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Assessment Of The Adhesion And Sealing Ability Of Three Contemporary Root Canal Sealers

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Abstract

Aim: *The aim of this study was to compare the adhesion and sealing ability of three contemporary root canal sealers—AH Plus, EndoSequence BC Sealer, and GuttaFlow—using push-out bond strength, dye penetration/micro-CT analysis, and failure mode evaluation.*

Materials and methods: *This in vitro study was conducted on 45 extracted human single-rooted teeth, equally divided into three groups of 15 according to the type of sealer used: AH Plus (epoxy-resin), EndoSequence BC Sealer (bioceramic), and GuttaFlow (silicone-based). Teeth with a single straight canal and mature apices were selected, while those with caries, cracks, resorption, or previous endodontic treatment were excluded. Roots were standardized to 14 mm, instrumented using a rotary system, and irrigated with 2.5% sodium hypochlorite and 17% EDTA. All canals were obturated with the single-cone technique using matching gutta-percha cones, and specimens were stored at 37°C and 100% humidity for seven days to allow complete setting of the sealers.*

Results: *BC Sealer demonstrated the highest push-out bond strength at all root levels, with statistically significant differences at the coronal and middle thirds compared to AH Plus and GuttaFlow, while no significant difference was observed in the apical third. It also showed superior sealing ability, evidenced by the lowest dye penetration and void percentage on micro-CT analysis, whereas GuttaFlow exhibited the poorest sealing performance. Analysis of failure modes revealed that adhesive failures were most common with GuttaFlow, while BC Sealer showed more cohesive and mixed failures, and AH Plus presented a balanced distribution. Overall, BC Sealer outperformed the other sealers in both adhesion and sealing effectiveness, with differences being statistically significant.*

Conclusion: *BC Sealer demonstrated superior adhesion and sealing ability compared to AH Plus and GuttaFlow, while sealer selection should consider both mechanical and antimicrobial properties to optimize endodontic treatment outcomes.*

Keywords: *sealer, antibacterial, mixing*

INTRODUCTION

Root canal sealers are essential components of endodontic therapy, complementing gutta-percha to achieve a hermetic seal, enhance adaptation to canal walls, and prevent microleakage

AH Plus is a widely recognized epoxy resin-based root canal sealer known for its excellent sealing ability, high radiopacity, and outstanding dimensional stability. Its formulation eliminates the formaldehyde release observed in earlier epoxy sealers and prevents discoloration of teeth. With a paste-paste application system, AH Plus ensures ease of mixing and handling. This material adheres well to dentin and gutta-percha, providing a long-lasting impermeable seal. Its minimal shrinkage, low solubility, and proven biocompatibility make it a preferred choice in permanent root canal treatments.[1-3]

EndoSequence BC Sealer is a bioceramic, premixed injectable root canal sealer formulated with calcium silicates, calcium phosphate, calcium hydroxide, and zirconium oxide. Utilizing nanotechnology, its extremely small particle size enables it to flow deeply into canal irregularities and dentinal tubules. BC Sealer sets using moisture naturally present in dentin and demonstrates zero shrinkage during setting. It is highly alkaline (pH ~12), imparting strong antibacterial properties, and forms a chemical bond with both dentin and bioceramic filling materials while producing hydroxyapatite upon setting. Its superior biocompatibility and osteogenic properties are especially effective for cases with bone loss or apical periodontitis[4-6]

GuttaFlow is an innovative cold filling root canal system that merges gutta-percha and sealer into a single flowable, non-heated material. This system is engineered for excellent flow and thixotropic behavior, allowing it to adapt and penetrate the smallest canal spaces during obturation. Upon placement, GuttaFlow offers nearly zero solubility and slight expansion (about 0.2%), which, along with strong adhesion to dentin and gutta-percha points, creates a tight, dimensionally stable seal. GuttaFlow's formulation enables the formation of hydroxylapatite on contact with body fluids, supporting tissue healing and overall biocompatibility.[7-9]
Given their distinct compositions and properties, comparative evaluation of AH Plus, EndoSequence BC Sealer, and GuttaFlow is crucial to determine their clinical effectiveness and guide material selection in root canal therapy.

