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Pushout bond strength evaluation of bioceramic sealer versus epoxy resin based sealer- An *in-vitro* study

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Abstract

Aim: To compare the push out bond strength of BioRoot RCS and Adseal using universal testing machine.

Methods and Material: After decoronating 30 extracted single-rooted teeth were decoronated, Instrumentation was done upto F3 file (universal protaper, Dentsply). The teeth were divided into three groups (n=10) based upon the sealer used. Group A: Epoxy resin based sealer (Adseal), Group B: Bioceramic sealer (BioRoot RCS), and Group C: zinc oxide eugenol (ZOE) based sealer (Root canal sealer, DPI, India). Manipulation and application of the sealer was done as per the manufacturer instructions. All the teeth were obturated using F3 gutta-percha (Dentsply- Maillefer, Ballaigues, Switzerland). After obturation, each tooth was prepared with root sections of 2 mm thickness at middle 1/3 and apical 1/3 for testing push out bond strength using universal testing machine. Data were analyzed using two-way ANOVA and multiple *post hoc* tests.

Results: The highest bond strength was found in BioRoot RCS followed Adseal and the lowest bond strength was found in ZOE based sealer.

Conclusions: Bioceramic sealer exhibit higher bond strengths when compared with resin-based sealer and in ZOE-based sealer.

Keywords: Adseal, BioRoot RCS, Push out bond strength, ZOE based sealer

Introduction

The primary focus in managing an infected root canal space involves thorough chemomechanical preparation followed by three-dimensional obturation using a biocompatible material. [1] Ensuring a strong bond between the sealer and the root canal wall or core material is crucial for the success of root canal treatment. Push-out bond strength serves as a valuable prognostic indicator for assessing this bond, thus minimizing the risk of dislodgement during mechanical stresses. Effective adhesion to dentin is essential for preventing bacterial leakage and ensuring endodontic success. [2]

Bioceramic sealers, have been recently introduced and exhibit exceptional biocompatibility resembling biological materials such as hydroxyapatite (HA). [3] The rationale behind assessing the bond between calcium silicate-based cement and dentin is rooted in both micro-mechanical interactions, such as the formation of tag-like structures, and chemical interactions at the interfacial dentin, which ultimately lead to the deposition of hydroxyapatite (HA), thus forming a stable bond.

The null hypothesis posits no significant difference in push-out bond strength among epoxy resin-based, calcium hydroxide-based, bioceramic, and zinc oxide-eugenol (ZOE) based sealers.

Materials and Methods

Sample Preparation

Thirty intact human single-rooted teeth were freshly extracted from the Department of Oral and Maxillofacial Surgery. Only teeth with single canals confirmed by radiographs, devoid of root caries, possessing well-developed and intact roots with closed apices were included. Excluded were multi-rooted teeth, those with immature apex, root resorption, fracture lines, endodontic fillings, instrumented canals, or calcified canals. The selected teeth were cleaned with an ultrasonic scaler to eliminate calculus and stain, followed by immersion in a 2.5% sodium hypochlorite (NaOCl) solution for 24 hours to remove tissue debris. They were then stored in distilled water until further use. [4, 5] The teeth were decoronated using a diamond disc mounted in a straight handpiece under constant water cooling. [6]

Root Canal Preparation: Maintaining apical patency, root canals were initially negotiated with a no. 10 K hand file, followed by creating a glide path using manual instrumentation with 10, 15, and 20 K-files (Mani. Inc). The working length was established by subtracting 1mm from the total root length, which had a mean of 12.00 ± 0.2mm. Crown-down technique was employed for canal preparation using the ProTaper Universal system (Dentsply-Maillefer, Ballaigues, Switzerland) incrementally up to size F3 at the working length. [3] Canals were irrigated successively with 2ml 3% Sodium Hypochlorite for 1 minute, 2ml 17% EDTA for 3 minutes, and 2ml Normal Saline.

Sealer Placement and Obturation

Following biomechanical preparation, the samples (n=30) were randomly assigned to three experimental groups of n=10 each based on the sealer used

Group A: Epoxy resin-based sealer (Adseal, Meta Biomed Co, Cheongju, Korea)

Group B: Bioceramic sealer (BioRoot RCS, Septodont, Saint-Maur-des-Fosses, France)

Group C (Control group): ZOE-based sealer (Root canal sealer, DPI, India)
All sealers were mixed per manufacturer instructions and placed in the canals with a lentulo spiral. Root canal obturation was carried out using the single-cone technique with F3 gutta-percha (Universal Proper, Dentsply), compacted 1mm below the canal orifice. Teeth were sealed with temporary cement barrier Cavit G (3M ESPE, Seefeld, Germany). [3, 6]

Push-Out Bond Strength Measurement
The tooth roots were kept moist with gauze soaked in sterile saline solution and incubated at 37°C with 100% humidity for 7 days. Subsequently, all specimens were embedded in acrylic blocks and horizontally sectioned into approximately 2-mm thick slices at the middle 1/3rd (7mm from apex) and apical 1/3rd (2mm from apex) using a diamond disc. Sections were labeled as middle or apical for identification. The thickness of each slice was measured using a Vernier caliper. Push-out bond strength testing was conducted using a universal testing machine (INSTRON-8801, Norwood, MA, USA). A cylindrical stainless-steel plunger with diameters of 0.6mm and 0.3mm was used for middle and apical thirds, respectively. Loading was applied apically to coronally at 0.5mm/min until debonding occurred, and the bond strength was recorded. [5, 7]

Calculation of Bond Strength: The area under load was calculated using the formula: Area = $2\pi r \times h$, where π is the constant 3.14, r is the root canal space radius, and h is the slice thickness in mm. The bond strength (δ) in MPa was calculated as force (N) divided by the area in mm². [8]

Statistical Analysis
The push-out bond strength of three different sealers was analyzed at the middle and apical thirds. A two-way ANOVA followed by Post Hoc Multiple Comparisons test was conducted to compare the three groups. All statistical tests were two-sided, with significance set at p=0.05. IBM SPSS Statistics (version 22.0) was utilized for statistical analysis.

