RESEARCH PAPER

Dislocation Resistance of Epoxy Resin and Bioactive Glass Root Canal Sealers Following Diode Laser-Assisted Disinfection: An In Vitro Study

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Abstract

AIM: To evaluate and compare the dislocation resistance of Epoxy resin and Bioactive glass sealers following laser-assisted root canal disinfection.

MATERIALS AND METHODS: Forty-four extracted human intact single-rooted mandibular premolar teeth were decoronated to obtain a standardized root length of 14 mm. Cleaning and shaping was performed using ProTaper Universal rotary file up to size F3 and 2.5% sodium hypochlorite irrigation in between each instrument change. Final irrigation protocol consisted of 5 mL 2.5% NaOCl (30 s), 3 mL 17% EDTA (60 s), followed by 3 mL NaOCl (30 s) and saline flush. Canals were dried with paper points.

Laser-assisted disinfection was performed using a 980-nm diode laser with a 200-µm fiber optic tip at 2.4 W in pulsed mode (20 µs pulse duration), delivering 12 J per cycle. Irradiation was done for 20 seconds followed by a 10-second pause, constituting one cycle, and this cycle was repeated three times.

Samples were randomly divided into two groups using the lottery method (n = 22):

Group 1: Epoxy resin–based sealer (AH Plus)

Group 2: Bioactive glass–based sealer (Nishika Canal Sealer BG)

Obturation was performed using single cone technique and the respective sealers. Access cavities were sealed with Cavit and stored at 37°C and 100% humidity for one week.

Each root was sectioned horizontally into coronal, middle, and apical thirds (2 mm thickness each), yielding a total of 132 specimens. Push-out bond strength was evaluated using a Universal Testing Machine at a crosshead speed of 0.5 mm/min with appropriate plunger diameters for each section. Dislocation resistance (MPa) was calculated by dividing the force at dislodgement (N) by the bonded surface area. Data was analyzed using two-way ANOVA and Tukey's post hoc test.

RESULTS: The epoxy resin–based sealer (Laser with AH Plus) demonstrated significantly higher push-out bond strength compared to the bioactive glass–based sealer (Laser with Nishika Canal BG) ($p < 0.001$). AH Plus showed mean bond strength values of 3.75 MPa (coronal), 2.63 MPa (middle), and 1.80 MPa (apical), whereas Nishika Canal BG exhibited lower values of 1.51 MPa (coronal), 0.78 MPa (middle), and 0.90 MPa (apical). In both groups, bond strength decreased progressively from coronal to apical thirds. Two-way ANOVA revealed a significant effect of sealer type and root canal section on push-out bond strength ($p < 0.05$), with a significant interaction between the variables ($p < 0.05$). Tukey's post hoc analysis confirmed that AH Plus exhibited significantly higher bond strength than Nishika Canal BG in all root sections.

CONCLUSION: Laser-assisted root canal disinfection influenced the push-out bond strength of both sealers. The epoxy resin–based sealer showed significantly higher dislocation resistance than the bioactive glass–based sealer in all root canal thirds. Bond strength was highest in the coronal third for both sealers. The apical third remained the most challenging

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region for sealer adhesion. Further long-term and clinical studies are required to assess the aging behaviour and clinical performance of bioactive glass–based sealers following laser-assisted disinfection.

KEYWORDS: Bioactive glass–based sealer, Diode laser, Epoxy resin–based sealer, Laser-assisted root canal disinfection, Push-out bond strength.

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Introduction

The long-term success of endodontic therapy is closely related to accurate diagnosis, adequate cleaning and shaping, reduction of intracanal microorganisms, and effective three-dimensional obturation of the root canal system [1,2]. Although instrumentation and irrigation remain fundamental steps in treatment, they do not reliably produce a bacteria-free canal because microorganisms may persist in fins, isthmuses, lateral canals, and dentinal tubules [2]. In addition, instrumentation produces a smear layer on canal walls that contains dentinal debris, organic remnants, microorganisms, and bacterial by-products, all of which may interfere with irrigant action and sealer adaptation [3].

