.

Results

The normality of data in the present study was tested using Shapiro–Wilk test and was found to be normally distributed ($p > 0.05$) (Table 1).

The highest mean of fracture resistance was found in Group IV (TotalFill BC) (125.41 N), followed by Group I (AH Plus), Group III (MTA-Fillapex), and Group II (GuttaFlow 2) (95.25, 89.26, and 88.33 N, respectively), while Group V (control) shows the lowest mean value (65.16 N) (Fig. 1).

The ANOVA test (Table 2) showed a significant difference among groups by setting a level of significance at 0.05. *Post hoc* Tukey's test was performed for multiple comparisons between groups (Table 3). It was seen that TotalFill BC sealer showed a statistically significant difference when compared with other groups ($p \leq 0.05$). The AH Plus group showed statistically a nonsignificant difference when compared with the MTA-Fillapex and GuttaFlow 2 groups ($p > 0.05$). The control group showed a significant difference with all other groups ($p \leq 0.05$).

Discussion

The current study compared four root canal sealers in terms of fracture resistance of root dentin. Based on the results, the highest

Table 1: Shapiro–Wilk test

		Shaprio–Wilk		
	Groups	*Statistic*	*df*	*Sig.*
Groups	Group I	0.878	12	0.81
	Group II	0.879	12	0.84
	Group III	0.900	12	0.161
	Group IV	0.930	12	0.384
	Group V	0.972	12	0.934

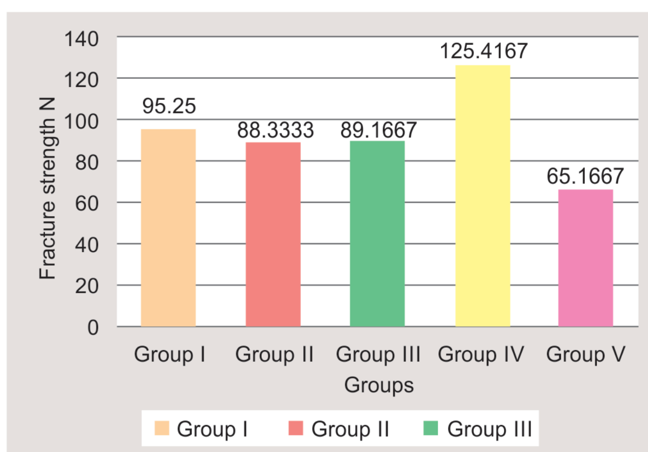

Fig. 1: Mean values of fracture force of all groups (in Newton)

Table 2: ANOVA test to compare fracture resistance among groups

ANOVA					
Groups	*Sum of squares*	*df*	*Mean square*	*F*	*Sig.*
Between groups	22398.167	4	5599.542	14.236	0.000
Within groups	21633.167	55	393.330		
Total	44031.333	59			

Table 3: *Post hoc* test for multiple comparisons between groups

Dependent variable: groups							
						95% confidence interval	
	(I) groups	*(J) groups*	*Mean difference (I–J)*	*Std. error*	*Sig.*	*Lower bound*	*Upper bound*
Tukey HSD	AH plus	GuttaFlow 2	6.91667	8.09661	0.912	−15.9184	29.7518
		MTA-Fillapex	6.08333	8.09661	0.943	−16.7518	28.9184
		TotalFill BC	−30.16667*	8.09661	0.004	−53.0018	−7.3316
		Control	30.08333*	8.09661	0.004	7.2482	52.9184
	GuttaFlow 2	MTA-Fillapex	−0.83333	8.09661	1.000	−23.6684	22.0018
		TotalFill BC	−37.08333*	8.09661	0.000	−59.9184	−14.2482
		Control	23.16667*	8.09661	0.045	0.3316	46.0018
	MTA-Fillapex	TotalFill BC	−36.25000*	8.09661	0.000	−59.0851	−13.4149
		Control	24.00000*	8.09661	0.035	1.1649	46.8351
	TotalFill BC	Control	60.25000*	8.09661	0.000	37.4149	83.0851

*Presence of significant difference between two pair groups

mean fracture resistance of root dentin was seen in the TotalFill group followed by the AH Plus group, MTA-Fillapex group, and GuttaFlow 2 group, and the lowest mean fracture resistance was shown in the instrumented but unfilled group.

