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Evaluation of fracture resistance of roots obturated with two different sealers and three obturation techniques

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Abstract

Aim: The study's aim was to compare the fracture strength of root obturated with AH Plus and AH Plus Bioceramic sealers utilizing different obturation techniques. **Materials and Methods:** The palatal roots of fifty-six extracted maxillary-first molars were used in this study. All samples were sectioned to keep the root length constant at 11 mm. The roots were instrumented utilizing 'EdgeFileX7 rotary files to size 40/0.04. Eight-roots were left unobturated as a control-group, while the others roots were divided into two different groups (n=24) based on the sealant used for obturation; AH plus &AH Plus BC. Each group was then subdivided into three-subgroups (n = 8) based on the obturation approach; single-cone, Warm vertical compaction (WVC) and soft-core. All roots were embedded in acrylic-resin blocks, and fracture force was evaluated with universal-testing equipment utilizing a metal-like spreader tip at a rate of 0.5 mm per minute. The results had undergone statistical evaluation using ANOVA and Tukey-test. **Results:** The fracture-resistance was significantly affected by the 'obturation-technique' and by "sealer/obturation technique" interaction. Obturation with AH Plus BC+WVC had the highest mean fracture-resistance value (351.5000 Newtons) while the control-group demonstrated the lowest mean fracture-resistance value (116.3750 Newtons). **Conclusion:** Obturation using AH plus BC+WVC was more effective combination providing highest fracture root resistance.

Keywords: AH plus, AH plus Bioceramic, Fracture resistance, Single cone technique, soft core technique, Warm vertical compaction.

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Introduction

An endodontically treated tooth exhibits an increased susceptibility to vertical root fracture attributable to various causes, including caries or trauma, access cavity preparation, root canal instrumentation, lateral condensation force during obturation, post space preparation, and functional occlusal loading, ultimately resulting in failure(Touré et al. 2011).Vertical root fracture is recognized as a prevalent complication associated with endodontic treatment, often resulting in tooth extraction(Bhat et al. 2012). Compromised tooth structure may lead to complications during or following root canal treatment. Consequently, strengthening the residual tooth structure is regarded as a crucial component of endodontic therapy (Topçuoğlu et al. 2013).

Research demonstrates that a root filling's adhesion to radicular dentin enhances root strength and improves fracture resistance (Uzunoglu-Özyürek, Küçükkaya Eren, and Karahan 2018; Ribeiro et al. 2008). The gold standard is to clean and shape root canals, then obturate them with Gutta-percha (GP) and root canal sealant. Due to their reduced modulus of elasticity, GPs are unable to strengthen the weakened root structure (Punjabi, Dewan, and Kochhar 2017). A root canal sealant serves as a connection among the canal and the obturating substance. An optimal root canal sealant must effectively fill the apical and lateral gaps and abnormalities between gutta-percha points and the walls of the root dentin (Zamin et al. 2012). Moreover, it was proposed that a sealer demonstrating adherence to the dentin of canal fortifies the teeth and improves fracture strength against occlusal stresses by preserving coherence at the sealer-dentin contact(Sandikci and Kaptan 2014).

AH Plus "Dentsply, Konstanz, Germany" is Sealer based on epoxy resin, distinguished by its enhanced wettability of dentin and gutta-percha, simplicity of handling and effective characteristics of sealing. Root canal sealants based on resin are preferred materials because of their capacity to infiltrate dentinal tubules. The significance of these properties is critical in the context of root canal sealers(Mohammed and Al-Zaka 2020).

A new premixed tricalcium silicate-based sealer called AH-Plus Bioceramic (Dentsply Sirona, Charlotte, NC, USA) has been launched. The manufacturer indicates that the material exhibits a rapid and predictable setting time, characterized by low solubility, enhanced washout resistance, and biocompatibility. Additionally, it features reduced film thickness and improved radiopacity, does not cause tooth color change, and can be eliminated post-setting with either manual file or a nickel titanium file. The sealer comprises Zirconium dioxide, carbonate of lithium, a tricalcium silicate, dimethyl sulfoxide, and thickening ingredients(Almasri, Abduljalil, and Aksoy 2024).

Literature indicates a lack of data assessing the fracture toughness of teeth filled with AH Plus Bioceramic Sealer utilizing various obturation techniques. Thus, the current study sought to evaluate and compare the fracture strength of endodontically treated roots obturated with two distinct sealers, AH Plus & AH Plus BC sealers, utilizing single cone, warm vertical compaction, and soft-core techniques. The null hypothesis indicated that there is no difference in fracture resistance between endodontically

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treated roots filled with gutta-percha using AH Plus & AH Plus BC sealants, employing single cone, warm vertical compaction, and soft core obturation approaches.

