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The effect of two different intracanal medicaments on the push-out bond strength of AH Plus BC Sealer – An Ex *vivo* study

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Abstract
Background and objectives: To assess and compare the influence of calcium hydroxide (CH) and triple antibiotic paste (TAP) on the push-out bond strength of AH Plus BC sealer at the coronal, middle, and apical thirds of the root canal.
Materials and methods: Altogether of 45 extracted, single-rooted premolar teeth were selected, decoronated, and instrumented using the ProTaper rotary file system up to size F3. The samples were distributed randomly into three groups (n=15) in accordance with the intracanal medicament applied: Group A — no medicament, Group B — calcium hydroxide, and Group C — triple antibiotic paste. The medicaments remained in the canals for three weeks. Following this period, canals were irrigated sequentially with 10 mL of 17% EDTA, 10 mL of 2.5% sodium hypochlorite, and a final rinse with 5 mL distilled water. Canal spaces were subsequently obturated using AH Plus BC sealer in combination with a single-cone gutta-percha technique. Post-obturation, horizontal sections of the roots were made to create 2 mm thick slices from the coronal, middle, and apical thirds. The bond strength between the root canal dentin and the sealer was evaluated using a universal testing machine through a push-out bond strength test.
Result: Variation in intracanal medicaments notably affected the push-out bond strength of AH Plus BC sealer. Bond strength was nearly twice as high following the application of triple antibiotic paste (TAP) compared to calcium hydroxide (CH), and these results were independent of the position along the canal.
Interpretation and conclusion: Calcium hydroxide (CH) had no impact on the bond strength of the AH plus BC sealer. Furthermore, using triple antibiotic paste (TAP) rather than calcium hydroxide (CH) enhances the bond strength of AH plus BC sealer throughout the canal space.

Keywords: Bond strength, ah plus bc sealer, intracanal medicament, root canal dentin, universal testing machine

Introduction

The essential purpose of endodontic treatment is to effectively eliminate bacteria and pulpal remnants from an infected root canal and ensure that the canal is properly sealed following disinfection. The success of this treatment relies on thorough cleaning and the creation of a seal that prevents reinfection. Achieving asepsis of the endodontic system requires a combination of mechanical instrumentation, irrigation solutions, and the application of intracanal medicaments. These approaches help in removing bacterial biofilms and intracanal debris, which has an environment conducive to microbial growth [1, 2].

The root canal's microenvironment, characterized by warmth, moisture, and the presence of nutrients, supports microbial colonization, particularly if the treatment process is prolonged or incomplete. When endodontic treatments cannot be finished in a single session, Employment of intracanal medicating agents becomes essential to maintain asepsis and prevent the expansion of bacterial communities between appointments [2].

Among these medicaments, calcium hydroxide (CH) stands out as extensively utilized due to its broad-spectrum antimicrobial properties, particularly against many root canal pathogens. CH is favored for its biocompatibility, ability to dissolve necrotic tissue, anti-inflammatory properties, and inhibition of osteoclastic activity, which helps prevent further tissue breakdown. Additionally, it promotes the formation of mineralized tissue and neutralizes lipopolysaccharides (LPS), which are harmful endotoxins produced by Gram-negative bacteria [2, 3].

Despite its widespread use, CH possesses certain drawbacks that must be addressed. One of the major challenges is its reduced efficacy against certain bacterial species, such as Enterococcus faecalis, a pathogen commonly associated with persistent endodontic infections. Furthermore, CH may weaken the structural integrity of the root, leading to reduced fracture resistance in treated teeth [13, 14]. Another significant drawback is that residual CH on the canal walls can interfere with the properties of the root canal sealer, a critical component in the filling process. Residual CH may alter the sealer's chemistry, limiting its ability to penetrate the dentinal tubules, which is vital for creating a tight seal. This reduced penetration can weaken the bond between the sealer and the dentin, ultimately affecting the treatment's long-term success [15]. Moreover, the high alkalinity of CH can denature proteins within the dentin, weakening the dentinal structure and compromising the adhesion of the sealer [3].

Given that root canal infections are often polymicrobial, calcium hydroxide alone may not be sufficient to fully eradicate the infection, particularly in cases involving necrotic teeth. This limitation has led to the recommendation of using antibiotic combinations as an adjunct to CH or as an alternative intracanal medicament.[16] Antibiotic pastes are employed not only in pulp regeneration and revascularization procedures but also in managing complex cases such as periapical lesions, external inflammatory root resorption, root fractures, and the treatment of primary teeth. These antibiotic pastes are designed to have a broad spectrum of antibacterial action while being minimally toxic to surrounding tissues [17].

