Q

International Journal of Applied Dental Sciences 2025; 11(3): 264-269

ISSN Print: 2394-7489
ISSN Online: 2394-7497
IJADS 2025; 11(3): 264-269

www.oraljournal.com
Received: 24-05-2025
Accepted: 27-06-2025

Dr. P Samba Shiva Rao
MDS Professor, HOD, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Nizamabad, Telangana, India

Dr. R Janavathi
MDS Professor, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Telangana, India

Dr. K Balaraju
MDS Professor, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Telangana, India

Dr. J Deepa
MDS Reader, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Nizamabad, Telangana, India

Dr. K Sowmya
MDS Senior Lecturer, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Nizamabad, Telangana, India

Dr. S Tejaswi
Post Graduate, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Nizamabad, Telangana, India

Corresponding Author:
Dr. S Tejaswi
Post Graduate, Department of Conservative Dentistry and Endodontics, Meghna Institute of Dental Sciences, Nizamabad, Telangana, India

Comparative evaluation of pushout bond strength of resin-based sealer using different irrigation protocol - an *in vitro* study

P Samba Shiva Rao, R Janavathi, K Balaraju, J Deepa, K Sowmya and S Tejaswi

DOI: https://www.doi.org/10.22271/oral.2025.v11.i3d.2215

Abstract
Aim: The primary goal of this research is to assess the pushout bond strength of Resin-based sealer using different irrigation protocols.
Materials and Methods: 36 single-rooted premolars were decoronated using a diamond disc to obtain a standardised root length of 13mm. Then, canal patency and working length were established. The root canals were then instrumented using protaper universal nickel-titanium rotary instruments. Sodium hypochlorite was used to passively irrigate the root canals. Based on the final irrigant used, all the samples were divided into three groups. Group1: Sodium hypochlorite followed by Diode laser. Group 2: 7%Maleic acid, Group 3: N-Acetyl Cysteine. After the final irrigation procedure, all the root segments were obturated with Gutta percha points using AH plus sealer and then sectioned into coronal, middle, and apical thin sections after 7 days. Then all the samples were subjected to a Universal testing machine and statistical analysis was done using ANOVA and Post hoc tests.
Results: The mean highest pushout bond strength was observed in Group 1 which used Sodium hypochlorite, followed by Diode Laser, followed by Group 2 Maleic acid and then Group 3 N Acetyl Cysteine, the lowest.
Conclusion: With the use of Diode laser, there is an increase in the pushout bond strength of AH plus sealer, eliminating all the smear layer and exposing all the dentinal tubules, thereby better adherence of obturation material.

Keywords: Maleic acid, diode laser, n acetyl cysteine, AH plus sealer, pushout bond

Introduction

One of the primary goals of endodontic therapy is to eradicate microorganisms and their byproducts from the root canal system; however, this has proven to be the most difficult task.

Because of the intricate and variable anatomy of the root canal, mechanical preparation for endodontic therapy is ineffective even with notable advancements in instrumentation development using new techniques and irrigation solutions. This causes some areas that are inaccessible to the preparation process to retain germs and debris [1]. This will eventually lead to the development of a smear layer, which is brought on by the burnishing and translocation of the superficial dentin wall components, regardless of the type of tool and instrumentation technique employed. If the root canal walls and fillings are not precisely aligned, obturation materials might not adhere entirely to the canal surfaces [2]. When the root canal system is not well sealed, irritants continue to act continuously, which exacerbates inflammation and infection [3].

Better adaptation between the sealer and dentinal walls is made possible by the use of irrigations during chemomechanical preparation, which also serves as an antibacterial agent, removes loose debris, and breaks down the smear layer's inorganic and organic constituents [4].

The majority of endodontic irrigants struggle to reach the typical depth of 100µm that microbial penetration in the dentin tubules can reach, according to *in vitro* SEM measurements. Enterococcus faecalis, for instance, reached 600-1000 µm of the dentinal tubules, but sodium hypochlorite barely penetrated60-150 µm [5]. Better research and clinical applications are possible with diode lasers that emit at 980 nm because they transfer energy via thin, flexible fibers that fit the curved shapes and architecture of root canals [6]. Diode lasers have a good penetration potential because of their limited interactions with water and hydroxyapatite and high absorption peaks for hemoglobin and melanin. With a power output ranging from 0.5 to 7 W, it can be utilized in a variety of operating modes, including chopped, pulsed, and continuous wave [7]. Wang *et al*. showed how a diode laser with a wavelength of 980 nm helped to remove debris and the smear layer from obturated teeth as well as the extent of apical leakage [8].

