Influence of N-acetyl cysteine on the Pushout Bond Strength of Glass Fiber Post luted to Radicular Dentin: an in-vitro Comparative Evaluation.

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Abstract:

Background: The purpose of this study was to evaluate the effect of N-acetyl cysteine (NAC) as a post-space irrigant on the push-out bond strength of glass fiber posts luted with dual-cure resin cement in endodontically treated mandibular premolars. Endodontically treated teeth often suffer from compromised bonding due to residual irrigants and smear layer, affecting the longevity of post restorations. NAC, known for its antioxidant and smear layer removal properties, may enhance the adhesion of resin-based materials to root dentin. This study aimed to investigate whether its application could improve the bond strength of fiber posts and potentially enhance clinical outcomes.

Materials and Methods: An in-vitro study was conducted on 20 freshly extracted single-rooted mandibular premolars with straight canals and mature apices, divided into two groups (n=10). After decoronation to 14 mm, canals were prepared using Protaper Gold till F3 and obturated, leaving 5 mm apically. Group B samples were irrigated with 5 ml of 200 mg/ml N-acetyl cysteine for 1 minute before post cementation; Group A served as control. Size 2 Angelus Reforpost glass fiber posts were luted using dual-cure resin cement. After incubation at 37°C in 100% humidity for 15 days, three 1 mm slices (coronal, middle, apical) were sectioned from each sample and subjected to push-out bond strength testing using a universal testing machine. Data was collected and subjected to statistical analysis.

Results: In the NAC-treated group, the mean push-out bond strength values were 12.55 ± 0.578 MPa in the coronal third, 11.89 ± 0.930 MPa in the middle third, and 8.68 ± 0.577 MPa in the apical third, showing a significant decrease from coronal to apical regions ($p < 0.05$). The untreated group also showed a similar trend, with mean values of 8.37 ± 0.683 MPa, 8.20 ± 0.919 MPa, and 6.80 ± 1.060 MPa in the coronal, middle, and apical thirds, respectively. Intergroup comparisons revealed significantly higher bond strength in the NAC-treated group across all root levels ($p < 0.001$), demonstrating the positive effect of N-acetyl cysteine on improving glass fiber post adhesion to root dentin.

Conclusion: N-acetyl cysteine treatment significantly improved push-out bond strength across all root canal sections when compared to untreated group, indicating its potential as a root canal irrigant to enhance adhesion of glass fiber posts to radicular dentin.

Keywords: Bond strength, Dentin Biomodification, Endodontically treated teeth, Glass Fiber Post, N-acetyl cysteine and Universal Testing Machine.

I.   Introduction

Endodontically treated teeth often experience substantial loss of coronal and radicular structure due to decay, access preparation, or previous restorations. This structural compromise makes them more susceptible to fracture under functional loads, especially in posterior regions. When limited tooth structure remains, a post and core system become essential to support the definitive restoration and enhance retention. The core replaces the lost coronal structure, while the post helps retain the core within the root canal, especially when natural retention is insufficient. [1,2]

Although posts do not inherently strengthen the root, they assist in redistributing occlusal forces more evenly along the root, reducing the risk of catastrophic failure. The decision to place a post should be based on factors such as the amount of remaining tooth structure, location in the dental arch, and anticipated functional demands. [3] Modern adhesive systems and fiber-reinforced posts have further improved the biomechanical compatibility of such restorations, offering better esthetics and reduced risk of root fracture compared to traditional metal posts. [4]

Glass fiber posts play a significant role in the restoration of endodontically treated teeth with compromised coronal structure. Their primary function is to provide retention for the core material and distribute masticatory forces along the root, thereby minimizing the risk of fracture. [5] Due to their modulus of elasticity being similar to that of natural dentin, glass fiber posts exhibit more favorable stress distribution compared to metallic posts, reducing the incidence of root fractures. [6] Additionally, their translucency

and esthetic properties make them ideal for anterior restorations. The use of adhesive bonding systems with fiber posts further enhances the integrity of the post-core complex, contributing to the long-term success of the final restoration. [7]

