



Comparative Evaluation of Apical Microleakage of Endodontic Sealers Using Scanning Electron Microscopy: An Ex Vivo Study

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KEYWORDS

Apical microleakage; Endodontic sealers; GuttaFlow Bioseal; Scanning electron microscopy; Root canal obturation; Zinc oxide eugenol

ABSTRACT:

Introduction: Achieving a hermetic apical seal is a critical determinant of long-term success in endodontic therapy, as inadequate sealing permits microleakage and subsequent periapical pathology. Despite advances in obturation materials, complete sealing of the root canal system remains a challenge. Endodontic sealers play a vital role in filling irregularities and minimizing apical leakage. Therefore, evaluating the sealing ability of various commonly used sealers is essential for improving clinical outcomes.

Objective

The present ex vivo study aimed to comparatively evaluate the apical microleakage of four commonly used endodontic sealers using scanning electron microscopy (SEM).

Materials and Methods

Eighty freshly extracted human permanent mandibular first premolars with single straight canals were selected for the study. Standardized biomechanical preparation was performed for all specimens. The samples were randomly divided into four groups ($n = 20$) based on the sealer used: zinc oxide eugenol, calcium hydroxide-based sealer (Apexit), GuttaFlow 2, and GuttaFlow Bioseal. All canals were obturated using the lateral compaction technique, and the access cavities were sealed with glass ionomer cement. The external root surfaces were coated with nail varnish, leaving the apical 2 mm exposed, and the specimens were immersed in 1% methylene blue dye for 72 hours. After longitudinal sectioning, apical microleakage was evaluated under SEM at 500 \times magnification and measured in micrometers. Statistical analysis was performed using one-way ANOVA, Tukey's post hoc test, and Chi-square test.

Results

The results demonstrated statistically significant differences among the four groups ($p < 0.05$). GuttaFlow Bioseal exhibited the least apical microleakage, followed by GuttaFlow 2 and Apexit, whereas zinc oxide eugenol showed the highest microleakage values.

Conclusion

Within the limitations of the present study, bioceramic-based sealers demonstrated superior apical sealing ability compared to conventional sealers, suggesting their potential advantage in achieving a more effective apical seal in endodontic therapy.

1. Introduction

Successful endodontic treatment depends on effective cleaning, shaping, and three-dimensional obturation of the root canal system to prevent reinfection. Among

these steps, achieving an adequate apical seal is considered a key determinant of long-term clinical success, as failure to seal the apical region permits microleakage and subsequent periapical inflammation [1–4]. Microleakage allows the passage of



microorganisms, fluids, and toxins along the sealer–dentin interface and remains a major biological risk factor for post-treatment disease.

Root canal sealers play a crucial role in obturation by filling irregularities, accessory canals, and dentinal tubules that cannot be occupied by core obturating materials alone. Conventional sealers such as zinc oxide eugenol and calcium hydroxide–based sealers have been widely used because of their ease of handling and antimicrobial properties; however, concerns remain regarding their solubility, dimensional stability, and long-term sealing ability [5–8].

Recent advances in material science have led to the development of silicone-based and bioceramic sealers with improved physicochemical and biological properties. Materials such as GuttaFlow 2 exhibit enhanced flow and adaptability, while bioceramic-containing sealers like GuttaFlow Bioseal release calcium ions and promote hydroxyapatite formation, resulting in chemical bonding with dentin [9–13]. These properties may contribute to improved interfacial adaptation and reduced microleakage. Several experimental methods have been employed to evaluate apical sealing ability, including dye penetration, bacterial leakage, fluid filtration, and scanning electron microscopy (SEM). SEM provides high-resolution visualization of the sealer–dentin interface and allows direct assessment of adaptation, penetration, and interfacial gaps [14–17]. However, variations in methodology and material composition necessitate further comparative evaluation.

Therefore, the present ex vivo study aimed to comparatively evaluate the apical microleakage of zinc oxide eugenol, Apexit, GuttaFlow 2, and GuttaFlow Bioseal using scanning electron microscopy.

2. Objectives The objective of the present ex vivo study was to comparatively evaluate the apical microleakage of four commonly used endodontic sealers, namely zinc oxide eugenol, calcium hydroxide–based sealer (Apexit), GuttaFlow 2, and GuttaFlow Bioseal. The study aimed to assess and compare the sealing ability of conventional, silicone-based, and bioceramic-based sealers following root canal obturation using the lateral compaction technique. Scanning electron microscopy (SEM) was employed to analyze the sealer–dentin interface and quantify apical microleakage at high

magnification. Additionally, the study sought to determine statistically significant differences among the tested sealers. The findings were intended to provide insight into the effectiveness of newer bioactive sealers in achieving a hermetic apical seal. Ultimately, this study aimed to aid clinicians in selecting sealers that may enhance the long-term success of endodontic treatment

