Push-Out Bond Strength of Calcium Silicate Based and Resin-Based Root Canal Sealers: Influence of Different Obturation Techniques - An In Vitro Investigation

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Abstract:

- ***Background:***

A durable, fluid-tight seal of the root canal system is essential for successful endodontic treatment. Push-out bond strength is an important indicator of the ability of a sealer to resist dislodgement and maintain long-term sealing.

- ***Aim:***

To compare the push-out bond strength of calcium silicate–based sealers (CeraSeal and MTA Plus) and an epoxy resin–based sealer (AH Plus) when used with lateral condensation and single-cone obturation techniques.

- ***Materials and Methods:***

Sixty extracted human mandibular premolars with a single root canal were instrumented using a standardized rotary system. The teeth were randomly assigned to three sealer groups (MTA Plus, CeraSeal, and AH Plus; n = 20), and each group was further divided into lateral condensation and single-cone subgroups (n = 10). After storage at 37°C in 100% humidity for 30 days, the roots were sectioned into coronal, middle, and apical slices. Push-out bond strength was evaluated using a universal testing machine, and the mode of failure was assessed under a stereomicroscope.

- ***Results:***

Calcium silicate–based sealers demonstrated higher push-out bond strength than AH Plus. The single-cone technique produced better bond strength for the bioceramic sealers, especially in the apical region, whereas AH Plus showed improved performance with lateral condensation. Mixed and cohesive failures were more common in the bioceramic groups, while adhesive failures predominated with AH Plus.

- ***Conclusion:***

Both the type of sealer and the obturation technique significantly influence push-out bond strength. Calcium silicate–based sealers used with the single-cone technique achieved stronger bonding to root dentin than the resin-based sealer.

Keywords: *Push-Out Bond Strength, Calcium Silicate Sealer, AH Plus, Ceraseal, MTA Plus, Obturation Technique.*

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I. INTRODUCTION

The success of root canal treatment depends on eliminating microorganisms and achieving a three-dimensional seal that prevents bacterial reinfection. Gutta-percha is the most commonly used obturation material because of its biocompatibility and stability; however, it does not bond directly to dentin. Therefore, an endodontic sealer is essential to fill the space between gutta-percha and the root canal walls.

AH Plus, an epoxy resin–based sealer, has been widely used because of its good sealing ability, dimensional stability, and low solubility. However, it is sensitive to moisture during bonding and lacks bioactive properties. In contrast, calcium silicate–based sealers such as MTA Plus and CeraSeal are hydrophilic, release calcium ions during setting, and form a hydroxyapatite layer that enhances bonding with dentin.

The bond strength of these sealers is also affected by the obturation technique. While lateral condensation remains a commonly used method, the single-cone technique is considered more suitable for bioceramic sealers because it provides better sealer distribution. Therefore, comparing the push-out bond strength of calcium silicate–based and resin-based sealers using different obturation techniques is important for selecting the most effective clinical approach.

II. AIM AND OBJECTIVES

➢ *Aim*

To evaluate and compare the effect of lateral condensation and single-cone obturation techniques on the push-out bond strength of calcium silicate–based sealers (MTA Plus and CeraSeal) and a resin-based sealer (AH Plus).

➢ *Objectives*

- To assess the push-out bond strength of MTA Plus, CeraSeal, and AH Plus sealers.
- To compare the bond strength of each sealer when used with lateral condensation and single-cone obturation techniques.
- To determine the effect of the obturation technique on the bonding performance of each sealer.
- To evaluate the mode of bond failure (adhesive, cohesive, or mixed) after push-out testing.

III. MATERIALS AND METHODOLOGY

This in vitro study was conducted in the Department of Conservative Dentistry and Endodontics after obtaining institutional approval. Sixty freshly extracted human single-rooted mandibular premolars with straight canals and fully developed apices were selected. Teeth with fractures, root resorption, open apices, or previous endodontic treatment were excluded. The teeth were cleaned, disinfected in 1% sodium hypochlorite for 30 minutes, and stored in 10% neutral buffered formalin until use.

The crowns were removed at the cementoenamel junction to obtain standardized root lengths. Working length was established using a #10 K-file, and root canals were prepared with the ProTaper Next rotary system. During instrumentation, canals were irrigated with 5.25% sodium hypochlorite. The smear layer was removed using 17% EDTA for one minute, followed by a final saline rinse. The canals were then dried with paper points.

The specimens were randomly divided into three groups (n = 20) according to the sealer used: **Group I:** MTA Plus, **Group II:** CeraSeal, and **Group III:** AH Plus. Each group was further divided into two subgroups (n = 10) based on the obturation technique: lateral condensation and single-cone.

