October University for Modern Sciences and Arts University
MSA Dental Journal

https://msadj.journals.ekb.eg/ PRINT ISSN: 2812 - 4944 VOL. 3, Issue 1, 1 - 5 January, 2024

Evaluation of the Effect of Three Root Canal Sealers on the Fracture Resistance of Endodontically Treated Teeth: A Comparative Study

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ARTICLE INFO.

Keywords:
GuttaFlow Bioseal; Ceraseal; AH Plus; Fracture resistance.

Abstract

Background: Root canal sealers play a crucial role in the success of endodontic treatment. The fracture resistance of endodontically treated teeth is an important consideration as it indicates the ability of the tooth to withstand functional forces and prevents vertical root fractures. Therefore, the aim of this study was to compare the effect of Ceraseal, Guttaflow Bioseal and AH Plus root canal sealers on the fracture resistance of endodontically treated teeth.

Methods: Fourty-five lower premolars were decoronated and divided into one control group and two experimental groups where Group A (n = 15) (Control): canal preparation was done with Protaper Gold system and obturated with AH Plus sealer, Group B (n = 15): canal preparation was done with Protaper Gold system and obturated with Ceraseal sealer and Group C (n = 15): canal preparation was done with Protaper Gold system and obturated with GuttaFlow Bioseal sealer. All root canals were obturated using single cone obturation technique and evaluated radiographically. Roots were then mounted and a universal testing machine was used to assess root fracture resistance.

Results: The highest mean value was recorded in Group (A) AH Plus (651.19±61.97), with a significantly lower value recorded in Group (C) GuttaFlow Bioseal (556.16±36.24), followed by Group (B) Ceraseal (511.71±53.5). One-way ANOVA test revealed a significant difference between groups. Post hoc Bonferroni test revealed that the difference between group B and group C was not statistically significant.

Conclusion: AH Plus improved the fracture resistance of endodontically treated teeth in comparison with Ceraseal and GuttaFlow Bioseal.

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1 Introduction

Root canal sealers are binding agents used to seal the space between the canal walls and the obturating materials and fill up irregularities, discrepancies, lateral canals and accessory canals. They are used in conjunction with solid or semi-solid biologically compatible obturating materials to achieve an adequate seal of the root canal system [1]. Bio-ceramics are ceramic materials designed specifically for medical and dental use. They include alumina, zirconia, bioactive glass, glass ceramics, hydroxyapatite, and calcium phosphates. These sealers must provide acceptable biocompatibility and be well tolerated by surrounding tissues [2].

Ceraseal is an anti-bacterial premixed calcium-silicate based sealer with a high pH level [3]. This bioceramic root canal sealer is based on several metal oxides, calcium silicate, and its derivatives [4]. GuttaFlow Bioseal is also a two-in-one- cold filling system for root canals with high biocompatibility and flow qualities [5]. Finally, AH Plus is an epoxy-resin sealer with minimal solubility and excellent flow properties that is often regarded as the gold standard for comparison [6].

It is worth noting that endodontically treated teeth are considered weaker and their roots are susceptible to fracture compared to vital teeth [7]. It has been suggested that the primary causes of the intrinsic problems are changes in the collagen-cross linking of endodontically treated teeth and their gradual drying-out [8]. As a result, before clinical application, the fracture resistance of endodontically treated teeth should be evaluated. Therefore, the present study aimed to evaluate and compare the effect of the three previously mentioned root canal sealers on the fracture resistance of endodontically treated teeth.

2 Materials and Methods

2.1 Ethical Approval:

The method employed in this study was approved by the research ethical committee (Faculty of Dentistry - MSA University). The research was granted confirmation of conductance number (ETH37).

2.2 Sample size calculation:

The sample size calculation in this study was based on the results of a previous study by Kumar et al 2022 [9]. The sample size calculation was performed assuming a type I error of 0.05 and a study power of 0.8 and found to be seven samples per group. Samples were double folded to 15 with a total of 45 samples to detect a significant difference in the fracture resistance between the three study groups. The sample size was calculated using G Power software version 3.1.9.7.

