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Comparative Study on the Rheological Behavior and Adhesion of Calcium Hydroxide-Based Root Canal Sealers

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Abstract | **Original Research Article**

Background: Optimal flowability and adhesiveness are critical properties of root canal sealers to ensure effective sealing and prevention of microleakage. Calcium hydroxide-based sealers such as Calapex and Sealapex are widely used due to their biological and physicochemical properties. ***Aim:*** To evaluate and compare the flowability and adhesiveness (push-out bond strength to dentin) of two calcium hydroxide-based root canal sealers: Calapex (Prevest DenPro, India) and Sealapex (Kerr, USA). ***Materials and Methods:*** Forty extracted single-rooted human teeth were prepared and randomly divided into two groups (n=20). Group 1: Calapex; Group 2: Sealapex. Flowability was assessed using ISO 6876 standards. Adhesiveness was evaluated using push-out bond strength testing with a universal testing machine. Failure modes were analyzed under stereomicroscopy. Statistical analysis was performed using independent t-test ($p<0.05$). ***Results:*** Both sealers demonstrated flowability within ISO recommended limits, with no statistically significant difference between groups ($p>0.05$). Push-out bond strength values showed comparable adhesion to dentin in both groups, indicating clinically acceptable adhesion. Predominantly mixed failure patterns were observed. ***Conclusion:*** Both Calapex and Sealapex exhibited optimal flow and adequate adhesiveness to root dentin, supporting their clinical use as reliable calcium hydroxide-based sealers.

Keywords: Calcium hydroxide sealer, flowability, push-out bond strength, adhesiveness.

INTRODUCTION

Successful endodontic treatment relies on achieving a three-dimensional hermetic seal within the root canal system to prevent reinfection and ensure long-term success [1]. Root canal sealers play a crucial role in filling voids between gutta-percha and dentinal walls, thereby enhancing sealing ability and adaptation [2]. Calcium hydroxide-based sealers have been widely used due to their antimicrobial properties, high alkalinity and ability to stimulate hard tissue formation [3,4]. Among these, Sealapex(Kerr) has been extensively studied and is known for its biocompatibility and clinical reliability [5]. Recently, newer formulations such as Calapex(Prevest Denpro) have been introduced, claiming improved handling characteristics and physicochemical properties. Flowability is a critical parameter influencing the ability of sealers to penetrate accessory canals, dentinal tubules and irregularities within the root canal system [6]. According to ISO 6876 standards, sealers must demonstrate adequate flow (≥17 mm) to ensure optimal adaptation and sealing performance [7]. Several studies have confirmed that most contemporary sealers meet these ISO requirements [8,9]. Adhesiveness, commonly evaluated using push-out bond strength, reflects the ability of the sealer to adhere to dentin and resist dislodgement [10]. Higher bond strength contributes to improved sealing ability and resistance to leakage [11]. However, calcium hydroxide-based sealers generally exhibit moderate bond strength compared to resin-based materials, though still clinically acceptable [12]. Bond strength is influenced by multiple factors including dentin surface condition, moisture and chemical composition of the sealer [13]. Standardized methodologies such as push-out bond strength testing using universal testing machines have been widely adopted in recent studies [14]. Despite the availability of various sealers, there is limited comparative literature evaluating newer calcium hydroxide-based sealers like Calapex against established materials such as Sealapex in terms of flowability and adhesiveness. Therefore, the present study aimed to evaluate and compare the flowability and adhesiveness of Calapex and Sealapex.

MATERIALS AND METHODOLOGY

The present in vitro study was conducted in accordance with ethical standards for research involving

extracted human teeth. Ethical approval was obtained from the Institutional Ethics Committee (IEC) prior to commencement of the study (Approval No.: 8657/IEC/2025). Extracted teeth used in this study were collected following informed consent from patients for their use in research purposes. All samples were anonymized to ensure patient confidentiality. The study adhered to the principles outlined in the Declaration of Helsinki.This in vitro experimental study was conducted using forty freshly extracted human single-rooted teeth with straight canals and fully formed apices. Teeth with cracks, caries, resorption, or previous endodontic treatment were excluded. The samples were cleaned of soft tissue debris and stored in 0.1% thymol solution until use. The crowns were sectioned using a diamond disc under water cooling to standardize root length to 15 mm. Working length was established 1 mm short of the apical foramen. Biomechanical preparation was performed using ProTaper Gold rotary files up to size F2 with irrigation using 5.25% sodium hypochlorite. A final rinse with 17% EDTA for 1 minute was performed to remove the smear layer, followed by distilled water, and canals were dried using paper points. Samples were randomly allocated using a computer-generated randomization sequence (n = 20): Group 1—Calapex and Group 2—Sealapex. The sealers were mixed according to manufacturer instructions and introduced into the prepared root canals using a lentulo spiral to ensure uniform distribution. No gutta-percha was used to isolate the sealer–dentin interface. The specimens were stored at 37°C and 100% humidity for 7 days to allow complete setting. After setting, each root was sectioned perpendicular to its long axis using a precision diamond saw under water cooling to obtain 2 mm thick slices from the middle third of the root. The thickness of each slice was measured using a digital caliper. Push-out bond strength testing was performed using a universal testing machine. Each specimen was positioned such that the load was applied from the apical side toward the coronal direction using a cylindrical plunger slightly smaller than the canal diameter to avoid contact with dentin. Load was applied at a crosshead speed of 1 mm/min until bond failure occurred. The maximum load at failure was recorded in Newtons (N).