The fracture resistance values of the unfilled group were significantly lower than the experimental groups ($p < 0.05$). This result agrees with previous study, and this could be explained that the preparation of root canals weakened the roots as the amount of remaining dentin root thickness was reduced, and there was no filling material to reinforce tooth structure.[15,16]

In this study, a root canal sealer reinforced endodontically treated teeth that had been weakened by preparation; TotalFill BC sealer showed significantly better results compared with the other sealers tested ($p < 0.05$). This may be explained that bioceramic-based endodontic sealers exhibit a chemical bond to the radicular dentin due to the production of hydroxyapatite throughout setting.[17] Another reason because of its hydrophilic nature, it has low contact angle, thereby allowing an easy spread over the canal walls. The results agree with other studies such as Patil et al.,[16] and Cobankara et al.,[17] and disagrees with Dibaji et al., in 2017 which found that bioceramic group showed less fracture resistance than AH Plus.[18] Moreover, Topçuoğlu et al. stated a higher value of bioceramic fracture resistance but statistically nonsignificant difference among groups.[15] This difference may be related to the differences in methodologies.

This chemical bonding may have improved the fracture resistance of obturated teeth with TotalFill BC sealer. Some authors suggest that the particle size is important, because it determines many properties of the material.[19] Smaller particles may better penetrate dentinal tubules, and this is confirmed by a study of dentinal tubule penetration of four different sealers: iRootTM SP (nowadays TotalFill BC Sealer), GuttaFlow Bioseal, AH Plus, and MTA-Fillapex. The bioceramic sealer exhibited a significantly higher dentinal tubule penetration than other sealers, which can be attributed to its very small particle diameter (<2 μm).[20] Small particles also hydrate faster than larger particles due to their higher surface-to-volume ratio and provide a low film thickness of the root canal sealer, which is suitable for this dental material and may improve the clinical performance of root canal filling.[19]

AH Plus sealer indicated higher but with a nonsignificant difference in fracture values than those filled with MTA-Fillapex and GuttaFlow 2 sealers. AH Plus has the ability to form a covalent bond by an open epoxide ring to any exposed amino groups in the collagen. AH Plus has better flow properties because of its viscosity and 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 dentin.[21,22]

This findings agrees with Phukan et al.; Upadhyay et al.; Mandava et al.; Fisher et al. and disagrees with Yendrembam et al., who found that MTA-Fillapex showed higher fracture resistance than AH Plus sealer although the results between groups were statistically nonsignificant as the present study;[8,23–26] thus, such a difference between their results and this study may be related that MTA-Fillapex having the modulus of elasticity similar to that of dentin or difference in methodologies.[27] In contrast to the current study, Jainaen et al. demonstrated low fracture resistance for teeth obturated with AH Plus sealer and stated that reduced fracture resistance of AH Plus was due to the reduced compressive and tensile strength of AH Plus in comparison with dentin.[28]

In the current study, MTA-Fillapex showed higher fracture resistance but not significantly different than GuttaFlow 2. MTA-Fillapex sealer by the formation of hydroxyapatite, having a compressive elastic modulus (14,000–18,600 MPa) similar to dentin, should be able to strengthen the roots.[24] The apatite formed by MTA-Fillapex 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.[29]

GuttaFlow 2 sealer showed the lowest mean fracture resistance compared with other experimental groups but statistically nonsignificant when compared with the AH Plus and MTA-Fillapex group. Although GuttaFlow 2 does not shrink but expands slightly by 0.2% and has a very good adhesion to GP points and dentin walls, this combination of expansion and adhesion creates an excellent seal but did not strengthened the root as much as other groups. The main limitation of this study is that single static load was used; therefore, this may not mimic clinical situation and fracture may occur earlier when there is a cyclic load.

Conclusion

It can be concluded that root canal sealers increased the fracture resistance of endodontically treated teeth, and the highest fracture resistance within the sealer groups was shown by TotalFill bioceramic, followed by AH Plus, MTA-Fillapex, and GuttaFlow 2. GuttaFlow 2 showed reasonable fracture resistance values in comparison with MTA-Fillapex, AH Plus, despite the lower bond strength GuttaFlow 2 has. The use of bioceramic sealer may enhance the survival of weakened roots by enhancement of fracture resistance of teeth against vertical and horizontal root fractures.

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