Traditional dual-cure resin cements are commonly used for post cementation due to their dual activation properties. However, their effectiveness can be compromised in clinical situations where light transmission is limited within the root canal. [8] Inadequate polymerization may lead to reduced bond strength and increased microleakage. Furthermore, polymerization shrinkage can introduce stresses at the adhesive interface, weakening the post-retention. Incompatibility between certain resin cements and bonding agents may also affect the integrity of the post-dentin bond, potentially reducing the long-term success of fiber post restorations. [9]

N-acetyl cysteine (NAC), an effective antioxidant, has been explored for its ability to improve the adhesion of resin-based materials to dentin. It works by reducing the oxidative effects of agents like sodium hypochlorite, which may interfere with the setting and bonding of resin adhesives. NAC helps restore the dentin surface by stabilizing the collagen network and reestablishing a suitable redox environment. This promotes better interaction between adhesive systems and the dentin substrate, potentially leading to stronger and more durable bonding outcomes. [10]

Hence, this in vitro study aimed to compare and evaluate the effect of N-acetyl cysteine (NAC) on the pushout bond strength of glass fiber post luted to root dentin; the null hypothesis being NAC had no effect on the pushout bond strength of the glass fiber post luted to radicular dentin.

II. Material And Methods

Ethical Approval: The study was conducted in Department of Conservative Dentistry and Endodontics, Darshan Dental College and Hospital after getting approval from the Institutional Ethics Committee. The study went on for a period of 1 month from inception to completion.

Sample Size Calculation: Sample size estimation was performed using G*Power software to achieve adequate statistical power. With an assumed effect size of 0.8, a significance level (α) of 0.05, and a desired power of 80% ($1-\beta = 0.80$), the calculated sample size was 10 specimens per group. Accordingly, a total of 20 single-rooted mandibular premolar teeth were selected and divided into two groups of 10 samples each for the study.

Sample Preparation: Twenty freshly extracted human mandibular premolars with single, straight roots and fully developed apices—collected primarily for orthodontic reasons—were selected based on anatomical similarity. Teeth presenting with previous root canal treatment, visible cracks, or calcified canals were excluded from the study. The selected samples were preserved in de-ionized water until further use. Each tooth was sectioned horizontally below the cemento-enamel junction using a slow-speed, water-cooled diamond disc, ensuring a standardized length of 14 mm from the apex.

Inclusion Criteria:
1. Freshly extracted human mandibular premolars
2. Single-rooted teeth with straight single canals
3. Fully developed apices
4. Teeth extracted for orthodontic purposes
5. Anatomically similar root segments
6. Teeth with round canal cross-section

Exclusion Criteria:
1. Teeth with previous endodontic treatment
2. Teeth exhibiting visible cracks
3. Teeth with calcified canals
4. Teeth with curved canals
5. Teeth with root caries or other root defects

Endodontic Procedure: Access was refined with #2 GG drill and a 15K file was used to record the working length under stereomicroscope at 10X magnification till the file was visible from the apex, the working length was kept 1mm short of that and verified radiographically. The canals were then prepared till F3 Protaper Gold Rotary file under continuous irrigation with alternate bouts of 3% Sodium Hypochlorite and normal saline with every file change. Obturation was carried out with F3 Protaper GP Points. Post Space was prepared using corresponding drills from Angelus Reforpost Glass Fiber (size 1 and followed by size 2) System leaving an apical obturation of 5 mm.