Materials and Methods

The ethics committee of the dental school of Mustansiriyah University has approved the current study (Project NO. MUOPR29, Ref.NO. REC130).
This research involved fifty-six extracted maxillary first molars, which were recognized by their matured apices and palatal root canals, which are circular and straight. To rule out pre-existing root fractures or cracks, teeth were inspected under magnification. At the furcation area, the palatal roots of teeth were sectioned perpendicular to the long axis of the root at 11 mm length (Mounes and Alhashimi 2022). The canal's initial size was established utilizing the size 20 K-file. For instrumentation, the EDGEENDO X7 rotary system files were used, A size 20/04 rotary file was used initially, followed by sizes 25/04, 30/04, 35/04, and 40/04. The procedure was performed at an average rotation speed of 300 rpm and a torque of 300 g-cm until the working length was attained, utilizing a gentle in-and-out motion. Between each rotary file, a size #20 hand K-file was used for recapitulation in order to maintain the glide route and improve the lubricant's access to the canal end. During canal preparation, 1 milliliter of 2.5% NaOCl irrigation was utilized between instruments with a 30-gauge side-vented needle, placed 2 mm just short of the working length to facilitate debris removal. The canals underwent a final irrigation treatment using 2 mL of a 2.5% sodium hypochlorite (NaOCl) solution, followed by 2 mL volume of a 17% ethylenediamine tetra acetic acid (EDTA) solution for a duration of 1 minute for each. Finally, five milliliters of distilled water were used. Following the irrigation procedures, (40/04) Paper points were employed to dry the canal of the root(Eren, Uzunoğlu-Özyürek, and Karahan 2021). At this stage, eight randomly selected shaped but unfilled teeth were isolated to act as a control group. The residual roots were classified into two main groups based on the sealer utilized (n=24). Group A: AH Plus sealer; Group B: AH Plus Bioceramic sealer. Every group was further divided into three subcategories based on obturation techniques utilized (n=8). As: Single cone obturation group, Warm vertical compaction obturation group, Soft core obturation group.
In the single cone technique, following the applying of sealers as per the manufacturer's guidelines, 40/04 master gutta-percha cone demonstrating sufficient tug-back was covered with sealant and progressively put into the canal until the working length was attained. The cone was carefully compressed with a plugger after it had been cut at the opening level(Topçuoğlu et al. 2013).

Concerning Warm Vertical Compaction, A plugger was employed that penetrated 4mm shorter than the working length for a binding point. Subsequent to applying the sealant according to the manufacturer's guidelines, the master cone 40/04 was put into the canal. A heated plugger was subsequently introduced into the canal to trim the master cone, leaving 4 mm of the apical gutta-percha intact. The canal was backfilled with

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warm gutta-percha injection utilizing CV-Fill (Cicada) at a temperature of 200 °C. The needle was placed on the apical gutta-percha for a duration of 5 seconds before the extrusion of the gutta-percha occurred. The mass of gutta-percha displaced the needle coronally to the canal opening, after which a plugger was utilized to compress the gutta-percha at the opening level(Al-Hiyasat and Alfirjani 2019).

The suitable size of the plastic core obturator from Soft-Core System Aps (Copenhagen, Denmark) for the soft-core technique was established using the Size Verifier. After applying sealers as directed by the manufacturer, the obturators were heated to a high temperature using the Soft-Core DT Oven (CMS, Orange, Copenhagen, Denmark) and then carefully inserted with light pressure until they reached the specified working length, holding their position for a short while a twisting action was used to remove the handle from the insertion pin. A tiny inverted cone bur was used to eliminate any extra gutta-percha and extra plastic core material. Next, a plugger was utilized to press down the gutta-percha vertically(Polesel et al. 2021).

BL and MD radiograph were utilized to evaluate the state of the root filling concerning length, density, and tapering. The entrance opening was sealed with a temporary filling material. The teeth were incubated at 37 degrees Celsius with a humidity of one hundred percent for 7 days to facilitate the setting of the sealers(Smran et al. 2023).