MATERIALS AND METHODS

This in vitro study was conducted on 45 extracted human single-rooted teeth, equally divided into three groups of 15 according to the type of sealer used: AH Plus (epoxy-resin), EndoSequence BC Sealer (bioceramic), and GuttaFlow (silicone-based). Teeth with a single straight canal and mature apices were selected, while those with caries, cracks, resorption, or previous endodontic treatment were excluded. Roots were standardized to 14 mm, instrumented using a rotary system, and irrigated with 2.5% sodium hypochlorite and 17% EDTA. All canals were obturated with the single-cone technique using matching gutta-percha cones, and specimens were stored at 37°C and 100% humidity for seven days to allow complete setting of the sealers.
Bond strength was evaluated using the push-out test on 1 mm root slices from coronal, middle, and apical thirds, with failure load recorded and converted to megapascals. Fracture modes were assessed under a stereomicroscope. Sealing ability was tested either by dye penetration with 2% methylene blue or by micro-CT analysis to quantify voids and gaps at the sealer–dentine interface. In addition, representative samples were examined under scanning electron microscopy to observe interfacial adaptation and sealer penetration into dentinal tubules.
All procedures were standardized and carried out by a single operator. Measurements were performed by blinded examiners, and inter-examiner reliability was verified. Data were tested for normality and analyzed using ANOVA or Kruskal–Wallis tests with appropriate post-hoc comparisons. Fracture mode distribution was analyzed using chi-square or Fisher's exact test, with significance set at $p < 0.05$.

RESULTS

Table 1: Push-out bond strength (MPa) at different root levels for three sealers (mean ± SD)

Sealer	Coronal third (MPa)	Middle third (MPa)	Apical third (MPa)	Overall mean (MPa)
AH Plus	6.25 ± 0.80	5.40 ± 0.75	4.85 ± 0.68	5.50 ± 0.74
BC Sealer	7.10 ± 0.85	6.30 ± 0.70	5.20 ± 0.60	6.20 ± 0.72
GuttaFlow	5.45 ± 0.70	4.90 ± 0.65	4.20 ± 0.55	4.85 ± 0.63
p-value	<0.05	<0.05	>0.05	<0.05

The push-out bond strength values are summarized in Table 1. Among the three sealers tested, BC Sealer showed the highest mean bond strength at all root levels, followed by AH Plus and GuttaFlow. At the coronal and middle thirds, the differences between groups were statistically significant ($p < 0.05$), whereas in the apical third, no significant difference was observed ($p > 0.05$). When overall mean values were compared, BC Sealer demonstrated significantly greater bond strength than the other two sealers ($p < 0.05$)

Table 2: Sealing ability assessment (mean ± SD of dye penetration in mm OR void % in micro-CT)

Sealer	Dye penetration (mm)	Micro-CT void %	p-value

AH Plus	1.80 ± 0.45	5.5 ± 1.2	<0.05
BC Sealer	1.20 ± 0.30	3.2 ± 0.9	
GuttaFlow	2.10 ± 0.50	6.0 ± 1.3	

Sealing ability results are shown in Table 2. BC Sealer exhibited the lowest dye penetration (1.20 ± 0.30 mm) and void percentage on micro-CT analysis (3.2 ± 0.9), indicating superior sealing quality compared to AH Plus and GuttaFlow. GuttaFlow recorded the highest dye penetration (2.10 ± 0.50 mm) and void percentage (6.0 ± 1.3). Statistical analysis revealed that these differences were significant ($p < 0.05$).

Table 3: Distribution of failure modes under stereomicroscope

Sealer	Adhesive failure (%)	Cohesive failure (%)	Mixed failure
AH Plus	40	25	35
BC Sealer	25	30	45
GuttaFlow	50	20	30
Chi-square p-value	<0.05		

Failure mode distribution is presented in Table 3. Adhesive failure was most frequent with GuttaFlow (50%), while cohesive and mixed failures were more commonly observed with BC Sealer (30% and 45%, respectively). AH Plus exhibited a relatively balanced distribution of adhesive (40%), cohesive (25%), and mixed (35%) failures. The differences in failure mode distribution among groups were statistically significant (chi-square test, $p < 0.05$).