Grouping of Samples:

Group A: Untreated Group consisting of 10 samples which were further subdivided in coronal, middle and apical sections

Group B: NAC Treated Group consisting of 10 samples which were further subdivided in coronal, middle and apical sections

20% N-acetyl cysteine Solution Preparation and Application: N-acetyl cysteine (AM Nutra Tech Pvt Limited, Delhi) solution was made by mixing it with sterile water in 200mg/ml concentration. The prepared solution was used as an irrigant for the post space of samples of Group B. 5 ml of the solution was kept in contact with root dentin for 1 minute and rinsed off with de-ionized water and dried with paper points.

Post Cementation: Angelus Reforpost Glass Fiber (Angelus, Brazil) was used in this study. Size 2 post was luted to all the samples using Dual cure resin cement (Calibra, Dentsply Sirona, USA) which was light cured according to manufacturer's instruction.

Incubation: All the samples were incubated at 100% humidity at 37°C for 15 days after which they were subjected to pushout bond strength evaluation.

Pushout Bond Strength Evaluation:

The specimens were embedded vertically in self-polymerizing acrylic resin blocks, each measuring 1 cm in width and 4 cm in height, ensuring alignment along the long axis of the root. From each mounted sample, three horizontal slices of 1 mm thickness were obtained representing the coronal, middle, and apical sections of the post luted to root. Slice thickness was verified using a digital caliper to ensure uniformity. Push-out bond strength testing was performed using a universal testing machine at a crosshead speed of 0.5 mm/min. The load in Newton was recorded to debond the post fragment. A stainless-steel cylindrical plunger with a flat tip (1 mm in diameter) was centered over the post to apply load only on the post surface, avoiding any contact with the surrounding dentin walls. The load in Newton was recorded to debond the post fragment. Pushout Bond Strength (PBS) was calculated with the formula: $PBS = Load(N)/Area$ in square millimeters (A), where, $A = 2\pi rh$, r is the radius of specimen (mm), h is the thickness of slice (mm), the π value is 3.14.

Statistical analysis:
Statistical analysis was performed using IBM SPSS Software version 25 to evaluate the push-out bond strength of glass fiber posts luted to root dentin in Group A (Untreated) and Group B (N-acetyl cysteine-treated) across the coronal, middle, and apical thirds of the root. Intragroup comparisons were analyzed using Repeated Measures ANOVA to determine significant variations in bond strength across the three root regions within each group, followed by Bonferroni post hoc tests for pairwise comparisons. Intergroup comparisons at each corresponding root level were conducted using independent (unpaired) t-tests. A p-value of less than 0.05 was considered statistically significant.

III. Result

In the NAC-treated group, push-out bond strength exhibited a clear decreasing gradient from coronal to apical regions, with the highest mean value recorded in the coronal third (12.55 ± 0.578 MPa), followed by the middle third (11.89 ± 0.930 MPa), and the lowest in the apical third (8.68 ± 0.577 MPa). Repeated Measures ANOVA (Table 1 and Graph 1) indicated a highly significant difference among the three root segments ($F = 109.723$, $p = 0.000$), confirming that bond strength is significantly influenced by root location. Bonferroni post hoc analysis (Table 2) revealed statistically significant differences between the coronal and apical thirds ($p = 0.000$), and between the middle and apical thirds ($p = 0.000$), while the difference between the coronal and middle thirds was not significant ($p = 0.234$), indicating similar bonding effectiveness in the upper two regions and a marked decline in the apical third.

A similar pattern was noted in the untreated group, where bond strength values were lower overall, with means of 8.37 ± 0.683 MPa in the coronal third, 8.20 ± 0.919 MPa in the middle third, and 6.80 ± 1.060 MPa in the apical third. These differences (Table 3 and Graph 2) were also statistically significant across the three regions ($F = 10.792$, $p = 0.002$), and post hoc comparisons (Table 4) showed significant reductions between the coronal and apical thirds ($p = 0.017$) and between the middle and apical thirds ($p = 0.012$), while the coronal vs. middle comparison remained non-significant ($p = 1.000$).