Fracture Resistance Test

A thin layer of polyvinylsiloxane impression substance was adapted to the root surface to replicate a periodontal ligament, extending 2 mm apically from the coronal terminus of the root. Each root was vertically embedded in acrylic resin, revealing only 2 mm of the root, with a metal ring serving as the mold for the acrylic packing. Fracture strength measuring was done with a 'universal testing machine' (Instron Corp.). Mounted sample blocks were positioned in the testing machine's lowest part. A customized metal-like spreader with a tip diameter of 0.8 mm was fixed to the upper part, and a vertical force was exerted along the longitudinal axis of the root. The metallic tip was centrally located above the canal opening. Each of the samples underwent a progressive vertical force application at a crosshead velocity of '0.5' mm/min till the root fractured. A fracture is characterized by a rapid and significant decrease of more than 25% in the exerted force. Most samples produced a distinct sound upon fracturing, and the load at fracture was recorded by the computer monitoring software and measured in Newton' (N). A vertical continuous fracture line was expected for a successful outcome(Mohammed and Al-Zaka 2020; Shukri 2024; Khdairah and Al-Gharrawi 2020).

Statistical Analysis

Fracture load data were statistically analyzed with SPSS V.27 "IBM, New York, USA" to determine the forces involved in root fracturing. The data's normality was evaluated utilizing the Shapiro-Wilk test. The differences between the control group and the obturated group were examined utilizing a one-way ANOVA test, with significant differences between groups

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determined by Dunnett's two-sided test. The study variables (obturation technique and sealer type) were tested for statistical significance in relation to the fracture resistance test findings using a two-way ANOVA. A subsequent comparison was conducted utilizing one-way ANOVA and the Tukey HSD test at a confidence level of 95%.

Results

The Shapiro-Wilk test validated the normality of the data in this study, indicating ,a normal distribution ($p > 0.05$). Table 1 displays descriptive statistics for fracture strength in Newton across all groups, including 'mean, standard deviation, minimum, and maximum values'. the highest mean in fracture resistance was recorded by Group (AH plus BC+WVC) (351.500) followed by Group (AH Plus+soft core) (291.000), Group (AH Plus BC+soft core) (281.8750), Group(AH Plus+WVC) (254.250) and Group (AH Plus+single cone) (205.875)and Group(AH Plus BC +single cone)(195.375) respectively whilst the lowest mean value of fracture was recorded by control group (116.375).A one-way ANOVA test revealed a difference of statistical significance between the control group and all obturated groups ($p < 0.001$)(Table 2). Obturated groups were statistically substantially greater than the control group ($p<0.005$), according to Dunnett's two-sided test. The Two-Way ANOVA test revealed that both the obturation techniques and the interaction between sealer and obturation technique significantly influenced fracture resistance. ($P < 0.001$, $P < 0.018$, correspondingly) (Table 3).

The tests for the overall sealer effect revealed that the fracture resistance in 'the AH Plus and AH Plus BC' groups was comparable ($P = 0.135$). The influence of the obturation technique on resistance to fracture revealed that both WVC and soft-core techniques exhibited significantly higher resistance compared to the single cone technique ($P < 0.05$). No significant distinction was noted between the soft core and WVC techniques ($P > 0.05$) (Table 4).

In order to enhance comprehension of the influence of the obturation method in conjunction with the sealer, the findings were reanalyzed utilizing one-way ANOVA, succeeded by the Tukey test for pairwise comparisons at 95% confidence intervals, (significance level 0.05).

The obturation technique in AH Plus did not significantly influence fracture resistance. Pairwise comparisons confirmed that there were no substantial variations across the groups.The AH Plus BC groups demonstrated that the obturation approach significantly influenced fracture resistance. Comparisons indicated that the fracture resistance of the WVC was much superior to that of the Single cone, however no substantial difference was noted between the soft core with the other two methods (WVC, single cone).

The only significant difference between the two sealers when the same obturation procedures were evaluated was in the WVC technique, where the AH Plus BC sealant demonstrated noticeably higher fracture resistance than the AH Plus sealer (Table 5).