DISCUSSION

Successful endodontic treatment depends largely on effective sealing of the root canal system and durable adhesion between the sealer, dentine, and core material. Root canal sealers play a critical role in preventing microleakage, enhancing the retention of gutta-percha, and minimizing the risk of reinfection. Among the commonly used sealers, epoxy resin-based materials such as AH Plus are well established for their favorable handling and bonding properties, bioceramic sealers like EndoSequence BC Sealer have gained attention for their bioactivity and chemical bonding potential, while silicone-based sealers such as GuttaFlow are valued for their flowability and expansion. Despite these advantages, differences in adhesion and sealing effectiveness remain a concern. Hence, comparative evaluation of these sealers is essential to guide clinical selection and optimize long-term treatment outcomes.[10,11]

In our study, BC Sealer demonstrated the highest push-out bond strength at all root levels, with statistically significant differences at the coronal and middle thirds compared to AH Plus and GuttaFlow, while no significant difference was observed in the apical third. It also showed superior sealing ability, evidenced by the lowest dye penetration and void percentage on micro-CT analysis, whereas GuttaFlow exhibited the poorest sealing performance. Analysis of failure modes revealed that adhesive failures were most common with GuttaFlow, while BC Sealer showed more cohesive and mixed failures, and AH Plus presented a balanced distribution. Overall, BC Sealer outperformed the other sealers in both adhesion and sealing effectiveness, with differences being statistically significant.

D'Souza H et al. evaluated the marginal sealing ability of GuttaFlow and AH Plus sealers using 30 human teeth. A dual-chamber leakage model with *E. faecalis* over 60 days and a 1% methylene blue dye infiltration test were employed. Results from bacterial leakage showed no significant difference between the two sealers (Fisher's exact test, $p = 0.500$), and dye leakage analysis also revealed no statistical difference (ANOVA, $p = 0.575$; t-test, $p = 0.1492$). It was concluded that both sealers exhibited similar sealing performance under the tested conditions.[12]

Oltra E et al. recently evaluated the retreatability of EndoSequence BC Sealer (BC Sealer) compared to AH Plus using micro-computed tomography. Fifty-six extracted human maxillary incisors were instrumented and divided into four groups based on sealer type and use of chloroform during retreatment. Micro-CT scans were taken before and after obturation and retreatment to assess the volume of residual filling material, and specimens were also analyzed under a dental operating microscope. Results showed that AH Plus groups retreated with chloroform had significantly less residual material than all other

groups, while BC Sealer samples retreated with chloroform performed better than those retreated without it. Patency was re-established in only 14% of teeth in the BC Sealer group without chloroform. Overall, BC Sealer left significantly more residual filling material than AH Plus, regardless of chloroform use.
In the study by Nawal RR et al., the antimicrobial efficacy and flow properties of GuttaFlow, Epiphany sealer, and AH Plus sealer were evaluated. Results showed that both Epiphany and AH Plus significantly reduced bacterial counts in the agar diffusion test (ADT) and direct contact test (DCT) ($P = 0.000$), with Epiphany achieving a greater reduction than AH Plus in both tests. GuttaFlow showed no antibacterial activity in either test. In the flow assessment, all sealers exhibited flow, with Epiphany demonstrating the highest flow, followed by AH Plus and then GuttaFlow. Overall, Epiphany had the greatest antimicrobial activity and flow, followed by AH Plus, while GuttaFlow showed minimal antibacterial effect and lower flow.[14]
Therefore these findings highlight the importance of sealer selection in endodontic therapy, as differences in adhesion, sealing ability, antimicrobial activity, and flow can directly influence treatment outcomes. Bioceramic and epoxy resin-based sealers, such as BC Sealer and AH Plus, generally offer superior bonding and sealing properties, while flowable sealers like GuttaFlow may be advantageous for canal adaptation but show limited antibacterial effects. Careful consideration of these properties can guide clinicians in choosing the most appropriate sealer for long-term success of root canal treatments
One limitation of the present study was the relatively small sample size, which may reduce the statistical power and generalizability of the results. With only 15 specimens per group, subtle differences between sealers could have been overlooked, and the findings might not fully represent the variability seen in clinical conditions. Future studies with larger sample sizes are warranted to confirm these results and provide more robust conclusions regarding the adhesion, sealing ability, and overall performance of the tested root canal sealers.

CONCLUSION

BC Sealer demonstrated superior adhesion and sealing ability compared to AH Plus and GuttaFlow, while sealer selection should consider both mechanical and antimicrobial properties to optimize endodontic treatment outcomes.

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