2.3 Samples selection:

Fourty-five recently extracted single-canaled lower premolars were collected and autoclaved over the course of three months from the oral and maxillofacial surgery clinic of MSA University.

Inclusion Criteria:

Lower Premolar teeth extracted for caries, periodontal or orthodontic reasons.

Teeth without soft tissue remnants or calculus.

Exclusion Criteria:

Teeth with additional canals, calcified canals, open apices, developmental abnormalities, root caries and endodontically treated teeth.

2.4 Samples preparation:

Teeth were decoronated to achieve 14-mm long roots using a high-speed wheel diamond bur under continuous water cooling. Samples were randomly assigned to one control group and two experimental groups after being decoronated. The decoronated teeth were distributed among one control group and two experimental groups.

2.5 Classification of samples:

- Group A (n = 15) (Control): Received canal preparation with Protaper gold system till size F5 (Taper 0.05 and tip size 50) and were obturated with AH Plus Sealer.

- Group B (n = 15): Received canal preparation Protaper gold system till size F5 (Taper 0.05 and tip size 50) and were obturated with Ceraseal sealer.

- Group C (n = 15): Received canal preparation Protaper gold system till size F5 (Taper 0.05 and tip size 50) and were obturated with GuttaFlow Bioseal sealer.

2.6 Root canal preparation:

Protaper Gold rotary file system (Dentsply Sirona-USA) was used in this study. All rotary files were used in a continuous clockwise rotation generated by a handpiece powered by an electric endodontic motor (E-connect pro, Eighteeth, Changzhou Sifary medical technology Co, Ltd, China) starting from speed 300 rpm and torque 5.10 Ncm (S1 file) till speed 300 rpm and torque 3.10 (F5 file).

Samples were instrumented using the following sequence (S1, S2, F1, F2, F3, F4 and F5). After three gentle in-and-out motion strokes in an apical direction, each instrument was removed from the canal and cleaned. This was repeated until the working length was reached, and after each step, the canal was irrigated with 2.5% NaOCl.

Following preparation, the root canals had a final flush with 5ml of 17% ethylenediaminetetraacetic acid (Meta-biomed MD, Korea) to remove the smear layer, followed by distilled water for the total removal of NaOCl before drying with paper points.

2.7 Root Canal Obturation

All endodontic sealers were mixed according to manufacturer's instructions and root canals were obturated by single cone technique using F5 gutta percha master cones. Following obturation, periapical radiographs were taken to evaluate the quality of root-filling. Any root with insufficient obturation was removed and replaced with a freshly produced sample [10].

2.8 Fracture resistance testing:

A thin layer of polyvinylsiloxane (PVS) impression material was applied to the specimen's root surface in order to replicate the periodontal attachment.

All roots were perpendicularly mounted in a polyvinyl ring filled with self-cure acrylic resin (Acrostone Dental and Medical supplies, Egypt) (Figure 1), with 9 mm of roots exposed cervically [11]. A universal testing machine (Instron, Model 3345, USA) was used to assess root fracture resistance.

Figure 1. Photograph showing root mounted in self- cure acrylic resin block.

All samples were placed in the lower plate of the testing machine, and a custom- made metal spreader with a diameter of 3 mm was secured in the upper part. The tip was positioned in the center of the canal orifice, and force was applied vertically to the root's long axis at 0.5 mm/min crosshead speed until root fracture. The amount of force required for root fracture was measured in Newtons (N). **Figure 2**

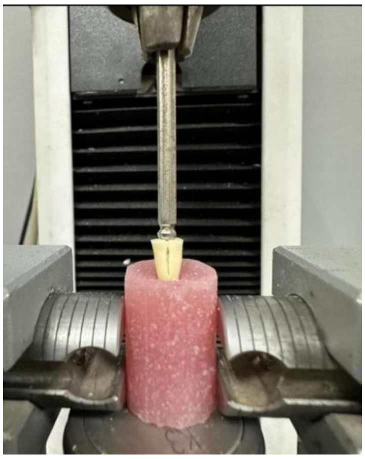

Figure 2. Photograph showing a tooth mounted in acrylic resin after being fractured using universal testing machine.