Some conditioning agents, such as maleic acid and phosphoric acid, were applied to the surface of the enamel or dentin. Maleic acid is used in adhesive dentistry as a mild organic acid conditioner due to its ability to eliminate smear layers. Using greater than 7% concentration of maleic acid may cause the intertubular dentin to erode, according to Prabhu *et al*. [9]

N-acetylcysteine (NAC) has antibacterial properties against endodontic, pathogenic microorganisms. NAC is an antioxidant, including thiol groups that effectively lower the formation of extracellular polysaccharides, breaking down established biofilms and reducing bacterial adhesion like that of a mucolytic medication [10].

Sealers create the hermetic barrier between the core filling material and the canal wall, which is essential for avoiding root canal infection brought on by microbial regrowth or newly acquired infection by coronal or apical leakage. Therefore, a key factor in evaluating the characteristics of different endodontic sealers is the bacterially tight seal that is produced by the sealer. The epoxy resin-based sealer, AH Plus is commonly used as a reference material due to its increased retention on root dentin, long-term dimensional stability, and decreased solubility.

Push-out bond strength, which measures the interfacial shear bond strength between the root dentin and intracanal filling material by determining the load needed to dislodge the filling material, is regarded as a relevant prognostic element for evaluating the bond between the core material and the sealer and the canal wall [4].

Therefore, the purpose of this study is to compare the pushout bond strengths of AH plus sealer after using different final irrigants.

Materials and Methods

After receiving institutional ethical approval, the current study was carried out (Ref No.: 05/MIDS/MDS/ENDO/IEC/2023). Thirty-six extracted single-rooted premolars were used in this study. Teeth extracted mostly for periodontal issues were chosen. Teeth with straight canals and fully developed apices were included in the study. However, teeth with open apices, cavities, fissures, curved roots, or previous root canal treatments were not used. Before being used, the teeth were thoroughly cleaned, sanitized, and kept in distilled water. With the use of water coolant and a high-speed diamond disc, the teeth were decoronated to produce 13 mm-long root segments. A K file of size #10 was used to establish the canal patency. ProTaper Universal files (Dentsply Maillefer, Ballaigues, Switzerland) were used in crown-down fashion with a gentle in-and-out motion up to F4 size, according to the manufacturer's instructions.

Then all the samples were divided into three groups based on the final irrigant used

Group 1(n=12) - Sodium hypochlorite followed by Diode Laser

Group 2 (n=12) - 7% Maleic acid

Group 3 (n=12) - N Acetyl Cysteine

- **Group 1:** Using a 200-µm diameter flexible optical fiber, the root canals were irrigated with 3% NaOCl (Prime Dental products Pvt Ltd, India) for two minutes before being exposed to a 980 nm diode laser (SIROlaser 2.2; SIRONA Dental, Bensheim, Germany) in two cycles of seven seconds with 5 W power in the continuous mode in a whirling motion from the root canal's apical to coronal section. Sodium hypochlorite was used to irrigate the root canals in alternating cycles passively.

- **Group 2**: Maleic acid, 5 mL of freshly prepared 7% Maleic acid was used.
- 7 g of Maleic acid is mixed in 100 ml of distilled water to obtain 7% of Maleic acid.

- **Group 3:** N-Acetyl Cysteine (NAC) solution was prepared by dissolving 0.2 g in 1 mL of sterile distilled water as directed, yielding a 200 mg/mL concentration. A volume of 5 ml of NAC solution was used as final irrigant.

In order to stop the irrigant's solvent effect and eliminate any precipitates that might have formed, 5 ml of regular saline was used for the final irrigation and the interval between two active irrigants for every group. Sterile paper points were used for drying the root canals.