The push-out bond strength (MPa) was calculated using the formula:

$$\text{Bond Strength (MPa)} = \frac{F}{A}$$

Where:
F = Force at dislodgement (N)
A = Bonded surface area (mm²)
The bonded surface area was calculated using the formula for a truncated cone:

$$A = \pi(R + r)\sqrt{(R - r)^2 + h^2}$$

Where:
R = Coronal radius (mm)
r = Apical radius (mm)
h = Thickness of the specimen (mm)

Each measurement was repeated three times and the mean value was considered for analysis. Failure modes were evaluated under a stereomicroscope at ×20 magnification and classified as adhesive, cohesive, or mixed. Adhesive failure: occurring at the sealer–dentin interface, Cohesive failure: occurring within the sealer material, Mixed failure: involving a combination of adhesive and cohesive failure. Statistical analysis was performed using IBM SPSS Statistics software (version 27, IBM Corp., Armonk, NY, USA). The normality of data distribution was assessed using the Shapiro–Wilk test. Intergroup comparisons were carried out using the independent t-test. A p-value of less than 0.05 was considered statistically significant.

Flowability was evaluated according to ISO 6876:2012 specifications. A volume of 0.05 mL of freshly mixed sealer was placed at the center of a glass slab and covered with another glass slab. A total load of 100 g was applied vertically. After 10 minutes from the start of mixing, the compressed disc of sealer was measured using a digital vernier caliper. The maximum (D1) and minimum (D2) diameters were recorded, and the mean diameter was calculated as:

$$\text{Flow (mm)} = \frac{D1 + D2}{2}$$

RESULTS

The flowability and push-out bond strength of the two-calcium hydroxide-based root canal sealers were evaluated and are presented in Table 1. Flowability was assessed according to ISO 6876:2012 standards by measuring the diameters of the compressed sealer discs. The mean flow values obtained for Calapex and Sealapex were 20.8 ± 0.9 mm and 21.1 ± 1.0 mm, respectively. Both materials demonstrated flow values exceeding the minimum requirement of 17 mm as specified by ISO standards, indicating adequate flow characteristics. Statistical analysis using the independent t-test revealed no significant difference between the two groups (p = 0.42). Push-out bond strength was evaluated by applying compressive load until dislodgement of the sealer from dentin slices. The mean push-out bond strength values were 5.6 ± 0.7 MPa for Calapex and 5.8 ± 0.8 MPa for Sealapex. Although Sealapex demonstrated slightly higher values, the difference between the groups was not statistically significant (p = 0.36), indicating comparable adhesion to root dentin. Failure mode analysis revealed a predominance of mixed failures in both groups (65% in Calapex and 70% in Sealapex), followed by adhesive and minimal cohesive failures. Overall, both materials exhibited comparable flowability and push-out bond strength, with no statistically significant differences between them.

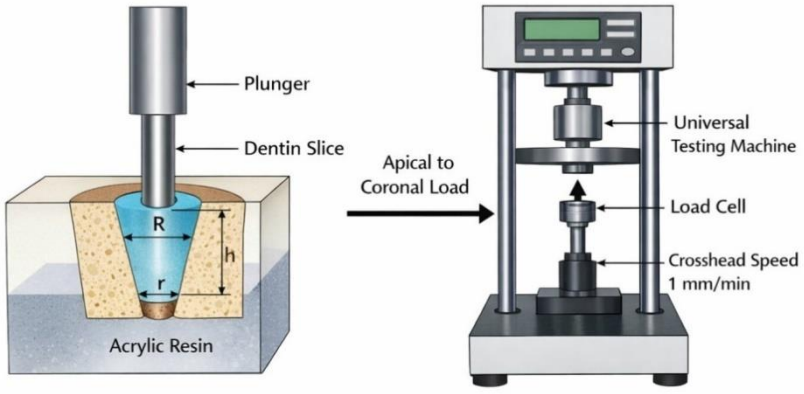

Figure 1. Schematic diagram of the push-out bond strength test. The root canal sealer-filled dentin slice is subjected to apical to coronal load using a universal testing machine.