Conventional syringe irrigation has limited penetration and may be insufficient in anatomically complex regions, particularly in the apical third [4]. For this reason, adjunctive methods such as laser-assisted irrigation and disinfection have gained attention. Laser irradiation has been shown to improve microbial reduction and modify dentin by removing or altering the smear layer, opening dentinal tubules, and increasing surface roughness, thereby potentially influencing the adhesion of root canal sealers [4-6].

Diode lasers are widely used in endodontics because they are compact, easy to handle, and capable of penetrating dentinal tubules with effective antibacterial action [5,6]. Previous studies have shown that 980 nm diode laser irradiation may enhance the bond strength of certain sealers, particularly epoxy resin-based materials, by modifying the intraradicular dentin surface [6]. A recent systematic review also reported that laser treatment tends to improve the bond strength of epoxy resin-based sealers, while its effect on calcium silicate-based or bioactive sealers is less consistent [7].

Among currently available sealers, AH Plus is one of the most commonly used epoxy resin-based materials and is often regarded as a reference standard because of its dimensional stability, low solubility, flow, and strong adhesion to dentin [8,9]. Its bonding is attributed to both micromechanical interlocking and chemical interaction between epoxide rings and amino groups within dentinal collagen [9]. In contrast, bioactive glass-based sealers are designed to release calcium and silicate ions and promote hydroxyapatite formation at the sealer-dentin interface [10,11]. Their bonding behaviour may therefore be more dependent on bioactivity and delayed mineralization than on immediate mechanical retention.

Nishika Canal Sealer BG is a bioactive glass-containing sealer developed for regenerative and endodontic applications. Bioactive glass-based materials have shown promising apatite-forming ability and favourable biological behaviour, but their immediate dislocation resistance after laser-assisted disinfection remains insufficiently explored [10-12]. Therefore, the present study aimed to evaluate and compare the dislocation resistance of epoxy resin-based and bioactive glass-based root canal sealers in the coronal, middle, and apical thirds following diode laser-assisted disinfection.

Materials and Methods

This in vitro study was carried out on forty-four extracted human mandibular premolars with single straight canals. Teeth with calcified canals, cracks, restorations, internal or external resorption, root caries, or anatomical variations were excluded. Decoronation was performed using a diamond disc under water cooling to obtain a standardized root length of 14 mm.

Working length was determined, and all canals were prepared using the ProTaper Universal rotary system up to F3. During instrumentation, 2.5% sodium hypochlorite was used as the irrigant. Final irrigation was performed with 5 mL sodium hypochlorite, followed by 3 mL of 17% EDTA and a final rinse with sodium hypochlorite and saline. The canals were then dried with paper points.

Diode laser irradiation was performed using a 980 nm laser with a 200 µm optical fiber. The output power was 2.4 W in pulsed mode. The fiber tip was introduced 1-2 mm short of the working length and moved from apical to coronal direction in a slow circular motion along the dentinal walls. Each irradiation cycle consisted of 20 seconds of activation followed by a 10-second pause, and the cycle was repeated three times. The laser parameters were selected in accordance with earlier studies investigating diode laser effects on intraradicular dentin and bond strength [6,13].

The samples were randomly allocated into two groups (n = 22): Group 1, epoxy resin-based sealer (AH Plus); and Group 2, bioactive glass-based sealer (Nishika Canal Sealer BG). In both groups, obturation was completed using a single-cone gutta-percha technique. Access openings were sealed with temporary restorative material, and the teeth were stored at 37°C and 100% humidity for one week to allow complete setting of the sealers.

After incubation, each root was sectioned perpendicular to its long axis to obtain 2 mm thick slices from the coronal, middle, and apical thirds. Push-out testing was performed using a universal testing machine at a crosshead speed of 0.5 mm/min. The load required to dislodge the root canal filling was recorded in Newtons and converted to MPa by dividing the force by the bonded surface area. Push-out testing is widely accepted as a reliable method for evaluating the dislocation resistance of endodontic sealers because it simulates stresses along the dentin-filling interface and provides reproducible quantitative data [14].

The collected data were analyzed statistically using two-way ANOVA followed by Tukey's post hoc test. A p-value of less than 0.05 was considered statistically significant.