One of the most extensively used antibiotic combinations in endodontics is the triple antibiotic paste (TAP), which is valued for its biocompatibility and potent antimicrobial properties. TAP is a mixture of three antibiotics—ciprofloxacin, metronidazole, and minocycline—each playing a distinct role in targeting a wide range of microorganisms. Ciprofloxacin and metronidazole are bactericidal, meaning they kill bacteria, while minocycline is bacteriostatic, inhibiting bacterial growth. Together, these antibiotics form a powerful combination that promotes the healing and repair of periapical tissues [2]. TAP is especially effective in treating infections caused by Escherichia coli and can treat dentin that is heavily infected. However, like other medicaments, TAP has its own limitations. It cannot be entirely eradicated from the root canal space once applied, leaving remnants that could hinder subsequent treatments [12, 18]. Additionally, minocycline in TAP is associated with crown discoloration, which can affect the aesthetic outcome of the treatment [19, 21]. Moreover, TAP has demonstrated to alter the chemical structure of dentin, potentially impacting the bonding of sealers to radicular dentin [9].

The success of root canal treatments depends significantly regarding the capacity of the sealer to form a durable and tight bond with the root canal walls and the filling material, typically gutta-percha (GP) [22]. Endodontic sealers are essential for creating this bond, as they fill the microscopic gaps between the filling material and the canal walls, preventing reinfection. Without a sealer, gutta-percha alone cannot achieve a complete seal of the root canal, leaving the tooth vulnerable to microbial leakage. A critical measure of sealer performance is its push-out bond strength (POBS), which refers to the resistance of the sealer to dislodgement from the dentin. Higher POBS values indicate a stronger bond between the sealer, core material, and root canal wall, reducing the risk of leakage and increasing the stability of the root canal obturation [5].

Several factors influence the bond strength between the sealer and dentin, including variations in the dentinal structure, the existence or lack of a smear layer, and the chemical composition of the sealer. Additionally, the interaction between the sealer and the dentin, such as how well the sealer penetrates the dentinal tubules and adapts to the canal walls, is pivotal in ensuring a strong and durable seal [8].

In recent years, a new type of sealer has been introduced to the market: AH Plus Bioceramic Sealer (Maruchi), which is a combination of resin and bioceramic materials. This pre-mixed tricalcium silicate cement-based sealer, developed by Dentsply Sirona USA, offers several benefits over conventional sealers. These include faster setting times, reduced solubility, thinner film thickness, and higher radiopacity, making it easier to detect on radiographs. AH Plus Bioceramic Sealer is also biocompatible and provides a gap-free seal, ensuring better long-term outcomes. Furthermore, it has improved wash-out resistance, meaning it is less likely to be washed away by fluids, and it demonstrates superior cytocompatibility, making it a promising option for clinical use [6, 7].

The utilization of intracanal medicaments, such as CH and TAP, has been shown to enhance the retention of root canal fillings and enhance the adhesion of sealers during endodontic treatments. However, the differences in their effects may be attributed to the ease of medicament removal and their interaction with the dentin. TAP has a high level of diffusion and retention within the dentin, and its residual minocycline binds to calcium ions through a process called chelation. This binding effect contributes to higher bond strength values, as the residual medicament promotes better sealer adhesion. In contrast, CH is more readily removed from the canal, but its high alkalinity can adversely affect the structure of the dentin, disrupting the bonding process and resulting in lower bond strength values [2, 4].

Therefore, this research intends to investigate and compare the impact the effects of calcium hydroxide and triple antibiotic paste containing amoxicillin on the push-out bond strength of AH Plus BC sealer. By examining the influence of these two commonly used intracanal medicaments, the study seeks to contribute to knowledge regarding their effect on sealer adhesion and the overall quality of the root canal seal. These insights could play a role in directing endodontic practices, leading to enhanced treatment results and the advancement of more effective disinfection protocols.

Material and method

source of data

A total of 45 single-rooted human premolars extracted for orthodontic and periodontal reasons were collected from the Department of Oral Surgery, AJ Institute of Dental Science and private clinics in and around Mangalore. They were stored according to the infection control protocol advised by the Centre of Disease Control Global.