2.9 Statistical Analysis

Data management and statistical analysis were performed using the Statistical Package for Social Sciences (SPSS) version 20. Numerical data were summarized using mean, standard deviation and confidence intervals. Data were explored for normality by checking the data distribution and using Kolmogorov-Smirnov and Shapiro-Wilk tests. Comparisons between groups for normally distributed numeric variables were performed by one-way ANOVA test, followed by Bonferroni post hoc test. All P-values are two-sided. P-values ≤0.05 were considered significant.

3 Results

The highest mean value was recorded in group A (AH Plus) (651.19±61.97), with a significantly lower value recorded in group C (GuttaFlow Bioseal) (556.16±36.24), followed by group B (Ceraseal) (511.71±53.5). One Way ANOVA test revealed a significant difference between groups (p=0.000) (Table 1) and (Figure 3). Post hoc Bonferroni test revealed that the difference between group B and group C was not statistically significant (p=0.070). **Table 2**

Table 1. Descriptive statistics and comparison of fracture resistance load (N) in different groups (One way ANOVA test)

			95% Confidence Interval for Mean				F value	P value
	Mean	Std. Dev	Lower Bound	Upper Bound	Min	Max		
AH plus	651.19^{a}	61.97	616.87	685.50	512.18	758.32	28.499	.000*
Ceraseal	511.71^{b}	53.50	482.09	541.34	426.19	591.63		
GuttaFlow Bioseal	556.16^{b}	36.24	536.09	576.23	509.64	648.47		

Significance level p ≤ 0.05, *significant.

means sharing the same superscript letter are not significantly different.

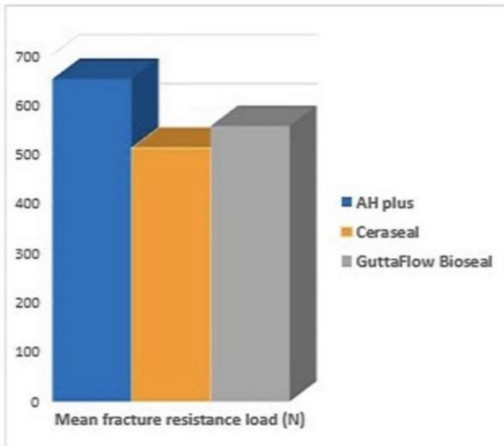

Figure 3. A bar chart illustrating mean fracture resistance load (N) in different groups.

Table 2. Detailed results of Bonferroni post hoc test for pairwise comparison of fracture resistance load (N) between groups.

	(I) Groups	(J) Groups	Mean Difference (I-J)	Std. Error	95% Confidence Interval Lower Bound	Upper Bound	P value
Bonferroni	AH plus	Ceraseal	139.47322*	18.87	92.41	186.54	.000*
		GuttaFlow Bioseal	95.02974*	18.87	47.96	142.10	.000*
	Ceraseal	AH plus	-139.47322*	18.87	-186.54	-92.41	.000*
		GuttaFlow Bioseal	-44.44348	18.87	-91.51	2.62	.070 ns
	GuttaFlow Bioseal	AH plus	-95.02974*	18.87	-142.10	-47.96	.000*
		Ceraseal	44.44348	18.87	-2.62	91.51	.070 ns

* The mean difference is significant at the 0.05 level.

Significance level p≤0.05, *significant, ns = non-significant.

4 Discussion

Endodontic treatment's major purpose, in addition to treating the infected pulp, is to reinforce the remaining tooth structure [12]. Instrumentation of the root canals is a necessary step in endodontic treatment. However, because root dentin is removed during the instrumentation phase, the weakening effect on the root is unavoidable. Because endodontically treated teeth are weaker than natural teeth, fatigue failures can occur even with normal functional pressures as well as higher functional and parafunctional stresses [11].