Intergroup comparisons (Table 5 and Graph 3) further confirmed that NAC treatment significantly enhanced bond strength at all three levels. The NAC-treated group consistently outperformed the untreated group, with highly significant differences in the coronal ($t = -14.772$, $p = 0.000$), middle ($t = -8.924$, $p = 0.000$), and apical thirds ($t = -4.925$, $p = 0.000$), emphasizing the efficacy of NAC in improving adhesion, particularly in the coronal and middle regions.

Table 1: Intragroup comparative analysis of push of bond strength values in three different root sections treated with NAC (Repeated measure ANOVA).

Groups	Sample Size (N)	Mean (Newton)	Standard Deviation	p-Value
Coronal Section	10	12.55	.578	0.000
Middle Section	10	11.89	.930	
Apical Section	10	8.68	.577	
p-Value was significant at 0.05 level				

Graph 1: Push out bond strength of three different root sections treated with NAC.
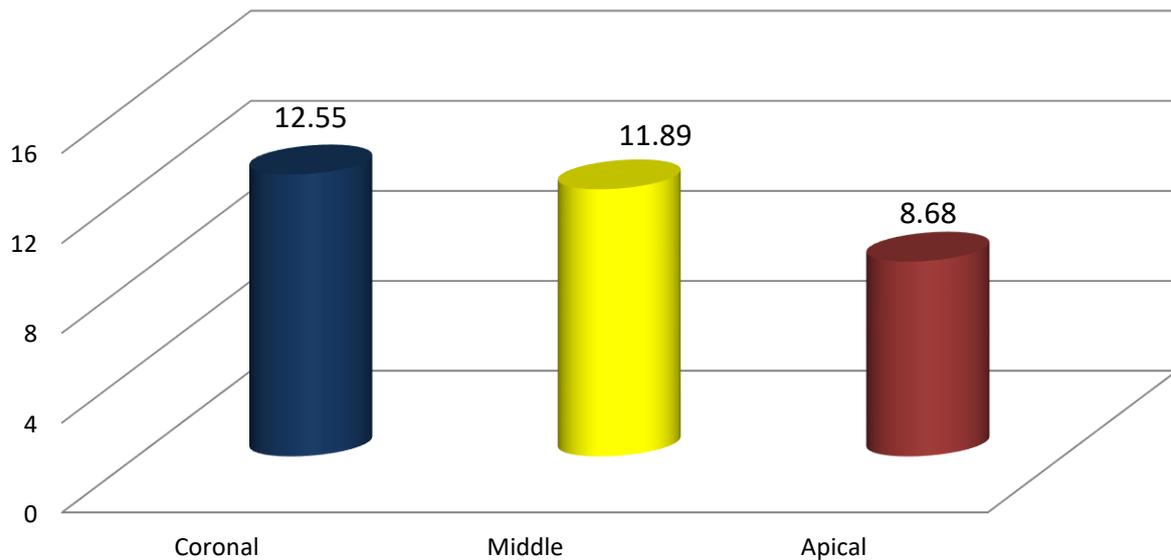
Table 2: Bonferroni post hoc analysis of push out bond strength values different root sections treated with NAC.

Groups	Comparison Groups	Mean Difference	Standard Error	p-Value
Coronal	Middle	.660	.332	.234
	Apical	3.870	.295	.000*
Middle	Coronal	-.660	.332	.234
	Apical	3.210	.193	.000*
Apical	Coronal	-3.870	.295	.000*
	Middle	-3.210	.193	.000*
p-Value was significant at 0.05 level				

Table 3: Intragroup comparative analysis of push of bond strength values in three different root sections for Untreated Group (Repeated measure ANOVA).