Test Specimens Selection

A total number of 45 freshly extracted human single-rooted premolar were selected.

Inclusion Criteria

Single rooted human premolar with fully formed apices and patent apical foramen.

To confirm a single root canal of the tooth a preoperative radiograph was taken.

Exclusion Criteria

- Teeth having root and root canals with accentuated curves.
- Teeth having calcified canals.
- Teeth with internal and external resorption.
- Teeth with coronal restoration or decay below the cemento-enamel junction (CEJ)
- Fractured teeth
- Teeth having attrition, abrasion, erosion and endodontically treated teeth.

Armamentarium

1. AH Plus BC sealer (DENTSPLY DE Trey, Konstanz Germany)
2. Calcium hydroxide powder (PREVEST)
3. Metronidazole (METROGYL 400 MG)
4. Ciprofloxacin (CIPLOX 500 MG, CIPLA)
5. Minocycline (MINOZ 100 MG, CIPLA)
6. 2.5% Sodium hypochlorite (MEDILISE)
7. 17% EDTA solution (PYRAX)
8. Chloramine T solution
9. Saline (FRESENIUS KABI INDIA PVT LTD)
10. Distilled water
11. Mortar and pestle (COMET)
12. K- Type Files - size #10 and #15 (MANI MEDICAL INDIA PVT LTD)

13. ProTaper Rotary Files- F1(#20/0.06), F2(#25/0.06), F3(#30/0.06) (DENTSPLY)
14. PaperPoints (DIADENT GROUP INTERNATIONAL)
15. Lentulospiral- #40 (MANI MEDICAL INDIA PVTLTD)
16. Diamond disc
17. ProTaper Gutta Percha F3- (#30/0.06) (DENTSPLY)
18. Composite resin (SHOFU)
19. Cold-Cure acrylic Resin (DPI RR COLD CURE)
20. Universal Testing Machine (INSTRON)
21. Stereomicroscope (LAWRENCE &MAYO)

Methodology

For this study, 45 freshly extracted single-rooted human premolars were carefully selected, confirming the absence of any defects and have mature apices with a patent apical foramen. Prior to the study, pre-operative radiographs were taken to verify the existence of a single canal with a fully developed root apex in all the selected teeth.

Meticulous cleaning of all teeth was done to eliminate debris and calculus, after which they were preserved in 1% Chloramine T solution. To achieve a standardized root length of 15 mm from the apex, all the teeth were decoronated using a high- speed diamond disc in the presence of water-cooling system.

To prevent the experimental solutions from extruding through the apical foramen, the foraminal openings of each specimen were sealed with resin composite. A glide path was created using #10 and #15 size K-files (Mani Inc, Tochigi Ken, Japan). The working length was determined by taking a radiograph and adjusting it to be 1 mm short of the root apex, following Ingle's method.

Cleaning and shaping of all specimens were conducted using ProTaper Universal rotary files (DENTSPLY) in a crown-down manner using SX, S1, S2, F1, F2, F3. The canals were enlarged till F3 (#30/0.09). After each instrument, the canals were irrigated with a 2 ml solution of 2.5% sodium hypochlorite solution (Medilise). 5 mL saline (Fresenius Kabi India Pvt Ltd) was used intermittently. The final irrigation for all samples involved the use of 5mL of 17% EDTA (SHIVAM DENTAL) for 1 min followed by by 5 ml of 2.5% NaOCl for 1 min. Finally, the canals were dried using #30 sterile absorbent paper points (DiaDent Group International, Korea).

A total of 100mg of CH powder was dispensed and mixed with distilled water until it reached a creamy consistency (1:1.5, powder to liquid ratio). TAP was prepared by removing the coating and crushing of antibiotic ciprofloxacin (Ciplox 500mg), metronidazole (Metrogyl 400mg) and minocycline (Minoz 100mg) tablets separately using a mortar and pestle. The powders thus obtained were weighed separately (100mg each) and mixed with distilled water(100ml) until it reached a creamy consistency (3:1, powder to liquid ratio).

The samples were randomly allocated into three groups (n =45) as per the intracanal medicament used. Intracanal medicament was applied within the root canals using #40 lentulo spiral.