The canals were obturated using a single-cone obturation technique using the resin based AH plus sealer. After that, all the samples were kept in distilled water at 37°C for 24 hrs. Using a slow-speed diamond saw with lubrication, all the samples were cut perpendicular to their long axis to obtain slices of 1 mm each, at coronal, middle, and apical third sections.

Push-out bond strength test

All the samples were assessed for the push-out bond strength with the help of a universal testing machine. To allow for free movement, the specimens were placed on a metal slab with a center hole and plunged with a 0.5 mm diameter and 2 mm/min. The plunger tip was positioned so that it only made contact with the test object. The maximum force applied to the materials at the time of dislodgement was measured in megapascals (MPa), and the test was continued until the bond failed. Pushout bond strength (MPa) = maximum load/adhesion of root canal filling (mm^2)

Statistical analysis

Data were collected and subjected to analysis using SPSS Software 22.0. Inter-group and intra-group comparisons were made using ANOVA Test (Table 1 and 2 respectively) and Pairwise comparison using Post hoc test (Table 3 and 4 respectively), and the level of significance was set at 0.05 ($p<0.05$).

Table 1: Intergroup Comparison - Anova Test

	Group	N	Mean	Std. deviation	F value	P value
Coronal	1.LASER	12	5.8147	2.07223	5.157	0.011*
	2. MA	12	4.8117	0.86300		
	3. NAC	12	4.0325	0.84251		
	TOTAL	36	4.8953	1.53995		
Middle	1.LASER	12	5.3675	2.48010	9.602	0.001*
	2. MA	12	2.8625	0.34168		
	3. NAC	12	3.2842	0.69041		
	TOTAL	36	3.8381	1.83116		
Apical	1.LASER	12	2.9550	1.06886	3.098	0.058
	2. MA	12	2.6075	0.74095		
	3. NAC	12	2.1033	0.66308		
	TOTAL	36	2.5553	0.89193		

MA- Maleic Acid, NAC- N Acetyl cysteine, Asterisk (*) - statistically significant.

Interpretation

- Statistically significant difference exists between the three experimental groups at the coronal and middle thirds (p<0.05).

Table 2: Intergroup Comparison - Post Hoc Test

		Mean Difference	P value
Coronal	Group 1 versus 2	1.03000	0.178
	Group 1 versus 3	1.80917	0.008*
	Group 2 versus 3	0.77917	0.363
Middle	Group 1 versus 2	2.50500	0.001*
	Group 1 versus 3	2.08333	0.005*
	Group 2 versus 3	0.42167	0.772
Apical	Group 1 versus 2	0.34750	0.576
	Group 1 versus 3	0.85167	0.048*
	Group 2 versus 3	0.50417	0.320

Asterisk (*) - statistically significant.

Interpretation

- Statistically significant difference exists between group 1 versus group 3 at the coronal thirds (p<0.05).
- Statistically significant difference exists between group 1 versus group 2, group 1 versus group 3, at the middle thirds (p<0.05).
- Statistically significant difference exists between group 1 and group 3 at the apical thirds (p<0.05).

Table 3: Intragroup comparison - Anova Test

		N	Mean	Std. Deviation	F value	P value
Group 1 diode laser	Coronal	12	5.8417	2.07223	7.445	0.002*
	Middle	12	5.3675	2.48010		
	Apical	12	2.9550	1.06886		
	Total	36	4.7214	2.29891		
Group 2 Maleic acid	Coronal	12	4.8117	0.86300	37.104	0.000*
	Middle	12	2.8625	0.34168		
	Apical	12	2.6075	0.74095		
	Total	36	3.4272	1.20007		
Group 3 N acetyl cysteine (nac)	Coronal	12	4.0325	0.84251	20.943	0.000*
	Middle	12	3.2842	0.69041		
	Apical	12	2.1033	0.66308		
	Total	36	3.1400	1.07693		

Asterisk (*) - statistically significant.

Interpretation

- Statistically significant difference exists between the coronal, middle, and apical thirds in group 1, group 2 and group 3 (p<0.05).