Groups	Sample Size (N)	Mean (Newton)	Standard Deviation	p-Value
Coronal Section	10	8.37	.683	0.002
Middle Section	10	8.20	.919	
Apical Section	10	6.80	1.060	
p-Value was significant at 0.05 level				

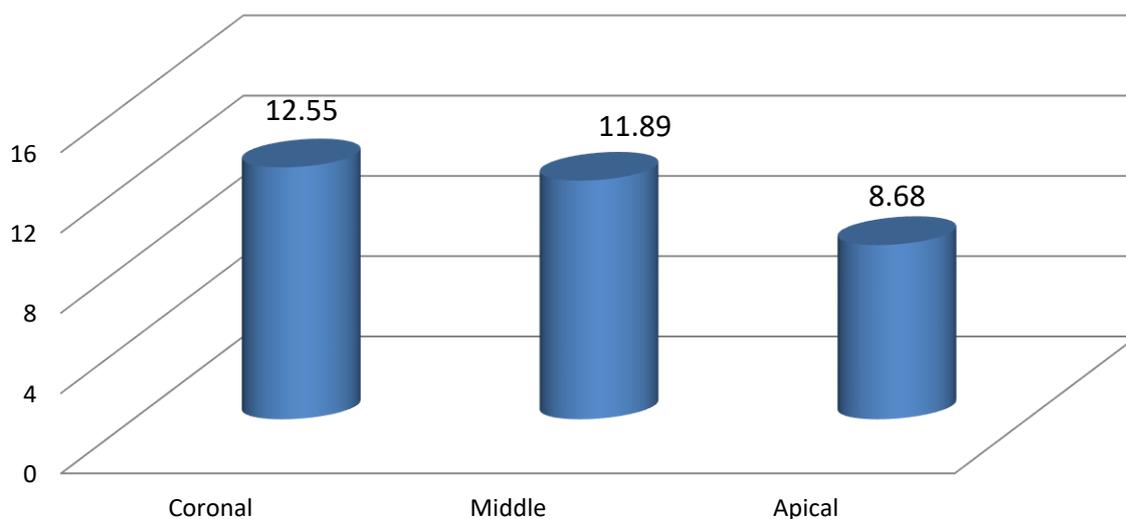**Graph 2: Push out bond strength of three different root sections in Untreated Group.**

Table 4: Bonferroni post hoc analysis of push out bond strength values different root sections in Untreated Group.

Groups	Comparison Groups	Mean Difference	Standard Error	p-Value
Coronal	Middle	.170	.299	1.000
	Apical	1.570	.434	.017*
Middle	Coronal	-.170	.299	1.000
	Apical	1.400	.368	.012*
Apical	Coronal	-1.570	.434	.017*
	Middle	-1.400	.368	.012*
p-Value was significant at 0.05 level				

Groups	Comparison Groups	Mean	Standard Deviation	T-value	p-Value
Coronal	Untreated Group	8.37	.683	-14.772	.000*
	NAC Treated Group	12.55	.578		
Middle	Untreated Group	8.20	.919	-8.924	.000*
	NAC Treated Group	11.89	.930		
Apical	Untreated Group	6.80	1.060	-4.925	.000*
	NAC Treated Group	8.68	.577		

Table 5: Intergroup comparative analysis of push out bond strength in both NAC treated and untreated groups (Unpaired t-test)