Results

Table No. 1: Summary of Push-out bond strength (MPa) scores in two groups and three sections.

Factors	Levels of	n	Mean	SD	SE	95% CI for mean	
						Lower	Upper
Groups	Laser with AH Plus sealer	66	2.75	0.86	0.11	2.54	2.96
	Laser with Nishika Canal BG sealer	66	1.07	0.37	0.05	0.98	1.16
Sections	Coronal section	44	2.63	1.18	0.18	2.27	2.99
	Middle section	44	1.74	1.00	0.15	1.43	2.04
	Apical section	44	1.36	0.49	0.07	1.21	1.51
Interactions	Laser with AH Plus sealer with coronal	22	3.75	0.41	0.09	3.57	3.93
	Laser with AH Plus sealer with middle	22	2.69	0.35	0.08	2.54	2.85
	Laser with AH Plus sealer with apical	22	1.81	0.17	0.04	1.74	1.89
	Laser with Nishika Canal BG sealer with coronal	22	1.51	0.22	0.05	1.41	1.61
	Laser with Nishika Canal BG sealer with middle	22	0.78	0.08	0.02	0.75	0.82
	Laser with Nishika Canal BG sealer with apical	22	0.91	0.20	0.04	0.82	1.00

The descriptive evaluation of push out bond strength revealed significant difference between the two groups and among the three root canal levels after laser-assisted disinfection. The Epoxy Resin–based sealer (Laser with AH Plus) demonstrated greater mean push out bond strength compared with the Bioactive Glass–based sealer (Laser with Nishika Canal BG). The absence of overlap between the 95% confidence intervals of the two groups indicates that this difference was statistically significant.

When analysed according to root canal level, the coronal third demonstrated the highest bond strength value ranges, followed by the middle third, with the apical third showing the lowest values. This pattern reflects a gradual decrease in bond strength toward the apex. Interaction analysis further indicated that AH plus achieved maximum bond strength in the coronal third, whereas Nishika Canal BG displayed comparatively lower values across all levels, particularly in the middle and apical regions. The small standard error values and narrow confidence intervals indicate reliable and consistent measurements.

Table No. 2: Comparison of two groups and three sections with mean Push-out Bond Strength (MPa) scores by two-way ANOVA

Sources of variation	Sum of squares	Degrees of freedom	Mean sum of squares	F-value	p-value
Main effects					
Group	93.80	1	93.80	1351.8617	0.0001*
Section	37.47	2	18.74	270.0446	0.0001*
2-way interaction effects					
Group*Section	10.65	2	5.32	76.7312	0.0001*
Error	8.74	126	0.07		

Total	150.66	131			

*p<0.05 indicates significant difference between them

Two-way ANOVA demonstrated a statistically significant implication of root canal sealer type on push out bond strength, confirming that the type of sealer significantly influenced dislocation resistance irrespective of canal level. A significant main effect of root canal level was also observed, showing that bond strength varied among the coronal third, middle third, and apical third regardless of the material used. These results confirm that both factors independently and interactively affected bond strength.

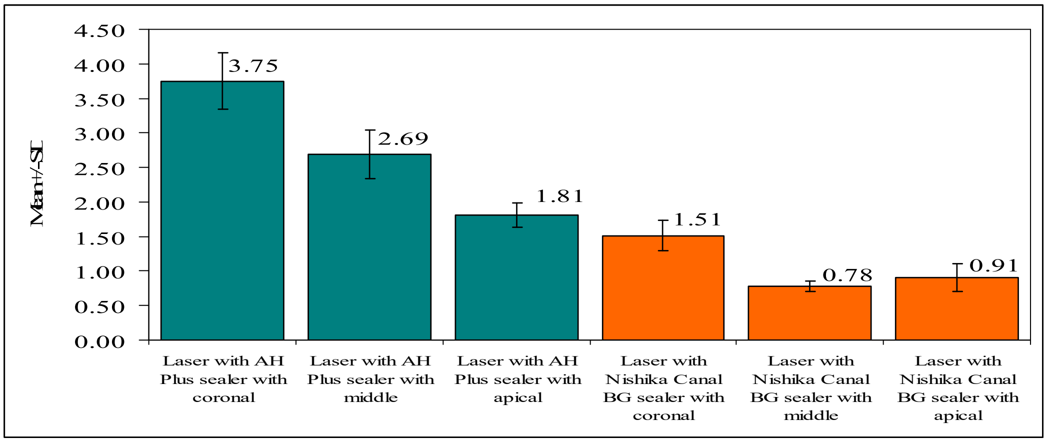
Table No. 3: Pair wise comparison of interactions two groups and three sections with mean Push-out Bond Strength (MPa) scores by Tukey's multiple posthoc procedures