Table 4: Intragroup Comparison - Post Hoc Test

		Mean Difference (I-J)	P value
Group 1 Diode Laser	Coronal versus Middle	0.47417	0.826
	Coronal versus Apical	2.88667	0.003*
	Middle versus Apical	2.41250	0.014*
Group 2 Maleic Acid	Coronal versus Middle	1.94917	0.000*
	Coronal versus Apical	2.20417	0.000*
	Middle versus Apical	0.25500	0.637
Group 3 N Acetyl Cysteine (NAC)	Coronal versus Middle	0.74833	0.046*
	Coronal versus Apical	1.92917	0.000*
	Middle versus Apical	1.18083	0.001*

Asterisk (*) - statistically significant.

Interpretation

- Statistically significant difference exists between the coronal versus apical thirds, middle versus apical thirds in group 1 ($p<0.05$).
- Statistically significant difference exists between the coronal versus middle thirds, coronal versus apical thirds in group 2 ($p<0.05$).

Statistically significant difference exists between the coronal versus middle thirds, coronal versus apical thirds, middle versus apical thirds in group 3 ($p<0.05$).

Fig 1: Irrigation using Sodium Hypochlorite

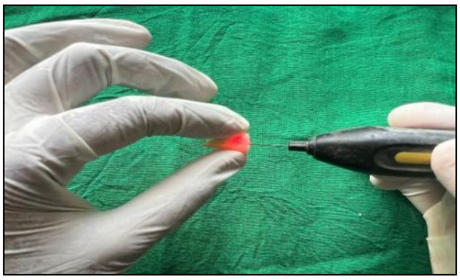

Fig 2: Irrigation using Sodium Hypochlorite

Fig 3: Irrigation using N Acetyl Csteine

Fig 4: Irrigation using Maleiic Acid

Discussion

In order to prevent reinfection, it is crucial to ensure that the root canal is completely sealed with the obturating material. A three-dimensional obturation is achieved by using an obturating material in conjunction with a root canal sealer, which creates a monoblock effect in which the obturating material, sealer, and root dentin all function as a single unit [2]. Extracted teeth were used in this study because they closely reflect the clinical circumstances. It was employed to preserve the gathered teeth in distilled water which did not affect the bond strength [11].

Despite the fact that there are several more recent sealers on the market, AH plus sealer was chosen for this study because it has been demonstrated to have the strongest bond to root dentin. The reasons are that it is an epoxy resin-based sealer that forms covalent bonds with root dentin by opening its epoxy ring, which lacks a photopolymerization system in its composition, and undergoes homogeneous polymerization with a higher bond strength than other monoblock systems [12, 13]. Additionally, the AH Plus sealer's chemical polymerization is a gradual process that permits sufficient shrinkage stress release [12].

In several aspects, the push-out test design is better than the other tests. This test design facilitates sample alignment for testing and is less susceptible to minute differences between specimens and changes in the distribution of stress during load application. This approach makes it possible to assess root canal sealers even in cases where bond strengths are weak because the model is reliable and efficient [14].

Consequently, a lot of researchers have chosen to use the laser. It has been reported that Argon, CO_2, Nd:YAG, Er:YAG, and Er,Cr:YSGG lasers may all successfully remove intracanal debris [8]. Diode lasers, unlike other lasers, exposed the dentinal tubules by ablation of the dentin and encouraged the dehydration of the dentin, which increased the sealer's ability to seal. The power setting and duration used in this study were chosen based on Wang *et al*.'s findings, which showed that these parameters produced a temperature increase of nearly 8.1°C, which is below the threshold that the periapical tissues support without resulting in thermal damage [6, 8, 15, 16].

The effect of lasers on dentin is caused mainly by the changes in temperature that can be extremely high at the irradiated spot, even for a short action time. A crater is created at the radiation spot as a result of the dentin tissue melting and vaporizing.

Laser energy causes a quick local rise in temperature and prompts melting, recrystallization and decomposition of the apatite crystals.

The surface changes after laser treatment was mostly due to the thermal effects on the dental hard tissues. Several researchers have demonstrated that photon energy is transformed into heat when a laser interacts with the tooth structure. Dentin melting and recrystallization are examples of surface alterations brought on by photoablative processes.