Results
The data presented in Table 1 show the mean and standard deviation of push-out bond strength values (in MPa) for the three tested sealers at the middle and apical thirds. Analysis revealed a significant difference in mean values between the bioceramic sealer and the ZOE-based root canal sealer ($p>0.05$). Moreover, no significant difference ($p>0.05$) was observed between Group A (epoxy resin-based sealer) and Group B (bioceramic sealer), whereas significant differences were noted between Group A - Group C and Group B - Group C ($p<0.05$). Notably, Group B demonstrated higher push-out bond strength than the other groups at both the middle and apical thirds.

Table 1

Group		Middle 1/3	Apical 1/3	p- value
Group A	Mean	2.05	3.56	0.024
	SD	0.48	1.81	
Group B	Mean	2.63	4.21	0.002
	SD	1.18	1.01	
Group C	Mean	1.01	1.73	0.042
	SD	0.40	0.74	

Mean and standard deviation of push-out strength values (MPa) within the middle, and apical thirds for each group.

The mean difference is significant at p< 0.05 level.

Discussion
The selection of endodontic sealers is critical in clinical practice to ensure favourable outcomes, considering both their composition and properties. [9] Both methacrylate-based and bioceramic sealers are known for their ability to adhere well to the dentinal surface. [10]
This study aimed to compare the push-out bond strength of various root canal sealers, including bioceramic, resin-based, and ZOE-based sealers, to evaluate their bonding capabilities.
The bond between the root canal sealer and gutta-percha is essential for resisting dislodgement, with chemical bonding to root dentin contributing to the required push-out strength. Enhanced bond strength to root dentin may improve the sealer's resistance to disruption through micromechanical retention or friction. [8] Neelankantan *et al.* demonstrated an inverse correlation between microleakage and bond strength, emphasizing the importance of assessing bond strength in evaluating sealing ability. [11]
In this study, three root canal sealers were tested for push-out bond strength using obturation techniques aligned with manufacturers' instructions and common clinical practices to ensure optimal results across all material types. While warm vertical compaction is typically preferred over the single-cone technique, it was not suitable for the bioceramic sealers in this study due to potential alterations in their adhesion properties with heat, which could affect the results. [12]
An important parameter identified is the plugger diameter-specimen diameter ratio. Studies have shown that ratios between 70% to 90% do not significantly affect bond strength, whereas ratios below 55% result in lower values. [13] In our study, pluggers of different diameters were used to closely match the root filling material's diameter for each sample. [10]
The resistance to dislodgement of root canal filling materials was assessed using the push-out test, which provides uniform shear strength within the root canal. [14] Dislodgement can occur due to adhesive failure, where the bond to dentin breaks, or cohesive failure, where the filling material suffers internal fractures. [10]
Consistent with previous findings associating higher bond strength with lower dentinal tubule density in the apical area, our study found consistently higher push-out bond strength in the apical third compared to the middle third. [6]
Among the sealers tested, BioRoot RCS exhibited the highest bond strength, significantly outperforming the others. This may be attributed to its true self-adhesive nature, forming a chemical bond with dentin through

hydroxyapatite production during setting. The alkaline caustic etching process likely facilitates mineral infiltration into dentin, reducing space formation in the canal compared to epoxy resin-based sealers. [10]

Bioceramic sealers' hydrophilic nature and low contact angle facilitate easy spreading over canal walls, ensuring good adaptation and a fluid-tight seal. [15] They rely on moisture within dentinal tubules for proper setting. Through hydration, silicates within these sealers produce hydrated calcium silicate gel and calcium hydroxide, which subsequently react with phosphate ions, yielding hydroxyapatite (HA) and water. As the remaining calcium silicates react further with water, HA precipitates. The bioactivity of these sealers lies in their ability to generate an HA layer upon contact with tissue fluid, thereby enhancing their biocompatibility, osteoconductive, osteoinductive, and sealing properties. [3] Christopher Delong's study also concluded higher bond strength for bioceramic sealers compared to MTA plus sealers when using a single-cone technique. [16]

Resin-based sealers are known for their high bond strength compared to others. Their flowability and long-term polymerization time enable deep dentinal tubule penetration, contributing to their superior performance. [17] Additionally, epoxy resin-based sealers, such as Adseal in our study, exhibited good bond strength comparable to BioRoot RCS, possibly due to their ability to form covalent bonds with collagen upon opening of the epoxide ring. [15,16]

Consistent with existing literature, ZOE-based sealers showed the lowest bond strength to dentin in our study. The findings underscore the importance of selecting the appropriate root canal sealer in clinical practice, with bioceramic sealers showing promise in enhancing resistance to disruption, potentially influencing long-term treatment success.

Limitations of this study include its lack of simulation of oral conditions and the absence of long-term testing of obturating material sealing ability.

Conclusion

Within the study's limitations, BioRoot RCS demonstrated higher push-out bond strength compared to resin-based sealers, though no significant difference was observed between the two. ZOE-based sealers exhibited the lowest strength values. Push-out bond strength was higher in the apical area compared to the middle area. Future investigations should explore sealing ability, the impact of different obturation techniques on bond strength, and the influence of root canal anatomy for comprehensive insights into endodontic treatment efficacy.

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