Discussion

The main aim of obturation is to prevent bacteria and their metabolites from entering the root canal space. Furthermore, it seeks to improve root strength by mechanically interlocking the obturating material with radicular dentin, thereby enhancing fracture

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resistance(Punjabi, Dewan, and Kochhar 2017).
The findings demonstrated that the unobturated group exhibited significantly less fracture resistance values than the obturated groups ($p<0.05$). This finding aligns with prior research, suggesting that root canal preparation may compromise root integrity due to reduced remaining dentin thickness and the absence of obturating material to strengthen the structure of the tooth(Sağsen et al. 2012; Patil et al. 2017; Mohammed and Al-Zaka 2020; Hajihassani et al. 2022).
Regardless of the sealant used, the thermoplasticized gutta-percha obturation method (WVC, Soft Core) produced noticeably better outcomes than the single cone method. The results can be related to an improved flow of warm gutta-percha, leading to a uniformly mixed gutta-percha mass with a minimal quantity of sealer(Venturi 2006). This phenomenon is often linked to enhanced material retention (Schilder 1967). Research indicates that thermoplasticized techniques allow gutta-percha material to soften and become pliable, facilitating its penetration into narrow and inaccessible regions, such as deep depressions, lateral canals, auxiliary canals, and areas devoid of sealer cement(Marciano et al. 2011). The thermoplasticized techniques produce a higher volume of gutta-percha, a reduced volume of sealer, and fewer unfilled gaps compared to Single Cone. The core carrier employed in the soft-core approach effectively reinforced the root dentin, consequently improving the fracture resistance of the roots(Ersoy and Evcil 2015; Al-Hiyasat and Alfirjani 2019). This is consistent with the findings of Mounes and Alhashimi (2022), who observed increased bond strength when employing WVC and carrier-based techniques compared to the single cone method (Mounes and Alhashimi 2022). This study contests the findings of Al-Hiyasat et al. (2023) and Pandey et al. (2024), which indicated that obturation with a single cone resulted in higher fracture resistance compared to WVC (Al-Hiyasat, Sawallha, and Taha 2023; Pandey et al. 2024). The discrepancy may arise from the distinct methodologies utilized in the two studies. No significant difference was observed between soft core and WVC, aligned with the results of Topçuoğlu et al. (2012) (Topçuoğlu et al. 2012).
The fracture resistance of the two sealers in the single cone and soft-core approaches was comparable, showing no significant difference. While in the warm vertical compaction technique the fracture resistance of AH Plus BC sealer significantly exceeded that of AH Plus. Shieh et al. (2023) found that the AH Plus BC sealer demonstrated significantly greater penetration into dentinal tubules than the AH Plus sealer (Shieh et al. 2023). This difference is attributed to its enhanced fluidity, smaller particle size, and reduced film thickness (20 mm for AH Plus BC compared to 80.5 mm for the epoxy resin-based sealer), which contributes to improved fracture resistance of the root (Hamdy et al. 2024). Also, the outcome may be ascribed to the influence of the heat on the composition and setting period of the epoxy resin sealant. Reports suggest that the introduction of heat during WVC expedites the setting reaction, thereby diminishing the setting period, which may adversely affect the flow capacity and infiltration of the sealer into canal irregularities and dentinal tubules(Al-

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Hiyasat and Alfirjani 2019). Atmeh and AlShwaimi (2017) demonstrated that the chemical structure of AH Plus underwent alterations upon exposure to heat (Atmeh and AlShwaimi 2017).

The assessment of obturation techniques' influence on the fracture resistance of the sealer indicated that these techniques did not significantly alter the fracture resistance of AH Plus sealer. This finding aligns with the study undertaken by Topçuoğlu et al. (2012), Ersoy and Evcil (2015), and Al-Hiyasat and Alfirjani (2019) (Topçuoğlu et al. 2012; Ersoy and Evcil 2015; Al-Hiyasat and Alfirjani 2019), while it contradicts the results of Al-Hiyasat et al. (2023), which suggest that obturation with single cone provides greater fracture resistance compared to WVC(Al-Hiyasat, Sawallha, and Taha 2023).This difference may result from variations in methodology.

The fracture strength of AH Plus BC was markedly greater when WVC was utilized compared to the single cone method. Eid et al. (2021) demonstrated that the use of WVC improved the penetration capability of calcium silicate-based sealers into dentinal tubules when compared to single cone technique (Eid et al. 2021). Alegre et al. (2022) found that the warm vertical obturation method exhibited greater sealer penetration compared to the single cone technique.(Alegre et al. 2022) Additionally, No substantial difference was noted between the soft-core technique with the other methods, WVC and single cone. A direct comparison with prior results was unfeasible, as no previous studies have investigated the effects of these obturation techniques on AH Plus BC sealer.