- **Group A:** No medicament (n = 15)
- **Group B:** Calcium hydroxide (n = 15)
- **Group C:** Triple antibiotic paste (n = 15)

The cavities of coronal access were sealed with small cotton pellets, and the samples were coronally restored using temporary filling material to prevent leakage. The specimens were then stored at 37ºC and 100% relative humidity for 21 days to simulate clinical conditions.

After 3 weeks, medicaments were rinsed with 10 mL 17% EDTA, followed by 10 mL 2.5% NaOCl and a final irrigation was performed with 5 mL of distilled water by a 27-gauge conventional irrigation needle. Later the canals were dried with sterile absorbent paper points. All the specimens were obturated with AH plus BC sealer and F3 size Gutta percha using the single cone obturating technique.

The samples were restored coronally using temporary filling material and stored in an incubator at 37ºC for 7 days. Each root was then embedded in cold-cure acrylic resin (DPI RR Cold Cure). Subsequently, each specimen was horizontally sectioned with a diamond disc to obtain 2 mm thick slices. Three sections were prepared at depths corresponding to the apical (4 mm), middle (7 mm), and coronal (10 mm) thirds of the root canal.

Statistical Analysis

Statistical Package for Social Sciences [SPSS] for Windows Version 24.0 (Armonk, NY: IBM Corp) was used to perform statistical analysis.

Descriptive statistics

Descriptive statistical analysis of push-out bond strength was done in terms of Mean & SD for each group.

Inferential statistics

One-way ANOVA Test subsequently followed by Tukey's post hoc Test was used for multiple comparisons of push-out bond strength between different groups. The level of significance was set at $P<0.05$.

Results

The effects of the type of intracanal medication on the adherence of AH plus BC sealer is summarized in Table 1 and Figure 1. The push-out bond strength of AH Plus BC sealer was notably influenced by the type of intracanal medicament used. Bond strength was nearly twice as high following the application of triple antibiotic paste (TAP) compared to calcium hydroxide (CH), and these results were independent of the position along the canal.

Table 1: Showing mean bond strength in coronal, middle and apical

H	Coronal	Middle	Apical
Control	2.562	2.715	3.241
CaOh	2.808	2.981	3.428
TAP	4.805	5.219	6.006

Bond strength increases from Control to CaOH to TAP across all regions. In the coronal region, TAP (4.805) is highest, followed by CaOH (2.808) and Control (2.562). The same trend is seen in the middle region (TAP: 5.219, CaOH: 2.981, Control: 2.715) and the apical region (TAP: 6.006, CaOH: 3.428, Control: 3.241).