Table 1. Comparative Evaluation of Flowability and Push-out Bond Strength

Parameter	Group	Mean	Standard Deviation (SD)	p-value	Statistical Significance
Flowability (mm)	Calapex	20.8	0.9	0.42	Not Significant
	Sealapex	21.1	1.0		
Push-out Bond Strength (MPa)	Calapex	5.6	0.7	0.36	Not Significant
	Sealapex	5.8	0.8		

DISCUSSION

The present in vitro study evaluated two critical physicochemical properties of calcium hydroxide-based root canal sealers- flowability and push-out bond strength which are directly associated with the sealing ability and long-term success of endodontic treatment. A hermetic seal is essential to prevent reinfection and entomb residual microorganisms within the root canal system [1,2]. Flowbility plays a vital role in enabling sealers to penetrate dentinal tubules, accessory canals, and anatomical irregularities. According to ISO 6876:2012 standards, a minimum flow of 17 mm is required for clinical acceptability. In the present study, both Calapex and Sealapex demonstrated flow values exceeding this threshold, indicating adequate rheological behaviour. These findings are consistent with recent studies reporting that most contemporary sealers meet ISO flow requirements and exhibit favourable handling properties [3,4]. The absence of a statistically significant difference between the groups suggests comparable viscosity and particle distribution, which are known to influence flow characteristics [5]. Push-out bond strength is a widely accepted method to evaluate the adhesion of sealers to radicular dentin, as it simulates dislodging forces acting along the sealer–dentin interface. In the present study, both sealers demonstrated comparable bond strength values with no statistically significant difference. This observation is in agreement with several recent studies that reported similar bond strength among different calcium hydroxide and bioceramic sealers when standardized methodologies were employed. The obtained bond strength values fall within the range reported in the literature for calcium hydroxide-based sealers, which generally exhibit moderate adhesion compared to resin-based sealers. Previous investigations have demonstrated that epoxy resin-based sealers tend to show superior bond strength due to their chemical bonding ability, whereas calcium hydroxide-based sealers rely primarily on micromechanical interlocking. Despite this limitation, their bond strength remains clinically acceptable and sufficient to resist dislodgement forces [6,7]. Several

factors influence push-out bond strength, including dentin surface treatment, irrigation protocol, moisture condition and obturation technique. In the present study, the use of sodium hypochlorite followed by EDTA ensured effective smear layer removal, which enhances sealer penetration and bonding. This is supported by studies demonstrating that final irrigation protocols significantly affect bond strength values. Additionally, canal drying techniques have also been shown to influence adhesion, with optimal moisture conditions improving bonding performance. Another important observation in the present study was the predominance of mixed failure modes. Mixed failures indicate that both adhesive and cohesive forces contribute to bond failure, suggesting a balanced interaction between the sealer and dentin. Similar failure patterns have been reported in contemporary studies evaluating endodontic sealers, further validating the reliability of the present findings. It is also noteworthy that bond strength values may vary across different regions of the root canal, with higher values often reported in the apical third due to better adaptation and compaction of the material. Furthermore, obturation techniques and timing of procedures can influence the final adhesion of sealers, as demonstrated in recent investigations. Although newer bioceramic sealers have gained popularity due to their bioactivity and ability to chemically bond with dentin, calcium hydroxide-based sealers continue to be widely used due to their antimicrobial properties, high alkalinity and long-standing clinical success [8–10]. Recent studies have also shown that modifications in sealer composition, such as nanoparticle incorporation can enhance properties without compromising bond strength.The findings of the present study are in agreement with multiple recent investigations that reported no statistically significant differences in bond strength among different sealer types when tested under standardized conditions. This suggests that, despite material differences, proper clinical technique plays a more critical role in achieving successful outcomes. However, certain limitations must be considered. Being an in vitro study, the experimental conditions do not fully replicate the oral environment, where factors such as thermal cycling, occlusal forces and biological interactions may influence material behaviour. Additionally, the absence of gutta-percha in the testing model isolates the sealer–dentin interface and may not completely reflect clinical obturation conditions. Future studies incorporating thermomechanical aging and long-term clinical evaluation are recommended.

CONCLUSION

Within the limitations of the present in vitro study, both calcium hydroxide-based root canal sealers-Calapex and Sealapex demonstrated optimal flowability in accordance with ISO standards and exhibited comparable push out bond strength to root dentin, indicating satisfactory clinical adhesion. No statistically significant difference was observed between the two materials in terms of flowability or bond strength, suggesting similar clinical performance. The predominance of mixed failure modes further supports the presence of a balanced adhesive interaction between the sealers and dentin. Therefore, both Calapex and Sealapex can be considered reliable root canal sealers with adequate physicochemical properties and acceptable adhesive behavior, suitable for clinical use. However, further long-term in vivo studies are recommended to validate these findings under clinical conditions.

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