After obturation, the access cavities were sealed, and all samples were stored at 37°C in 100% humidity for 30 days to allow complete setting of the sealers. The roots were then sectioned into coronal, middle, and apical slices (1.0 ± 0.2 mm thick). Push-out bond strength was measured using a universal testing machine, and the values were recorded in megapascals (MPa). The mode of failure was examined under a stereomicroscope at 20× magnification and classified as adhesive, cohesive, or mixed.

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IV. RESULTS

Table 1: Push Out Bond Strength Mean Values (MPa), Median Values and Standard Deviation (SD)of Different Root Canal Filling System

Groups	Subgroup	N	Mean	Median	SD
MTA	Single Apical	10	52.414	52.56	1.417
MTA	LC Apical	10	44.766	45.29	1.960
MTA	Single Middle	10	49.704	50.40	3.120
MTA	LC Middle	10	42.813	43.455	2.269
MTA	Single Coronal	10	44.165	44.165	1.182
MTA	LC Coronal	10	32.917	33.325	2.302
BIO-CERAMIC	Single Apical	10	68.486	67.525	2.988
BIO-CERAMIC	LC Apical	10	59.078	59.295	2.808
BIO-CERAMIC	Single Middle	10	63.942	64.655	2.831
BIO-CERAMIC	LC Middle	10	56.193	56.280	1.895
BIO-CERAMIC	Single Coronal	10	57.722	57.570	2.302
BIO-CERAMIC	LC Coronal	10	48.403	48.820	2.148
AH+	Single Apical	10	61.582	61.970	2.553
AH+	LC Apical	10	54.303	54.685	2.011
AH+	Single Middle	10	57.658	57.660	2.387
AH+	LC Middle	10	50.775	50.675	1.744
AH+	Single Coronal	10	52.433	52.300	2.006
AH+	LC Coronal	10	42.471	42.230	1.983

Table 2 :Percentage of Adhesive Failure, Cohesive Failure and Mixed Failure

Group	Adhesive (%)	Cohesive (%)	Mixed (%)
MTA Plus Single Cone	20%	30%	50%
MTA Plus LC	10%	40%	50%
Bioceramic Single Cone	10%	60%	30%
Bioceramic LC	0%	70%	30%
AH Plus Single Cone	70%	10%	20%
AH Plus LC	60%	10%	30%
No Sealer Control	90%	0%	10%

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The mechanical test showed that both the sealer type and obturation technique significantly affected push-out bond strength. Bioceramic sealers showed higher bond strength than the epoxy resin-based sealer. Among all groups, CeraSeal used with the single-cone technique achieved the highest bond strength.

At different root canal levels, the apical third of the single-cone bioceramic groups showed the highest bond strength. MTA Plus demonstrated moderate bond strength with both techniques. AH Plus performed better with the lateral condensation technique than with the single-cone technique.

Stereomicroscopic evaluation at 20× magnification showed that the failure pattern showed better bonding in bioceramic sealer groups, with more cohesive failures (60–70%), indicating strong adhesion to dentin. MTA Plus showed mainly mixed failures (50%), suggesting moderate bonding ability. AH Plus and the control group showed more adhesive failures (60–90%), indicating weaker bonding at the sealer–dentin interface. Overall, bioceramic sealers demonstrated the strongest and most favorable bonding performance.

V. DISCUSSION

The push-out bond strength test is a commonly used method to evaluate the adhesion and dislodgement resistance of endodontic sealers under controlled laboratory conditions. It provides valuable information regarding the quality of interaction between the sealer and radicular dentin, which is influenced by material composition, smear layer management, dentinal moisture, and obturation technique (1,2). In the present study, hydraulic calcium silicate-based sealers demonstrated higher push-out bond strength values than the epoxy resin-based sealer AH Plus when used with a matched single-cone obturation protocol. These findings agree with previous studies reporting superior adaptation and bonding potential of bioceramic sealers due to their bioactive properties and chemical interaction with dentin (3,4).

The higher bond strength observed for CeraSeal may be attributed to its premixed formulation, fine particle size, and hydrophilic characteristics. Hydraulic calcium silicate sealers utilize moisture present within dentinal tubules to initiate hydration reactions, resulting in calcium ion release and precipitation of calcium phosphate phases at the sealer–dentin interface (5,6). This biomineralization process contributes to the formation of an apatite-like interfacial layer, enhancing micromechanical interlocking and resistance to dislodgement forces (7,8). Furthermore, the slight setting expansion associated with calcium silicate materials may improve adaptation to irregular canal walls and reduce interfacial gaps (9).