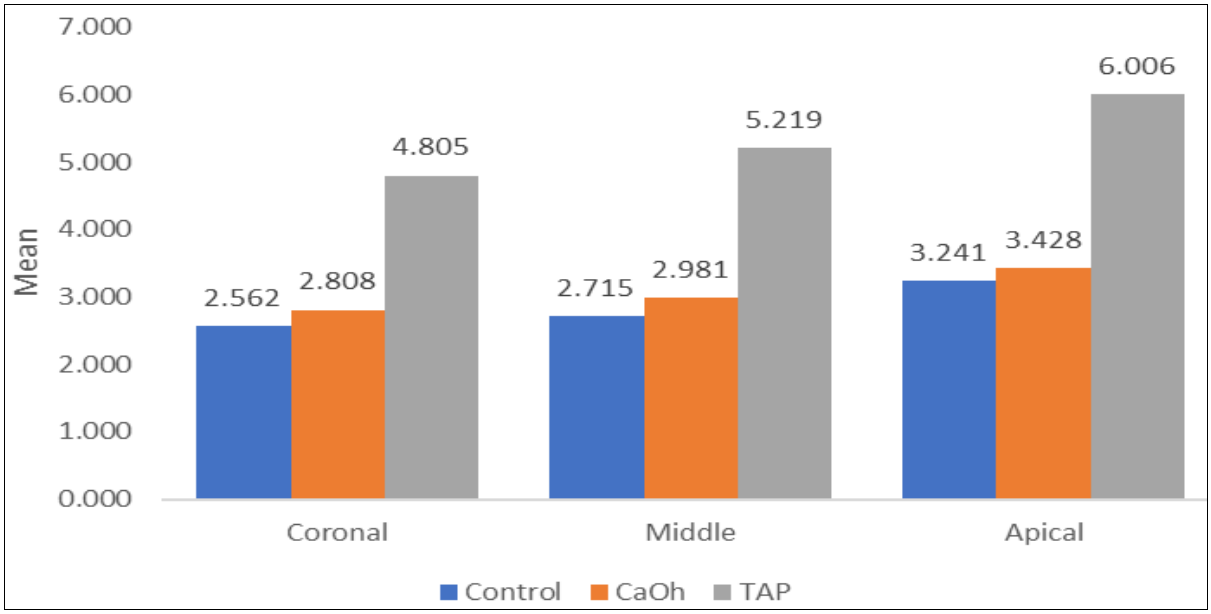

Fig 1: Representing mean bond strength in coronal, middle and apical

Evaluation

- The apical, middle and coronal aspects of each slice were investigated under a stereomicroscope
- The push-out bond strength assessment was executed using universal testing machine at crosshead speed of 1mm/min.
- Three sets of cyclindrical pluggers of diameter 0.6mm, 0.7mm, 0.8mm that matched each canal third diameter were used for push out test of each tooth. The pluggers diameter was confirmed to a minimum of 80% of the canal diameter.
- The maximum load of fracture was applied until the filling material was dislodged, which was recorded in newtons(N).
- The bond strength was calculated in megapascals (MPa) by dividing the greatest load (F, in N) by the adhesion area of the root filling (A, in mm^2) with the following equation:

$$MPa = F/A$$

- The parameter A was calculated with the equation:

$$A = \pi (r1 + r2) * L$$

where $L = \sqrt{(r1 - r2)^2 + h^2}$

r1 – minor radius (coronal radius in mm)
r2 - major radius (apical radius in mm)
h- thickness of the root section (in mm)

$\pi = 3.14$ (constant)

Discussion

Root canal procedure primarily aims to treat infection within the confines of the root canal system by completely eliminating bacteria and their byproducts, together with sealing the canal to prevent re-infection. The root canal system is highly complex, containing numerous accessory canals and lateral branches that can harbor bacteria, making complete disinfection a challenging task. After cleaning the canal with rotary instruments and irrigating with antiseptic solutions such as sodium hypochlorite (NaOCl), the next critical step is to eliminate any remaining bacteria or bacterial products. To achieve this, endodontists often rely on intracanal medications.[1,2]

Calcium hydroxide (CH) is the most frequently used intracanal medicament due to its well-known antibacterial effects and ability to induce a high pH environment that is hostile to many bacterial species.[16] However, the challenge arises as canal space infections are often polymicrobial, meaning that multiple bacterial species coexist within the canal, some of which may be resistant to the action of CH. This has resulted to the development of alternative or supplementary medicaments, such as Triple Antibiotic Paste (TAP), which combines metronidazole, ciprofloxacin, and minocycline [23]. These broad-spectrum antibiotics are specifically designed to target a wider array of bacterial pathogens, offering a more robust solution for infection control.[9] However, while the antimicrobial efficacy of TAP is well documented, its effects on the adhesion of root canal sealers—especially tricalcium silicate cement-based sealer like AH Plus BC Sealer remain relatively unexplored.

Sealer adhesion is one of the critical factors that determine the long-term success of root canal fillings. After the canal system has been disinfected, it is fundamentally necessary to fill the canal space with a sealer and a core material (such as gutta-percha) to ensure a tight, stable seal that will prevent the re-entry of bacteria. Any breakdown in this seal—whether from bacterial ingress or loss of adhesion—can lead to re-infection, treatment failure, and the need for retreatment [24, 25].

AH Plus BC Sealer is a recently introduced bioceramic endodontic sealer that offers notable advantages in terms of biocompatibility and sealing effectiveness. This premixed sealer is composed of several key ingredients, including tricalcium silicate, zirconium dioxide, dimethyl sulfoxide, lithium carbonate, and thickening agents, all contributing to its excellent performance. One of the standout features of AH Plus BC Sealer is its remarkable bond strength, which can be attributed to its true self-adhesive nature. This self-adhesion occurs because the sealer forms a chemical bond with the dentin, which is facilitated by the creation of a hydroxyapatite hybrid layer. This hybrid layer forms when calcium silicate from the sealer reacts with phosphate-

containing fluids in the root canal, releasing calcium and hydroxyl ions. As a result, the interaction between these ions and the root dentin leads to the development of a stable and durable chemical bond between the sealer and the dentinal walls [6, 7, 8].