Groups	Laser with AH Plus sealer with coronal	Laser with AH Plus sealer with middle	Laser with AH Plus sealer with apical	Laser with Nishika Canal BG sealer with coronal	Laser with Nishika Canal BG sealer with middle	Laser with Nishika Canal BG sealer with apical
Mean	3.75	2.69	1.81	1.51	0.78	0.91
SD	0.41	0.35	0.17	0.22	0.08	0.20
Laser with AH Plus sealer with coronal	-	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*
Laser with AH Plus sealer with middle	p=0.0001*	-	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*
Laser with AH Plus sealer with apical	p=0.0001*	p=0.0001*	-	P=0.0020*	p=0.0001*	p=0.0001*
Laser with Nishika Canal BG sealer with coronal	p=0.0001*	p=0.0001*	P=0.0020*	-	p=0.0001*	p=0.0001*
Laser with Nishika Canal BG sealer with middle	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*	-	P=0.6197
Laser with Nishika Canal BG sealer with apical	p=0.0001*	p=0.0001*	p=0.0001*	p=0.0001*	P=0.6197	-

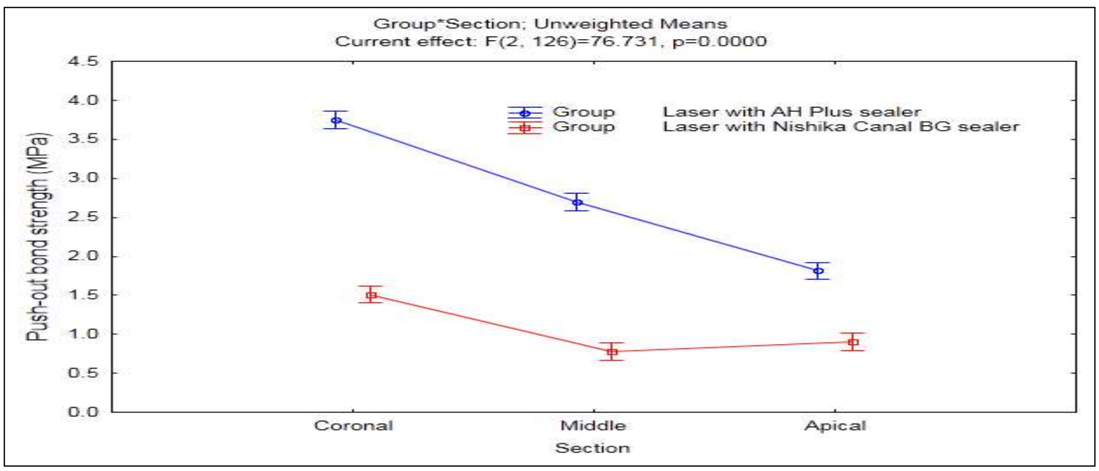
*p<0.05 indicates significant difference between them

Tukey's test revealed significant discrepancy among most group–level combinations. Within the AH plus group, the coronal third showed significantly greater bond strength than the middle and apical third, and the middle third exhibited significantly greater values than the apical third. In the Nishika Canal BG group, the coronal third had significantly greater bond strength than the middle and apical third; however, no significant difference was found between the middle and apical levels. Intergroup comparisons demonstrated that AH plus produced significantly higher bond strength than Nishika Canal BG at all three canal levels, indicating superior bonding performance of the Epoxy Resin–based sealer.

