ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 7643-7646 (2026)
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BIOINFORMATION
Discovery at the interface of physical and biological sciences
BIOMEDICAL INFORMATICS
www.bioinformation.net
Volume 22(10)
Research Article

Received October 1, 2026; Revised October 31, 2026; Accepted October 31, 2026, Published October 31, 2026
DOI: 10.6026/973206300227643

SJIF 2026 (Scientific Journal Impact Factor for 2026) = 8.478
2022 Impact Factor (2023 Clarivate Inc. release) is 1.9

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Citation: Nawale *et al*. Bioinformation 22(10): 7643-7646 (2026)

Effect of intracanal medicaments on bioceramic sealer bond strength: An *in vitro* study

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ISSN 0973-2063 (online) 0973-8894 (print)
Bioinformation 22(10): 7643-7646 (2026)
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Abstract:
Intracanal medicaments may influence the bonding of bioceramic sealers to root dentin. Therefore, it is of interest to compare the effects of calcium hydroxide, triple antibiotic paste (TAP) and nitrofurantoin in 60 extracted single-rooted teeth divided into four groups (n = 15), including an untreated control. Push-out bond strength was highest with TAP (2.234 MPa), followed by nitrofurantoin (0.972 MPa), control (0.764 MPa) and calcium hydroxide (0.542 MPa), with significant intergroup differences ($p < 0.05$), except between nitrofurantoin and control. Thus, data shows that TAP may enhance bioceramic sealer bond strength, whereas nitrofurantoin warrants further investigation as an alternative intracanal medicament.

Keywords: Bioceramic sealer, calcium hydroxide, intracanal medicaments, nitrofurantoin, push-out bond strength, triple antibiotic paste (TAP)

Background:
The primary goals of endodontic treatment are microbial elimination and prevention of reinfection through adequate canal sealing **[1]**. Persistent intraradicular infection remains a major cause of treatment failure, with *Enterococcus faecalis* frequently associated with persistent infections **[2]**. Chemomechanical preparation reduces microbial load, but anatomical complexities may leave portions of the canal wall untouched **[3, 4]**. Therefore, intracanal medicaments are used as adjuncts to improve disinfection between appointments **[5]**. Calcium hydroxide (CH) is widely used because of its antimicrobial and biological properties **[6]**, although it may alter dentin characteristics and sealer adhesion **[7]**. Its effectiveness against resistant microorganisms such as *E. faecalis* may also be limited **[8]**. Triple antibiotic paste (TAP), containing metronidazole, ciprofloxacin and minocycline, provides broad-spectrum antimicrobial activity **[9]** but residual medicament may adversely affect dentin and sealer bonding **[10]**. Nitrofurantoin has emerged as a potential alternative because of its antibacterial activity against endodontic pathogens, including *E. faecalis* **[11]**. Studies have suggested that nitrofurantoin may favourably influence the push-out bond strength of root canal sealers **[12]**. Push-out testing is commonly used to evaluate sealer adhesion and interfacial resistance to dislodgement **[13]**. However, limited evidence directly compares CH, TAP and nitrofurantoin regarding their effects on bioceramic sealer bonding **[14]**. Therefore, it is of interest to evaluate the effects on push-out bond strength, with the null hypothesis that no significant difference exists among the groups.

Methodology:
After obtaining approval from the Institutional Ethical Committee, 60 extracted human permanent single-rooted teeth were collected. Teeth extracted for periodontal or orthodontic reasons were included and samples were stored according to CDC guidelines. Teeth with a single root and single canal, confirmed radiographically in mesiodistal and buccolingual directions were selected. Teeth with caries, fractures, calcifications, immature apices, dilacerations, previous endodontic treatment or internal and external resorption were excluded.

Preparation of samples:
All teeth were decoronated perpendicular to the long axis using a diamond disc under water cooling to obtain a standardised root length of 15 mm, verified using a digital caliper. Canal patency was established using a size #10 K-file (Mani, Japan) extending slightly beyond the apical foramen and working length was determined 1 mm short of this length. Biomechanical preparation was performed using ProTaper rotary files (Dentsply Maillefer, Switzerland) in a crown-down technique up to F3 (#30/.09) at 300 rpm and 0.2 Ncm torque. During instrumentation, canals were lubricated with EDTA paste and irrigated with 5.25% sodium hypochlorite after each file. Following preparation, canals were irrigated with 17% EDTA for 1 min and finally rinsed with 10 mL of 0.9% normal saline. The canals were dried using paper points. The specimens were randomly divided into four groups (n = 15): Group 1 (calcium hydroxide), Group 2 (triple antibiotic paste), Group 3 (nitrofurantoin paste) and Group 4 (control, without intracanal medicament).