Additionally, AH Plus BC Sealer's hydrophilic properties play a crucial role in enhancing its adhesion to dentin. Its low contact angle allows the sealer to easily spread over the canal walls, creating a thin, uniform layer. The smaller particle size further enhances this spreadability, enabling deep penetration into the dentinal tubules. This penetration facilitates mechanical interlocking, reinforcing the bond between the sealer and the tooth structure. The combined effects of chemical bonding, mechanical interlocking, and the hydrophilic nature of the sealer contribute to superior adhesion and an excellent hermetic seal, which is essential for preventing bacterial leakage and ensuring long-term success in root canal treatments [6, 7, 8].

Despite these benefits, the ability of AH Plus BC Sealer to form a strong bond with root dentin can be influenced by several factors related to the conditions within the root canal prior to sealing. For instance, the cleanliness and moisture content of the canal, as well as the presence of residual medicaments or debris, can impact the quality of the bond. The sealer's performance is also contingent upon the preparation and irrigation protocols followed during the procedure, as any interference with the optimal conditions for bonding can compromise the adhesive properties of the sealer. Therefore, careful attention to canal preparation is essential to maximize the bond strength and ensure the effectiveness of AH Plus BC Sealer in clinical applications [6, 7, 8].

In particular, the presence of intracanal medicaments such as CH or TAP may impact the bond strength of the sealer to dentin. Bond strength refers to the force required to dislodge the sealer from the dentinal walls and is typically assessed using a push-out test. The stronger the bond, the less likely it is that the sealer will fail over time, ensuring a durable, impermeable seal. The push-out bond strength is critical for ensuring that the sealer remains in place, preventing any gap formation that could act as a conduit for bacteria [5, 8].

The push-out test is widely recognized as a standard method for assessing the adhesion effectiveness of dental materials to root canal dentin. The resistance of root canal fillings to displacement from the radicular dentin plays a crucial role in preventing both coronal and apical leakage, thus ensuring the long-term integrity of the root canal system. This resistance also helps to reinforce the tooth structure against potential fractures and prevents the dislodgement of the root filling during various dental procedures, including post space preparation and tooth flexure. Previous research has indicated that materials demonstrating strong push-out test results are associated with improved longevity and overall prognosis for teeth that have undergone root canal treatment [37].

The bond strength of root canal fillings can be influenced by irregularities in canal anatomy, such as lateral and accessory canals, as well as areas of resorption. These anatomical variations can lead to discrepancies between the expected bonding area and the actual available bonding surface, potentially skewing the results of bond strength evaluations. Additionally, studies have shown that several factors, including the use of medicaments before filling the canal, the technique employed for root filling, the thickness of the slices, and the final irrigation protocol, all have an impact on the bond strength of root canal fillings [27, 36].

In this study, the focus was on comparing the effects of CH and TAP on the push-out bond strength of AH Plus BC Sealer to root canal dentin. The null hypothesis of the study posited that there would be no significant difference in the bond strength between the two groups (CH vs. TAP). However, the results of the study demonstrated that TAP significantly improved the bond strength of the AH Plus BC Sealer compared to CH. This suggests that TAP may have beneficial effects on sealer adhesion that are not shared by CH.

The mechanisms behind the different responses to TAP and CH may reside in the ability to remove them after treatment and their interactions with the dentin.

TAP, due to its chemical properties, appears to diffuse more deeply into dentinal tubules and remains more readily retained within the canal system compared to CH. TAP is known for its high retention rate, with over 80% of the paste remaining in the dentinal tubules even after irrigation. This characteristic likely provides a more consistent and stable environment for the sealer to bond to, particularly in areas that are difficult to irrigate, such as the apical third of the root canal [16, 26].

Minocycline, a key component of TAP, has a strong affinity for calcium ions abundantly present in the dentin matrix, resulting in the formation of calcium-minocycline complexes on the dentin surface. These complexes may serve as intermediaries at the sealer-dentin interface, enhancing the bond's strength and stability. The chelating property of minocycline not only alters the dentin's chemical composition but also creates a more favorable surface for adhesion by increasing physical interaction between the sealer and dentin. Additionally, the acidic pH of TAP induces demineralization and erosion of radicular dentin, increasing surface roughness and available bonding area, which improves sealer penetration and micromechanical retention. This is further supported by studies reporting a decrease in the phosphate/amide I ratio following TAP application, indicating alterations in dentin's mineral and organic content. Such changes, likely due to demineralization and exposure of collagen fibrils, enhance the adhesive interaction between dentin and sealers, thereby contributing to improved bond strength [2, 4, 9, 16].