p-Value was significant at 0.05 level

Graph 3: Intergroup comparative analysis of push out bond strength in both NAC treated and untreated groups
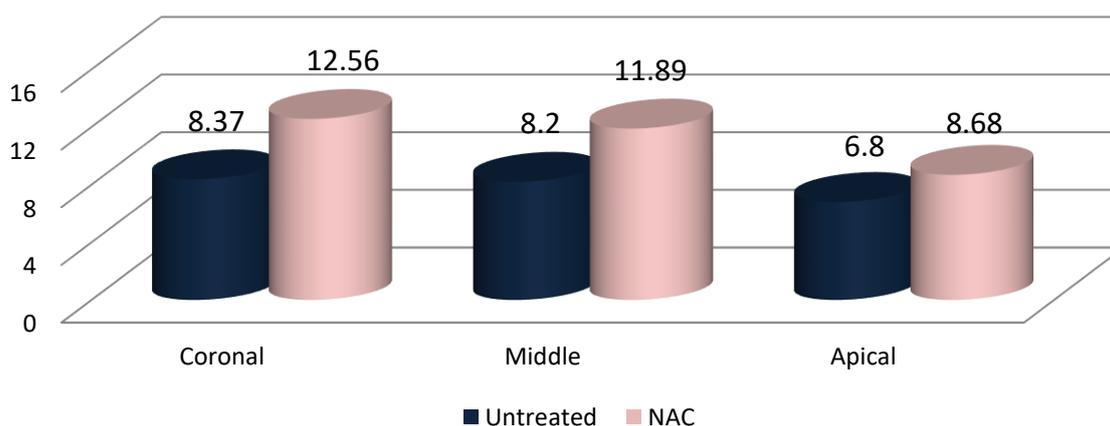
IV. Discussion

Endodontically treated teeth often face structural deficiencies resulting from caries, extensive access preparations, or repeated restorative procedures. These alterations in tooth architecture reduce the mechanical resistance of the remaining structure, thereby increasing the need for post and core systems to restore function and aesthetics. [11] Among the various post systems, glass fiber posts have become widely accepted due to their elastic modulus being similar to dentin, offering better stress distribution and minimizing root fracture risks. However, the success of such restorations is largely dependent on the bond strength between the post and radicular dentin, which may be negatively influenced by irrigants and residual chemicals used during root canal therapy. [12]

One of the significant challenges affecting the durability of resin-dentin adhesion is the progressive degradation of the collagen matrix within the hybrid layer. This degradation, often caused by residual oxidative agents like sodium hypochlorite and endogenous enzymes such as matrix metalloproteinases (MMPs), can weaken the structural integrity of the bonded interface over time. [13] The breakdown of exposed collagen fibrils compromises the infiltration and polymerization of adhesive resins, leading to reduced bond strength and long-term restoration failure [13].

This study was undertaken to evaluate strategies that may preserve dentin integrity and improve the bond strength of glass fiber posts, enhancing the success of post-endodontic restorations. The aim of the study was to compare the effect of N-acetyl cysteine on the pushout bond strength of glass fiber post luted to root dentin. The null hypothesis stated that there would be no significant difference in the push-out bond strength of glass fiber posts by the action of N-acetyl cysteine.

The findings of the present study demonstrated a distinct corono-apical gradient in push-out bond strength in both NAC-treated and untreated groups, with the highest values consistently observed in the coronal third and the lowest in the apical third. In the NAC-treated group, bond strength was significantly higher in the coronal (12.55 ± 0.578 MPa) and middle thirds (11.89 ± 0.930 MPa) compared to the apical third (8.68 ± 0.577 MPa), as confirmed by Repeated Measures ANOVA (F = 109.723, p = 0.000) and Bonferroni post hoc analysis, which showed significant differences between coronal–apical (p = 0.000) and middle–apical thirds (p = 0.000), but not between coronal and middle thirds (p = 0.234). This suggests that NAC effectively maintained bond strength in the coronal and middle regions, while the apical third remained a site of reduced adhesion.

The untreated group followed a similar trend, albeit with lower overall values—coronal (8.37 ± 0.683 MPa), middle (8.20 ± 0.919 MPa), and apical thirds (6.80 ± 1.060 MPa)—and statistically significant differences across root levels (F = 10.792, p = 0.002). Post hoc analysis in this group also revealed significant differences between coronal–apical (p = 0.017) and middle–apical thirds (p = 0.012), with no significant difference between coronal and middle thirds (p = 1.000).

Intergroup comparisons confirmed the superior performance of the NAC-treated group across all levels, with highly significant differences in the coronal (t = -14.772, p = 0.000), middle (t = -8.924, p = 0.000), and apical thirds (t = -4.925, p = 0.000). These results strongly support the efficacy of NAC pretreatment in enhancing the adhesion of glass fiber posts to root dentin, particularly in the coronal and middle segments, where mechanical interlocking and resin infiltration are most effective.