Preparation of medicaments:
Triple antibiotic paste was prepared by mixing equal proportions of powdered metronidazole, ciprofloxacin and minocycline with sterile distilled water in a powder/liquid ratio of 3:1. Nitrofurantoin paste was prepared by pulverising nitrofurantoin tablets and mixing with distilled water to obtain a concentration of 100 mg/mL. The medicaments were introduced into the canals using lentulo spirals. The coronal openings were sealed with a cotton pellet and temporary restorative material and the samples were incubated at 37°C and 100% humidity for 21 days. After incubation, the medicaments were removed using an EndoActivator with 10 mL of 17% EDTA and 10 mL of 3%

sodium hypochlorite, followed by a final rinse with normal saline.

Obturation:
All canals were dried and obturated using gutta-percha cones (Dentsply, Germany) with BioActive RCS sealer by the lateral compaction technique. The sealer was applied using a lentulo spiral and excess material was removed coronally. The access cavities were sealed with temporary restorative material and the samples were stored at 37°C and 100% humidity for 7 days to allow complete setting of the sealer. Each root was sectioned perpendicular to its long axis under water cooling and one 2 ± 0.1 mm thick slice was obtained from the mid-root region of each specimen.

Push-out bond strength test:
Push-out bond strength was evaluated using a universal testing machine (ACME Engineers, India; UNITEST-10). Each specimen was positioned on a metallic support with a central opening and a compressive load was applied using a stainless-steel plunger at a crosshead speed of 1 mm/min until bond failure occurred. The maximum dislodgement force was recorded in Newtons (N) and converted to megapascals (MPa) using the formula: push-out bond strength (MPa) = dislodgement force (N) / bonded surface area (mm^2). The bonded surface area was calculated based on the canal circumference and specimen thickness.

Statistical analysis:
SPSS version 25 (Statistical Package for the Social Sciences, SPSS Inc., Chicago, IL) was used to perform the statistical analysis. A value of $P < 0.05$ was set as statistically significant. One-way ANOVA was used to compare means and standard deviations for between- and within-group interactions. The multiple-comparison post-hoc Tukey test was performed to calculate the exact difference between the groups.

Results:
The mean and standard deviation of push-out bond strength for all groups are presented in **Table 1** and intergroup comparisons in **Table 2**. The results demonstrated a statistically significant difference among the groups ($P < 0.05$). The TAP group exhibited the highest bond strength, followed by nitrofurantoin, control and calcium hydroxide. Intergroup comparison revealed that TAP showed significantly higher bond strength than all other groups ($P < 0.05$). Calcium hydroxide showed significantly lower bond strength compared to the remaining groups ($P < 0.05$). No significant difference was observed between the nitrofurantoin and control groups ($P > 0.05$).

Table 1: Mean and standard deviation of push-out bond strength (mpa) for the study groups (one-way descriptive statistics).

Group	N	Mean	Std. Deviation	Std. Error	95% CI Lower	95% CI Upper
Calcium Hydroxide	15	0.542	0.10115	0.2612	0.486	0.538
TAP	15	2.234	0.29796	0.7693	2.063	2.399
Nitrofurantoin	15	0.9727	0.24417	0.06305	0.8374	1.1079
Control	15	0.764	0.19755	0.05101	0.6546	0.8734

Table 2: Post hoc tukey test for multiple comparisons between the groups

(I) group	(J) group	Mean Diff. (I–J)	Std. Error	Sig.	95% CI Lower	95% CI Upper
TAP	Nitrofurantoin	1.26133*	0.08117	0	1.0464	1.4763
	Control	1.47000*	0.08117	0	1.2551	1.6849
	Calcium Hydroxide	1.69200*	0.08117	0	1.4771	1.9069
Nitrofurantoin	Control	0.20867	0.08117	0.06	-0.0063	0.4236
	Calcium Hydroxide	0.43067*	0.08117	0	0.2157	0.6456
Control	Calcium Hydroxide	0.22200*	0.08117	0.04	0.0071	0.4369