3. Methods

This ex vivo experimental study was conducted in the Department of Conservative Dentistry and Endodontics, Seema Dental College and Hospital, Rishikesh, in collaboration with Uttaranchal University for scanning electron microscopic analysis. Eighty freshly extracted intact, caries-free human permanent mandibular first premolars with single straight canals and fully formed apices were selected and randomly allocated into four groups (n = 20): zinc oxide eugenol, Apexit, GuttaFlow 2, and GuttaFlow Bioseal. Standardized access cavity preparation and biomechanical preparation were performed using a crown-down technique with irrigation using 3% sodium hypochlorite and 17% EDTA. Canal preparation was carried out up to a **#35 master apical file with a 0.06 taper**, and the **master cone was selected corresponding to the final master apical file**. All canals were obturated using the lateral compaction technique. Specimens were coated with nail varnish leaving the apical 2 mm exposed and immersed in 1% methylene blue dye for 72 hours. Longitudinally sectioned samples were evaluated under scanning electron microscopy at 500× magnification. Statistical analysis was carried out using one-way ANOVA, Tukey’s post hoc test, and Chi-square test, with $p < 0.05$ considered statistically significant.

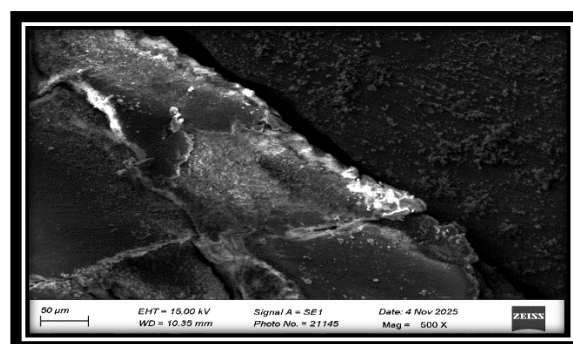


FIGURE 1: SCANNING ELECTRON MICROSCOPE IMAGES OBTAINED FOR GROUP A- ZOE

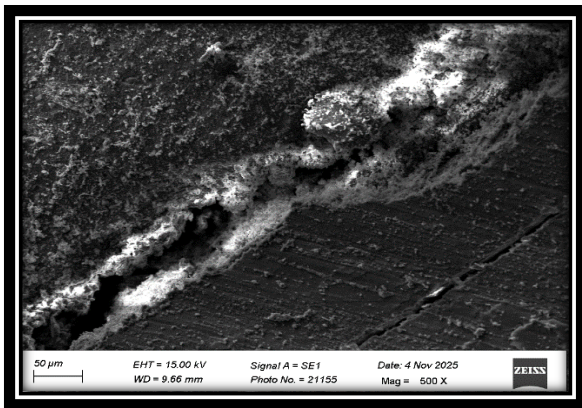


FIGURE 2: SCANNING ELECTRON MICROSCOPE IMAGES OBTAINED FOR GROUP B- APEXIT

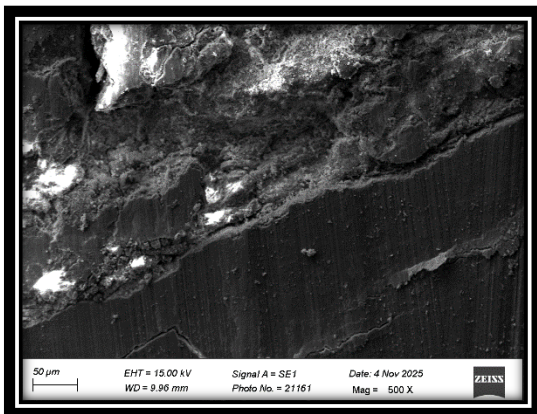


FIGURE 3: SCANNING ELECTRON MICROSCOPE IMAGES OBTAINED FOR GROUP C- GUTTA FLOW 2

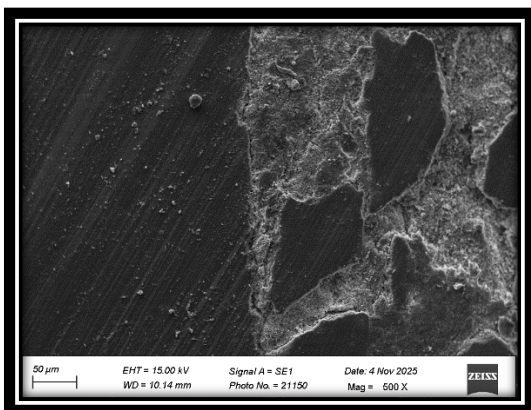


FIGURE 4: SCANNING ELECTRON MICROSCOPE IMAGES OBTAINED FOR GROUP D- GUTTA FLOW BIOSEAL

4. Results

Statistically significant differences in apical microleakage were observed among the four groups ($p < 0.05$). GuttaFlow Bioseal exhibited the least microleakage, followed by GuttaFlow 2 and Apexit, while zinc oxide eugenol showed the highest microleakage. SEM analysis demonstrated superior adaptation and fewer interfacial gaps in the GuttaFlow Bioseal group.