Mandibular premolars with straight, single canal were selected to maintain anatomical uniformity, minimize variability in root morphology, and ensure consistent post space dimensions. Their standardized structure allows reliable sectioning for push-out bond strength testing, improving the accuracy and reproducibility of results. [14]

Calibra (Dentsply Sirona, USA) is recognized for its effective bonding capabilities to both enamel and dentin, providing reliable adhesion in various restorative procedures. Its dual-cure nature ensures adequate polymerization even in areas with limited light access, which is crucial for intraradicular applications. [15]

The Angelus Reforpost Glass Fiber (Angelus, Brazil) is designed with a modulus of elasticity similar to that of natural dentin, promoting uniform stress distribution and reducing the risk of root fractures. Its parallel-sided design with grooves enhances mechanical retention within the root canal. [16]

N-acetyl cysteine (NAC) is a low-molecular-weight thiol compound derived from the amino acid L-cysteine, characterized by the presence of a free sulfhydryl (-SH) group, which imparts its antioxidant and mucolytic properties. [17] Its ability to disrupt biofilms and neutralize reactive oxygen species makes NAC particularly effective against persistent endodontic pathogens like *Enterococcus faecalis*, commonly found in failed root canal treatments. NAC exhibits antibacterial effects by disrupting bacterial cell membranes, inhibiting ATP production, and reducing extracellular polysaccharide matrix formation in biofilms. [18]
Beyond its antimicrobial action, NAC also functions as a collagen crosslinking agent. It achieves this by stabilizing the collagen fibril network within demineralized dentin, minimizing enzymatic degradation and enhancing the mechanical integrity of the hybrid layer. The mechanism involves the formation of disulfide bonds and protection of the collagen matrix from metalloproteinase-mediated breakdown. This stabilization of collagen not only preserves the dentin substrate but also improves the micromechanical retention of resin-based materials, thereby significantly enhancing the bond strength at the resin-dentin interface. [10,13] In our study, NAC pretreatment gives higher pushout bond strength values owing to the above-mentioned characteristics of N-acetyl cysteine.

Literature consistently shows that dentin pretreatment with natural collagen crosslinkers significantly increases pushout bond strength of glass fiber post luted to root dentin because of an improved resin-dentin interface by their action. [2,19] Our study also highlights the collagen crosslinking action of N-acetyl cysteine and can be considered as an adjunct in cases of restoration of endodontically treated teeth with fiber posts.

Limitations of the study were such that this experiment was performed under in-vitro laboratory settings, which do not fully mimic the complex oral environment, including dynamic temperature changes, moisture fluctuations, and mechanical forces from chewing. Additionally, the research focused on a single glass fiber post type, one resin cement, and a specific concentration of the test solution, which may not account for variability encountered in clinical scenarios. Future research should aim to include different adhesive systems, a range of post designs and sizes, and long-term aging simulations such as thermocycling or fatigue testing to better understand the clinical relevance and durability of the observed outcomes.

V. Conclusion

Within the limitations of this in vitro study, it can be concluded that pretreatment of root dentin with N-acetyl cysteine (NAC) significantly improves the push-out bond strength of glass fiber posts compared to untreated samples. Although a gradual decrease in bond strength was observed from the coronal to apical thirds in both groups, the NAC-treated specimens consistently demonstrated higher bond strength values across all root levels, especially in the coronal and middle regions. These results suggest that NAC enhances dentin conditioning by potentially improving adhesive infiltration and retention. This points to its potential as an effective adjunct in endodontic post cementation to enhance restoration durability. Nonetheless, further clinical trials and long-term studies are necessary to confirm these findings and evaluate the practical application of NAC in routine dental practice.

VI. References

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