Graph No. 1: Comparison of interactions between two groups and three sections with mean Push-out Bond Strength (MPa) scores



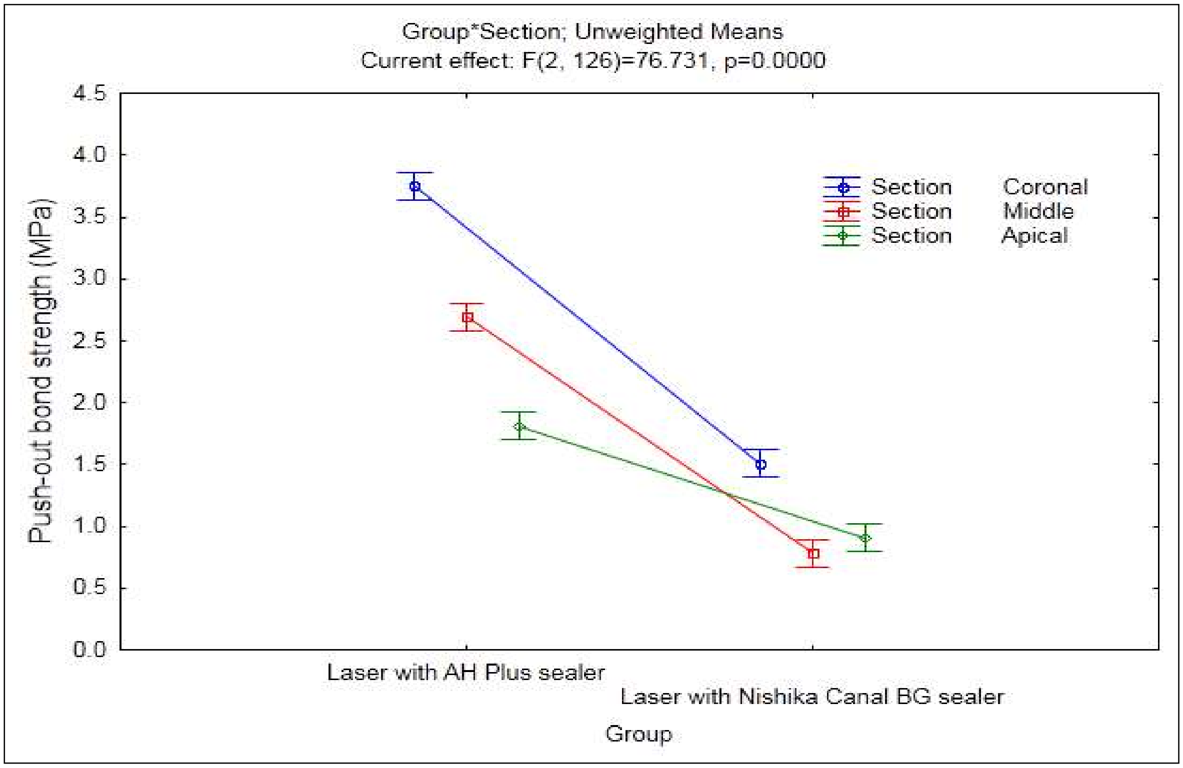
Graphical analysis of the interaction effect displayed non-parallel trends, supporting the presence of a significant interaction between sealer type and canal level. The Epoxy Resin–based sealer consistently yielded higher bond strength values across all sections, with a pronounced decline from coronal to apical regions. In contrast, the bioactive glass–based sealer showed generally lower values and less variation between the middle and apical thirds.



Graph No. 2: Section-wise Comparison of Mean Push-out Bond Strength (MPa) Between the Two Sealers

Section-wise graphical comparisons further illustrated consistently greater mean bond strength values for the Epoxy Resin–based sealer across the coronal, middle, and apical thirds. Both materials exhibited a decreasing trend in bond strength from coronal to apical regions; however, the separation between the two groups remained evident throughout.

Graph No. 3: Overall Comparison of Mean Push-out Bond Strength (MPa) Between the Two Experimental Groups



Overall graphical comparison confirmed a substantially higher mean push strength for the Epoxy Resin–based sealer following laser-assisted disinfection. This visual observation aligns with the statistically significant main effect of sealer type identified in the two-way ANOVA, reaffirming the superior overall dislocation resistance of the Epoxy Resin–based sealer.