TABLE 1: Intergroup comparison of endodontic sealers for microleakage

Materials	Gutta Flow Bioseal	Gutta Flow 2	Apexit	ZOE
Mean ± S.D	2.707 ± 1.248	3.834 ± 1.711	5.901 ± 2.954	9.734 ± 4.360
Minimum	1.10	1.21	2.13	3.45
Maximum	5.85	8.97	13.50	18.68
ANOVA Statistic	24.008			
Df	3			
P value	0.000*			

*=Significant; NS –Not Significant

TABLE 2: Post hoc analysis of sealants for microleakage

Pairwise Comparisons	Mean Difference	St. Error	Significance
Bioseal vs GuttaFlow 2	-1.12684	.90591	.601
Bioseal vs Apexit	-3.19426*	.89506	.003*
Bioseal vs ZOE	-7.02988*	.89506	.000*



GuttaFlow 2 vs Apexit	-2.06742	.89506	.105
GuttaFlow 2 vs ZOE	-5.90304*	.89506	.000*
Apexit vs ZOE	-3.83562*	.88408	.000*

*=Significant; NS –Not Significant

TABLE 3: Distribution of scores amongst the groups

Groups	Score 1 N (%)	Score 2 N (%)	Score 3 N (%)	Total N(%)
Bioseal	13 (65.0)	4 (20.0)	3 (15.0)	20 (24.4)
GuttaFlow 2	4 (20.0)	12 (60.0)	4 (12.1)	20 (24.4)
Apexit	1 (4.8)	11 (35.5)	9 (42.9)	21 (25.6)
ZOE	0 (0.0)	4 (19.0)	17 (81.0)	21 (25.6)
Total	18 (22.0)	31 (37.8)	33 (40.2)	82 (100)
Chi Square test	45.660			
Df	6			
P value	0.000*			

*=Significant; NS –Not Significant

Intergroup comparison of mean apical microleakage values revealed statistically significant differences among all experimental groups (Table 1). Post hoc analysis demonstrated significantly lower microleakage in the GuttaFlow Bioseal group compared to Apexit and zinc oxide eugenol (Table 2). Distribution of microleakage scores among the groups showed a higher frequency of lower scores in the Bioseal group and higher scores in the zinc oxide eugenol group (Table 3).

5. Discussion

The present study evaluated the apical microleakage of four different endodontic sealers using scanning electron microscopy and demonstrated statistically significant differences among the materials tested. GuttaFlow Bioseal exhibited the least microleakage, followed by GuttaFlow 2 and Apexit, while zinc oxide eugenol showed the highest microleakage values.

The superior performance of GuttaFlow Bioseal may be attributed to its bioactive composition, which includes bioactive glass particles capable of releasing calcium ions and promoting hydroxyapatite formation at the sealer–dentin interface [18–21]. This bioactivity enhances chemical bonding with dentin, reduces interfacial gaps, and improves long-term sealing ability. SEM observations in the present study confirmed better adaptation and reduced discontinuities in specimens obturated with GuttaFlow Bioseal.

GuttaFlow 2 demonstrated better sealing ability than conventional sealers, likely due to its silicone-based matrix and thixotropic behavior, which facilitate improved flow into canal irregularities and dentinal tubules [22–25]. However, the absence of bioactive components may explain its comparatively higher microleakage values when compared with GuttaFlow Bioseal.

Apexit, a calcium hydroxide–based sealer, showed moderate microleakage. Although calcium hydroxide sealers possess antimicrobial properties, their higher solubility and limited dimensional stability may compromise long-term sealing, resulting in increased leakage [26–29]. This finding is consistent with previous studies reporting inferior sealing performance of calcium hydroxide–based materials when compared with resin or bioceramic sealers.

Zinc oxide eugenol demonstrated the highest microleakage among all groups. This may be attributed to its lack of adhesion to dentin, higher solubility, and dimensional changes over time [30–33]. SEM images revealed irregular adaptation and wider interfacial gaps, which further support its inferior sealing performance.

The findings of this study are in agreement with multiple SEM-based investigations reporting improved sealing ability of bioceramic and silicone-based sealers compared with conventional materials [34–38].



Nevertheless, the ex vivo design of this study and the absence of long-term aging and functional stresses represent limitations. Future in vivo and long-term studies are recommended to further validate these findings.

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