MTA Plus demonstrated acceptable bond strength values, which may be related to its calcium silicate composition, bioactivity, and ability to form mineral deposits along dentinal walls. Previous investigations have shown that MTA-based materials release calcium ions and interact with phosphate-containing fluids, resulting in apatite formation and improved adaptation (10,11). However, the slightly lower performance of MTA Plus compared with CeraSeal may be associated with its powder-liquid mixing requirement, which may introduce variations in consistency and handling compared with premixed formulations (12).

AH Plus exhibited lower bond strength values when used with the single-cone technique. Although epoxy resin sealers demonstrate excellent mechanical properties and form resin tags within dentinal tubules, their hydrophobic nature makes them more sensitive to residual moisture conditions within the root canal system (13,14). Additionally, the increased sealer volume associated with single-cone obturation may contribute to greater polymerization shrinkage stresses, resulting in interfacial gaps and reduced adhesion (15,16). Previous studies have demonstrated that AH Plus may achieve improved bonding when used with techniques that reduce sealer thickness, such as lateral condensation (17).

Differences in bond strength among root thirds may be explained by anatomical variations, including dentinal tubule density, canal morphology, and sealer adaptation. Higher values observed in the apical region of bioceramic groups may be associated with the hydraulic pressure generated during placement of the matched-taper gutta-percha cone, which promotes sealer adaptation and penetration into canal irregularities (18,19). Although the apical region contains fewer dentinal tubules than the coronal third, the closer fit of the single-cone system may enhance sealer distribution and mechanical retention in this area (20).

Failure mode analysis supported the bond strength findings. The greater occurrence of cohesive and mixed failures in bioceramic groups indicates a stronger sealer–dentin interface, whereas adhesive failures observed with AH Plus suggest weaker interfacial bonding (21). Overall, the findings indicate that hydraulic calcium silicate sealers used with a matched single-cone obturation technique provide favorable adaptation and resistance to dislodgement within the root canal system.

The differences in bond strength among root thirds may be attributed to anatomical variations in dentin structure, canal morphology, and sealer adaptation. The apical region generally contains fewer dentinal tubules and greater tubular sclerosis compared with the coronal third, which may influence sealer penetration and micromechanical retention (20). However, the higher push-out values observed in the apical third of bioceramic groups may be explained by the close adaptation of the matched-taper gutta-percha cone, which generates hydraulic pressure and promotes lateral movement of the sealer into canal irregularities (18,19). Similar findings have been reported in recent investigations comparing hydraulic calcium silicate sealers and epoxy resin sealers using the single-cone technique, where bioceramic groups demonstrated higher bond strength values, particularly in apical sections (22).

The interaction between irrigation procedures and dentinal surface characteristics may also influence sealer adhesion. Removal of the smear layer and adequate conditioning of dentin improve sealer penetration and adaptation by exposing dentinal tubules and increasing surface availability for interaction with the sealer (23). However, excessive alteration of dentin structure or inappropriate moisture control may negatively affect bonding performance .

Failure mode analysis provides additional information regarding the quality of the sealer–dentin interface. In the present study, the predominance of cohesive and mixed failures in the bioceramic groups indicates that the adhesive interface was stronger than the internal strength of the sealer material. Similar observations have been reported for hydraulic calcium silicate sealers, where cohesive and mixed failures are commonly associated with improved bonding and interfacial adaptation (21). In contrast, the greater occurrence of adhesive failures in the AH Plus group suggests weaker interaction at the sealer–dentin interface, which may be related to polymerization shrinkage, moisture sensitivity, and limited chemical bonding ability (13,15).

Overall, the findings of this study suggest that hydraulic calcium silicate sealers, particularly premixed formulations such as CeraSeal, provide favorable bond strength and adaptation when used with a matched single-cone obturation protocol. Their hydrophilic nature, bioactivity, and ability to form mineral deposits at the dentin interface may provide advantages over conventional epoxy resin sealers under clinical conditions where complete moisture control is difficult to achieve.

VI. CONCLUSION

Within the limitations of this study, both the type of sealer and the obturation technique significantly influenced push-out bond strength. Bioceramic sealers, particularly CeraSeal used with the single-cone technique, demonstrated superior bond strength and more favorable cohesive failure patterns, indicating stronger adhesion to root canal dentin. MTA Plus exhibited moderate bonding performance, whereas AH Plus performed better with lateral condensation but showed comparatively weaker adhesion overall. These findings suggest that bioceramic sealers, especially when used with the single-cone technique, may provide improved bonding performance and enhance the quality of root canal obturation.

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