Lasers have been used to increase the adherence of sealers made of epoxy resin. MD Sousa *et al* found that, the epoxy resin-based sealer had better penetration in the microirregularities created by the surface alteration of dentin by Nd:YAG and diode lasers, thus increasing mechanical retention and resistance to shear forces. After obturation, dentin permeability decreased due to dentin melting and recrystallization, which in turn reduced microleakage. AH Plus sealer adhesion was increased onto the dentinal walls after laser irradiation due to complete removal of smear layer, which were similar to the current study [17]

A laser-activated irrigation method called photon-induced photoacoustic streaming (PIPS) can reduce infection and eliminate biofilm more effectively than passive ultrasonic irrigation, but it cannot totally eradicate bacteria from infected dentinal tubules from root canal therapy [18]. The more effective kind of light-activated disinfection known as Advanced Non-Invasive Light-Activated Disinfection (ANILAD) has a higher rate of bacterial killing and superior penetration into dentinal tubules [19].

Maleic acid (Group 2) has a stronger bond strength than NAC could be because it is extremely acidic and has a better demineralizing effect in a shorter amount of time. It eliminates the smear layer, resulting in effective micro-retention between the dentinal tubules and the AH plus sealer, which may be the cause of the stronger bond [12, 20].

N-Acetyl Cysteine has a lower bond strength than the diode laser group. This may be as a result of NAC decreasing the synthesis of extracellular polysaccharides, which raises the obturating material's adherence to the root dentin walls [20]. Although N Acetyl Cysteine plays a part in breaking down bacterial biofilms (extracellular polysaccharides), its sluggish antibacterial activity causes it to have the lowest bond strength [21].

Olofsson's study found that NAC did not significantly degrade extracellular polysaccharides (EPS), suggesting that NAC decreased EPS generation in the majority of studied bacteria, even at concentrations that did not affect growth [22].

Limitations

- Accurate results may not be possible due to a small sample size.
- Since single-rooted teeth are used, the results couldn't simulate other multi-rooted teeth in clinical scenarios.
- Furthermore, studies are necessary for confirmation of the diode laser as a final irrigant, in evaluating the pushout bond strength of AH plus sealer.

Conclusion

According to the current in-vitro study's limitations, the diode laser group's mean pushout bond strength was greater than that of Maleic acid and N-Acetyl Cysteine. The rationale is that it has a greater penetration rate into the dentinal tubules, which results in an effective sealer bond. Hence, irrigation protocols influenced the push-out bond strength of resin-based AH Plus sealer.

Conflict of Interest

Not available

Financial Support

Not available

References

1. Camargo CHR, Gomes LCL, Franca MCM, *et al*. Incorporating N-acetylcysteine and tricalcium phosphate into epoxy resin-based sealer improved its biocompatibility and adhesiveness to radicular dentine. Dent Mater; c2019.
2. Ghatole K, Indi S, Diwanji P, Janavathi, Hambire A, Thimwala A. Comparative evaluation of N-acetylcysteine and chlorhexidine as final irrigation on the push-out bond strength of different sealers: An *in vitro* study. Endodontology. 2022;34:180-183.
3. Torabinejad M, Hong CU, Pitt Ford TR, Kettering JD. Cytotoxicity of four root end filling materials. J Endod. 1995;21(10):489-492.
4. Srivastava A, Yadav DS, Rao HM, Arun A, Siddique R. Evaluation of push-out bond strength of BioRoot RCS and AH Plus after using different irrigants: An *in vitro* study. J Conserv Dent. 2020;23:26-31.
5. George S, Kishen A, Song KP. The role of environmental changes on monospecies biofilm formation on root canal wall by *Enterococcus faecalis*. J Endod. 2005;31(12):867-872.
6. Sreedev C, Raju I, Kumaravadivel K, *et al*. (April 24, 2020) Influence of Different Types of Root Canal Irrigation Regimen on Resin-based Sealer Penetration and Pushout Bond Strength. Cureus. 2020;12(4):e7807.
7. Moritz A, Gutknecht N, Goharkhay K, Schoop U, Wernisch J, Sperr W. *In vitro* irradiation of infected root canals with a diode laser: results of microbiological, infrared spectrometric, and stain penetration examinations. Quintessence Int. 1997;28:205-209.
8. Wang X, Sun Y, Kimura Y, Kinoshita J, Ishizaki NT, Matsumoto K. Effects of diode laser irradiation on smear layer removal from root canal walls and apical leakage after obturation. Photom Laser Surg. 2005;23:575-581.
9. Gupta PR, Aggarwal SD, Kshirsagar SP, Bhargava K, Rai V, Chawla M. Comparative evaluation of push-out bond strength of resin-based sealer and mineral trioxide aggregate-based sealer after using normal saline and 2% chlorhexidine as a final irrigant: *In vitro* study. Endodontology. 2016;28:32-37.
10. Bhasin P, Sharma M, Bindal D, Tomar D, Sarin A, Sharma N. An *In vitro* Evaluation of Antimicrobial Effects of Three Different Root Canal Irrigating Solutions against *Enterococcus faecalis* and *Streptococcus mutans*. J Contemp Dent Pract. 2019;20(2):221-225.
11. Perdigão J. Dentin bonding-variables related to the clinical situation and the substrate treatment. Dent Mater.