**The mean difference is significant at the 0.05 level.*

Discussion:
Endodontic treatment aims to eliminate intracanal infection and establish a stable seal between the root canal filling materials and radicular dentin, making adequate sealer adhesion an important determinant of obturation quality **[15]**. The present study demonstrated a statistically significant difference in push-out bond strength among the experimental groups, resulting in rejection of the null hypothesis. Triple antibiotic paste (TAP) exhibited the highest bond strength, followed by nitrofurantoin, the control group and calcium hydroxide (CH). These findings indicate that the choice of intracanal medicament may influence the subsequent interaction between radicular dentin and the root canal sealer. The superior performance of TAP in the present study is consistent with recent evidence showing that antibiotic-based intracanal medicaments can influence sealer bonding. Maan *et al.* reported that intracanal medicaments, including TAP, affected the push-out bond strength of root canal sealers, although the response varied according to the sealer used **[16]**. More specifically, a recent study comparing nitrofurantoin and TAP demonstrated that TAP produced the highest push-out bond strength, followed closely by nitrofurantoin, whereas the control group showed the lowest values **[17]**. This pattern closely corresponds with the present findings and strengthens the evidence supporting the potential influence of these medicaments on sealer adhesion. TAP may enhance bonding by modifying the dentinal substrate and influencing the interaction between dentin and the sealer. However, its effect appears to depend on the chemical composition of both the medicament and sealer, as well as the effectiveness of medicament removal. Studies evaluating intracanal medications and bioceramic sealers have demonstrated that residual materials can alter the adhesive interface and produce differences in bond strength **[18]**. Therefore, the greater bond strength observed with TAP in the present investigation may reflect favorable changes in the dentin surface or improved sealer adaptation rather than a direct antimicrobial effect alone. Nitrofurantoin showed the second-highest bond strength and significantly exceeded the calcium hydroxide group. This finding is particularly relevant because nitrofurantoin has recently been investigated as an alternative intracanal medicament. The study by Maan *et al.* and Nair *et al.* the more recent comparative investigation both showed favorable bonding outcomes following nitrofurantoin application, supporting its potential as an alternative to

conventional medicaments **[16, 17]**. Nevertheless, its bonding performance remained lower than TAP in the present study, suggesting that differences in chemical interaction with dentin may influence the final sealer–dentin interface. CH produced the lowest push-out bond strength in the present investigation. Although a systematic review and meta-analysis found no overall significant effect of CH on the push-out bond strength of resin- or calcium silicate-based sealers, individual experimental studies have demonstrated that residual CH can reduce sealer penetration into dentinal tubules **[18]**. Kanmaz and Altunbaş reported that calcium hydroxide dressing could influence subsequent sealer penetration, with untreated controls showing greater penetration than some conventional removal protocols **[19]**. More recent research has further demonstrated that intracanal medicaments can significantly modify the bonding behavior of bioceramic sealers, emphasizing the importance of medicament removal and dentin condition before obturation **[20]**. The control group showed greater bond strength than CH, suggesting that the absence of residual medicament may provide a more favorable substrate for sealer adaptation. This observation is clinically relevant because bioceramic sealers interact closely with dentin and their bonding behavior can be influenced by the condition of the canal surface **[21]**. Overall, the present findings suggest that intracanal medicament selection should consider not only antimicrobial effectiveness but also its influence on the dentin–sealer interface. TAP showed the most favorable bonding performance, while nitrofurantoin showed promising intermediate results. However, the *in vitro* design and evaluation of immediate push-out bond strength limit direct clinical extrapolation. Further studies incorporating thermocycling, long-term aging, mechanical loading, different bioceramic sealers and microscopic evaluation of the adhesive interface are warranted.

Conclusion:

The type of intracanal medicament significantly influenced the push-out bond strength of the bioceramic sealer. Triple antibiotic paste demonstrated the highest bond strength, whereas calcium hydroxide showed the lowest. Nitrofurantoin showed intermediate performance, warranting further investigation under clinical conditions.

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