Although the gold standard for root canal fillings is gutta-percha combined with an insoluble root canal sealer, there is some debate over the ability of these materials to strengthen an endodontically treated root. In the present study, the effect of the epoxy-resin sealer (AH Plus), calcium-silicate bioceramic sealer (Ceraseal) and silicon-based bioceramic sealer (GuttaFlow Bioseal) on the fracture resistance of endodontically treated teeth was evaluated by applying a vertical force on the longitudinal long axis of the mandibular premolars using an Instron universal testing machine.

Due to their morphology, function, size of the crown relative to the size of the root, and fracture susceptibility, mandibular premolars were chosen for this study. They are subjected to both compressive and shear forces as a result of where they are located inside the dental arch [12]. In the present study, the preparation size, root width, and length were standardized for all specimens. Regarding the technique of root canal obturation, the single-cone obturation technique was used since it minimizes the spreaders' wedging effect. Another benefit of adopting the single-cone obturation approach is that, when combined with endodontic sealers, it creates a homogenous mass that prevents failures seen among several cones, as in the cold lateral condensation technique [13]. The periodontal ligament and alveolar bone were simulated using acrylic resin blocks where the teeth roots were mounted in them [14]. Furthermore, only 9 mm of root protruded above the embedding material in the samples [11]. Many studies [11, 15, 16] have employed a universal testing machine to determine the fracture resistance of teeth. The load was applied vertically along the longitudinal axis of the teeth in this study since this method completely transfers the load to the root [17].

The highest mean fracture resistance was found in group A (AH Plus) with a significantly lower value recorded in group C (GuttaFlow Bioseal), followed by group B (Ceraseal). The high value of AH Plus group was explained by Alkahtany et al 2021 [10], who stated that epoxy resin-based AH Plus sealer reveals some desired properties, such as adhesion, by creating a covalent bond between the exposed amino acids in the collagen and the open epoxide ring. Additionally, AH Plus has a creeping feature that gives it great penetration into surface micro-irregularities, increasing fracture strength. According to McMichen et al 2003 [18], AH Plus had a lower solubility and thicker layer than other sealers, which may contribute to its superior bond strength. Additionally, according to Nagpal et al 2012 [19], the intrinsic volumetric expansion property of AH Plus sealer adds to improved bond strength. Also, after removing the smear layer with EDTA, the sealer penetrates the tubules, conferring resistance to root dentin [20]. This is also in agreement with Ersev et al 2012 [16] who stated that AH Plus group with the matched taper single-cone approach had much higher fracture resistance than the instrumented but not obturated roots.

GuttaFlow Bioseal group showed the second highest mean fracture resistance value. This is in line with Gandolfi et al 2016 [21] who stated that GuttaFlow Bioseal demonstrated high water sorption, which resulted in volumetric expansion, good alkalinizing activity, low solubility, moderate calcium release, and apatite forming ability.

Ceraseal showed the lowest mean fracture resistance value. This is in disagreement with Ismail et al 2023 [22] who stated that the high fracture resistance of both bioceramic calcium-silicate sealers (BioRoot and TotalFill BC) may be attributed to the composition of calcium-silicate sealers which don't shrink during setting and set in the presence of moisture. The sealer collects water from dentinal tubules to start the setting reaction, which results in a calcium-silicate hydrogel and hydroxyapatite composite. These two chemicals form a strong chemical and microchemical bond with dentin hydroxyapatite. This chemical bond combined with the sealer's deep penetration into canal abnormalities and dentinal tubules, increase the fracture resistance of teeth.

5 Conclusion

Within the limitation of this study, it is possible to conclude that AH Plus sealer improved the fracture resistance of endodontically treated teeth in comparison with Ceraseal and GuttaFlow Bioseal root canal sealers.

Authors' Contributions

Khaled Ayman Behery, principal author. Prof. Dr. Alaa A. El-Baz, Lecturer. Dr. Ali Youssef Elgendy supervised the study. All authors have read and approved the manuscript.

Conflict of interest

The authors declare that they hold no competing interests.

Funding

The research study was self- funded by the authors.

Acknowledgement

The authors would like to thank Prof. Dr. Maged Negm for his valuable guidance throughout the study.

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