Discussion

The present study evaluated the immediate dislocation resistance of two different categories of root canal sealer following diode laser-assisted disinfection. The findings showed that AH Plus had significantly greater push-out bond strength than Nishika Canal Sealer BG at all root levels. These results are in agreement with earlier studies showing that epoxy resin-based sealers often exhibit stronger immediate adhesion to root dentin than bioactive or calcium silicate-based materials [7-9,13].

The superior performance of AH Plus may be explained by its established bonding mechanism. Epoxy resin-based sealers adapt well to root dentin because of their flow, dimensional stability, and ability to form both micromechanical and chemical bonds with collagen-rich dentin [8,9]. Diode laser irradiation may further enhance this interaction by modifying the smear layer and exposing dentinal tubules, thus increasing surface roughness and mechanical interlocking [5,6,13]. Alfredo et al. reported that 980 nm diode laser irradiation increased the bond strength of AH Plus to root dentin, supporting the present findings [6].

In contrast, the bioactive glass-based sealer showed lower immediate bond strength. This may be related to its different mode of adhesion. Bioactive glass materials depend on ion release and subsequent surface mineralization, resulting in hydroxyapatite formation over time rather than instant chemical bonding [10-12]. Washio et al. described bioactive glass-based endodontic sealers as promising materials because of their apatite-forming ability and bioactivity, but such benefits may not be fully reflected in immediate push-out testing [10]. Huang et al. also demonstrated favourable bioactive behaviour and dentinal tubule penetration of a bioactive glass-based sealer, yet immediate mechanical performance may still remain lower than that of resin sealers [12].

Another notable finding was the progressive reduction in bond strength from coronal to apical thirds. This pattern has been reported frequently in endodontic bond strength studies and may be explained by anatomical differences in dentin structure and irrigant penetration [15,16]. Dentinal tubule density and branching are greater in coronal dentin and decrease toward the apex, which directly affects sealer penetration and retention [15]. In addition, dentin permeability is influenced by tubule number and diameter, both of which are more favourable coronally than apically [16]. Narrower apical anatomy also limits irrigant exchange and laser distribution, reducing dentin modification in this region [4,17].

The present findings are also supported by studies showing that laser activation can improve smear layer removal, sealer penetration, and push-out bond strength compared with conventional needle irrigation [17]. Abdelgawad et al. found that both diode and Er: YAG laser activation improved irrigant penetration and bonding properties compared with side-vented needle irrigation [17]. Likewise, Bago et al. observed improved dislocation resistance of a bioceramic sealer following diode laser disinfection, although epoxy resin-based materials generally still demonstrate stronger immediate adhesion [18].

Despite its lower push-out bond strength, the bioactive glass-based sealer should not be considered clinically inferior on this parameter alone. Push-out testing measures resistance to displacement under immediate laboratory conditions and does not fully reflect long-term biological integration, ion release, or mineral deposition. Bioactive sealers may offer additional benefits such as alkaline pH, antibacterial potential, and support for periapical healing [10-12]. These properties may become more relevant over time and warrant further investigation.

This study has the limitations typical of an in vitro design. Thermocycling, long-term aging, simulated body fluid storage, and functional fatigue loading were not included. Only one laser wavelength and one set of irradiation parameters were tested. Future studies should assess whether the time-dependent mineralization of bioactive glass sealers improves their interfacial strength after aging and whether such changes alter their comparative performance against epoxy resin-based sealers.

Conclusion

Within the limitations of this in vitro study, the epoxy resin-based sealer demonstrated significantly higher dislocation resistance than the bioactive glass-based sealer following diode laser-assisted root canal disinfection. Bond strength was highest in the coronal third and lowest in the apical third for both materials. These findings suggest that, under immediate testing conditions, AH Plus provides superior mechanical adhesion to laser-modified dentin. However, the long-term bioactive potential of glass-based sealers requires further study before definitive clinical conclusions can be drawn.

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