The primary limitation of the current research was its limited sample size. This in vitro investigation will not produce a precise association with oral environmental factors. Future studies should involve randomized clinical trials with bigger sample sizes. To assess the tooth's resistance to fracture, a vertical stress was exerted parallel to its long axis. In real oral conditions, loads and forces are applied in multiple directions. Therefore, further research should investigate the application of cyclic loading.

Conclusion: This study yielded several conclusions within its constraints:
1-The use of AH Plus and AH Plus BC sealers alongside various obturation procedures (single cone, WVC, and soft core) improved the fracture resistance of endodontically treated roots.
2- The fracture resistance of root obturated with AH Plus and AH Plus BC did not differ significantly.
3-The fracture resistance of root obturated with WVC and soft core was substantially greater than that of the single cone technique.
4- Fracture resistance of root obturated with AH Plus sealer was not significantly affected by the type of obturation techniques.
5-The fracture resistance of AH Plus BC in combination with WVC was significantly greater than that observed with the single cone technique.
6- The fracture resistance of the two sealers did not differ statistically significantly when the single cone and soft core obturation procedures were applied. In the WVC group, AH Plus BC demonstrated significantly greater fracture strength than the AH Plus sealer.

Conflict of interest
The authors reported that they have no conflicts of interest.

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Table 1: Descriptive statistics for all the groups measured in Newton

Groups	N	Mean	Std. Deviation	Std. Error	Min.	Max.
AH Plus jet single cone	8	205.8750	47.73270	16.87606	154.00	268.00
AH Plus jet WVC	8	254.2500	61.23899	21.65125	188.00	330.00
AH Plus jet soft core	8	291.0000	65.98485	23.32917	230.00	390.00
AH Plus Bioceramic Single cone	8	195.3750	43.16393	15.26075	138.00	245.00
AH PLUS Bioceramic WVC	8	351.5000	68.37919	24.17570	257.00	424.00
AH Plus bioceramic soft core	8	281.8750	61.81872	21.85622	225.00	396.00
control group	8	116.3750	23.51861	8.31508	87.00	167.00
Total	56	242.3214	88.64661	11.84590	87.00	424.00

Table 2: One-way ANOVA test to compare the significance between obturated group and control group.

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	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	283129.214	6	47188.202	15.511	.000
Within Groups	149073.000	49	3042.306		
Total	432202.214	55			

Table 3: Two-way ANOVA test between-subjects affect the fracture resistance.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
sealer	8034.188	1	8034.188	2.324	.135
Obturation technique	96474.875	2	48237.437	13.953	.000
Interaction	30570.125	2	15285.062	4.421	.018
Error	145201.125	42	3457.170		
Total	3608287.000	48			
Corrected Total	280280.313	47			

Table 4: Multiple Comparisons between obturation techniques using Tukey's HSD test.

Obturation technique	Mean	Std.	p.value	95%Confidence

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	difference	Error		interval Lower bound-Upper bound	
Single cone technique Warm vertical compaction	-102.2500*	20.78813	.000	-152.7546	-51.7454
Single cone technique Soft core technique	-85.8125*	20.78813	.000	-136.3171	-35.3079
Warm vertical compaction Soft core technique	16.4375	20.78813	.711	-34.0671	66.9421

Table 5: Tukey pairwise comparisons at 95% confidence intervals for the sealer-obturation technique interaction.

Interaction I	**Interaction II**	**Mean Difference**	**Std. Error**	**Sig.**	**95% Confidence Interval** Lower Bound	Upper Bound
AH Plus jet single cone	AH Plus jet WVC	-48.37500	27.51656	0.709	-136.7588	40.0088
AH Plus jet single cone	AH Plus jet soft core	-85.12500	27.51656	0.068	-173.5088	3.2588
AH Plus jet WVC	AH Plus jet soft core	-36.75000	27.51656	0.917	-125.1338	51.6338
AH Plus BC Single cone	AH Plus BC WVC	-156.12500*	27.51656	**.000**	-244.5088	-67.7412
AH Plus BC Single cone	AH Plus BC Soft core	-86.50000	27.51656	0.060	-174.8838	1.8838
AH Plus BC WVC	AH Plus BC soft core	69.62500	27.51656	0.238	-18.7588	158.0088
AH Plus jet single cone	AH Plus BC singlecone	10.50000	27.51656	1.000	-77.8838	98.8838
AH Plus jet WVC	AH Plus BC WVC	-97.25000*	27.51656	**.021**	-185.6338	-8.8662
AH Plus jet soft core	AH Plus BC soft core	9.12500	27.51656	1.000	-79.2588	97.5088