2010;26:e24-e37.
12. Shivanna V. The effect of different irrigating solutions on the push out bond strength of endodontic sealer to dentin and assessing the fracture modes: An In-vitro study. J Int Clin Dent Res Organ. 2014;6:86-91.
13. Rocha AW, de Andrade CD, Leitune VC, Collares FM, Samuel SM, Grecca FS, *et al*. Influence of endodontic irrigants on resin sealer bond strength to radicular dentin. Bull Tokyo Dent Coll. 2012;53:1-7.
14. Jainaen A, Palamara JE, Messer HH. Push-out bond strengths of the dentine-sealer interface with and without a main cone. Int Endod J. 2007;40:882-890.
15. Moura-Netto C, Mello-Moura AC, Palo RM, Prokopowitsch I, Pameijer CH, Marques MM. Adaptation and penetration of resin-based root canal sealers in root canals irradiated with high-intensity lasers. J Biomed Opt. 2015;20:038002.
16. Arslan H, Ayrancı LB, Karatas E, Topçuoğlu HS, Yavuz MS, Kesim B. Effect of agitation of EDTA with 808-nanometer diode laser on removal of smear layer. J Endod. 2013;39:1589-1592.
17. Maneesha D, Anil KG, Sindhu R, Surendranath G, Deepak S. An *in vitro* Evaluation of Microtensile Bond Strength of Resin-based Sealer with Dentin Treated with Diode and Nd:YAG Laser. J Contemp Dent Pract. 2013;14(2):183-187.
18. Peters OA, Bardsley S, Fong J, Pandher G, Divito E. Disinfection of root canals with photon initiated photoacoustic streaming. J Endod. 2011;37:1008-1012.
19. Lim Z, Cheng JL, Lim TW, Teo EG, Wong J, George S, Kishen A. Light-activated disinfection: an alternative endodontic disinfection strategy. Aust Dent J. 2009;54:108-114.
20. Ballal NV, Kandian S, Mala K, Bhat KS, Acharya S. Comparison of the efficacy of maleic acid and ethylenediaminetetraacetic acid in smear layer removal from instrumented human root canal: A scanning electron microscopic study. J Endod. 2009;35:1573-1576.
21. Palaniswamy U, Lakkam SR, Arya S, Aravelli S. Effectiveness of N-acetyl cysteine, 2% chlorhexidine, and their combination as intracanal medicaments on *Enterococcus faecalis* biofilm. J Conserv Dent. 2016;19:17-20.
22. Olofsson A-C, Hermansson M, Elwing H. N-acetyl-l-cysteine affects growth, extracellular polysaccharide production, and bacterial biofilm formation on solid surfaces. Applied and Environmental Microbiology. 2003;69(8):4814-4822.

How to Cite This Article
Rao PSS, R Janavathi, K Balaraju, J Deepa, K Sowmya, S Tejaswi. Comparative evaluation of flexural strength and elastic modulus of interim resin materials for fixed prosthodontics: Comparative evaluation of pushout bond strength of resin-based sealer using different irrigation protocol - an *in vitro* study. International Journal of Applied Dental Sciences. 2025;11(3):264-269.