In the present study, TAP demonstrated superior bond strength in the apical third of the root canal — a region often characterized by secondary dentin, accessory canals, and resorption defects, which create irregular and challenging bonding surfaces. The enhanced bond strength in this region may be attributed to TAP's high retention capacity within these anatomically complex areas, allowing prolonged chemical interaction and surface modification. This sustained presence likely facilitates continued demineralization and calcium chelation, further optimizing the substrate for sealer adhesion. Together, these chemical and anatomical factors contribute to the improved bond strength values observed, especially in areas where achieving an effective seal is traditionally difficult and clinically critical [4].

Calcium hydroxide (CH) has been widely used for root canal disinfection. Studies have shown that it can improve bond strength [2, 4]. Carvalho *et al*. found that CH improves bond strength when used for 14 days, followed by proper rinsing with NaOCl and EDTA [27].

The variation in results may stem from the duration of CH exposure, as prolonged use could alter the dentin surface, making it softer and potentially interfering with bonding. In this study, we followed an optimal CH protocol (21 days with NaOCl/EDTA rinse), which minimized adverse effects on sealer adhesion. As anticipated, CH did not reduce the bond strength of AH Plus BC Sealer, aligning with the previous studies [2, 19].

This study's findings can be compared relative to other investigations examining the effect of intracanal medicaments on the bond strength of root canal sealers:

Ustun *et al*. studied the effects of CH and propolis on the bond strength of AH Plus Sealer and discovered that the propolis group showed significantly superior bond strength at the apical one third of the root compared to the CH and control groups. This suggests that natural substances like propolis, which also exhibit antimicrobial properties, may offer benefits similar to those of TAP in enhancing bond strength [30, 31].

Akcay *et al*. found that TAP, consisting of metronidazole, ciprofloxacin, and minocycline, improved the bond strength of epoxy resin-based sealers, especially in the middle and apical thirds of the root canal [4]. This aligns with our findings, where TAP treatment showed a two-fold increase in bond strength compared to CH treatment.

These studies reinforce the idea that TAP, notably in combination with other antibiotics, offers superior antimicrobial activity and may also positively influence the bond strength of resin-based sealers.

Despite its efficacy in improving bond strength and eliminating bacteria, TAP poses certain challenges, particularly in terms of its removal from the canal system. This high retention can be advantageous in terms of long-term antimicrobial action, but it also raises concerns about residual medicament in the root canal system [26].

The residual minocycline from TAP, in particular, may lead to tooth discoloration, as it has been shown to bind to calcium ions in the dentin [19]. The long-term effects of residual TAP and its potential to contribute to antibiotic resistance are also important considerations [2, 4]. On top of that, there are concerns about the cytotoxicity of TAP and other intracanal medicaments, which could potentially affect periapical tissues and healing [32]. Therefore, further research is needed to explore the optimal concentration, application time, and removal protocols for TAP to optimize its advantages while reducing potential risks.

In conclusion, this study provides valuable evidence that TAP can enhance the bond strength of AH Plus BC Sealer to root canal dentin, especially in the apical third, when compared to CH. TAP's higher retention in dentinal tubules and its chemical interaction with calcium ions in dentin likely contribute to the enhanced bond strength observed. However, despite its advantages, TAP must be used with caution due to potential side effects such as tooth discoloration, antibiotic resistance, and cytotoxicity. Future research should focus on refining TAP's clinical application, exploring its optimal concentration and application time, and addressing its long-term safety to ensure it is both effective and safe for patients.

Conclusion

In accordance to the methods and conditions applied in this study, the evidence suggests that treatment with with calcium hydroxide (CH) did not significantly affect the bond strength of the AH Plus BC sealer. Conversely, the application of triple antibiotic paste (TAP) led to a marked increase in the bond strength of AH Plus BC sealer, especially in the middle and apical thirds of the root canal. These findings demonstrate that while CH treatment may not influence the adhesive properties of the sealer, TAP has the ability to boost bonding effectiveness in specific areas of the root canal, which can have important implications for the success of endodontic treatments.

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