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Original Article

Comparative Evaluation of Apical Leakage Following Three Different Obturation and Post-Space Preparation Techniques with a Bioceramic Sealer

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Abstract

Purpose: The integrity of the apical seal following post-space preparation remains clinically relevant as endodontic techniques and materials evolve. No studies to date have directly compared the three obturation and post-space preparation techniques evaluated in this study using a uniform bioceramic (BC) sealer. This study hypothesized that obturation and post-space preparation technique would influence apical sealing ability despite consistent sealer use. It was further anticipated that full obturation using a continuous wave compaction technique followed by post-space preparation using a dedicated post drill would produce the most effective apical seal.

Methods: Thirty-five extracted single-rooted human teeth were cleaned, shaped, and randomly divided into three experimental groups (n = 10 each) along with a negative control group (n = 5) based on obturation and post-space preparation method. Group 1 (negative control = no obturation), Group 2 (single cone with sectioning), Group 3 (single cone with heat tip), and Group 4 (continuous wave compaction with post drill). All teeth were obturated using gutta-percha and EndoSequence BC Sealer. After obturation, roots were sealed with nail polish (excluding the apex), submerged in 2% methylene blue dye for 72 hours, then cleared using a standard decalcification and dehydration protocol. Dye penetration was measured from the apex to the most coronal extent using ImageJ. Statistical comparisons between groups were performed using two-tailed independent-samples t-tests with significance established at $p < 0.05$.

Results: Of the obturated groups, Group 4 (CWC + PD) showed the least dye leakage (0.75 ± 0.22 mm). Leakage increased significantly in Groups 2 (SC + SEC) (1.51 ± 1.14 mm) and 3 (SC + HT) (2.38 ± 1.64 mm) compared with Group 4. No significant differences were observed between Groups 2 and 3.

Conclusion: All groups exhibited apical leakage, yet the leakage depth varied based on the obturation method and post-space preparation technique utilized. The continuous wave compaction/post drill group demonstrated significantly less leakage than the two single-cone groups, indicating a superior apical seal.

Keywords: *Apical microleakage; Continuous wave compaction; Bioceramic sealer*

Introduction

Root canal treatment is predicated on the thorough removal of intracanal contents, including necrotic tissue and microbial biofilms, followed by effective disinfection and sealing to prevent reinfection of the root canal system and surrounding periapical tissues [1]. Following cleaning and shaping, the canal must be obturated three-dimensionally to establish an adequate seal at both the apical and coronal extents [2]. Establishing and maintaining an effective apical seal is critical to long-term treatment success, as inadequate sealing may permit residual microorganisms within dentinal tubules—or newly introduced bacteria through coronal leakage—to reestablish infection. These microorganisms may subsequently gain access to the periapical tissues through the apical foramen or accessory canals. Conversely, pathogens originating from an infected periodontium may infiltrate the canal space through apical or lateral pathways, contributing to persistent or recurrent disease [3]. In most cases, adequate obturation with gutta-percha (GP) and sealer provides an effective apical seal.

Contemporary obturation techniques commonly include continuous wave compaction (CWC), a form of warm vertical compaction, and the single-cone (SC) technique. The CWC technique was developed in 1987 by L. Stephen Buchanan to simplify the warm gutta-percha down-packing process [4]. This technique involves heating a pre-fitted master GP cone, compacting it apically, and subsequently backfilling the remaining canal space with thermoplasticized GP to create a dense, homogeneous, three-dimensional fill [5]. In contrast, the SC technique utilizes a single pre-fitted GP cone and relies primarily on the hydraulic properties of the sealer to occupy canal irregularities without the application of additional compaction forces [6].

Previous studies have reported mixed findings regarding the relative performance of these obturation techniques, depending on the sealer utilized, canal anatomy, and outcome measures evaluated, including void formation, apical leakage, and periapical healing. Monticelli et al. demonstrated greater leakage in single-cone groups compared with thermoplasticized obturation [7]. Moccia et al. performed a micro-computed tomography (micro-CT) study demonstrating improved filling density and adaptation with warm vertical techniques [8]. Kahate et al. reported superior periapical healing and adaptation with warm vertical compaction compared with single-cone and lateral condensation [9]. Elmsmari et al. conducted a 2025 systematic review and meta-analysis evaluating single-cone obturation with bioceramic sealers versus traditional obturation techniques such as warm vertical compaction and resin-based obturation systems and found that single-cone BC obturation demonstrated high clinical and radiographic success rates, including a reported success rate of 92.0% at 18 months, with no statistically significant difference in overall success rates between groups [10].

Despite mixed findings regarding the relative success of each technique, warm vertical compaction techniques such as CWC are frequently favored by endodontists because of their improved adaptation and sealing potential; however, they are technique-sensitive, require greater operator skill, and are generally more time-intensive [11]. Conversely, the SC technique offers procedural simplicity and efficiency, potentially reducing chair time and improving ease of use in general practice settings [12].

Sealers play a critical role in root canal obturation by filling spaces and canal irregularities that gutta-percha alone cannot adequately adapt to. Numerous sealers have been introduced throughout the history of endodontics, each possessing distinct advantages and limitations while demonstrating varying degrees of clinical success. The development of mineral trioxide aggregate (MTA) by Mahmoud Torabinejad in the 1990s marked a significant advancement in calcium silicate-based endodontic materials and served as the foundation for the evolution of modern bioceramic sealers [13]. Since their introduction in 2008, bioceramic sealers have gained widespread clinical acceptance because of their favorable biologic and physicochemical properties [14,15]. EndoSequence BC Sealer (Brasseler, Savannah, GA, USA) is a premixed calcium phosphate silicate-based material that is injectable, biocompatible, and non-toxic. Its favorable handling characteristics, dimensional stability, bioactivity, and sealing ability have contributed to its broad clinical adoption, making it the sealer selected for the present study.

Previous investigations have demonstrated favorable outcomes using bioceramic sealers in conjunction with both SC and warm obturation techniques. Chybowski et al. evaluated 307 teeth obturated using the SC technique with EndoSequence BC Sealer and reported an overall success rate of 90.9% at a mean follow-up period of 30.1 months [16]. DeLong et al. reported that EndoSequence BC Sealer demonstrated favorable bond strength to dentin when used in a single-cone technique, whereas thermoplasticized continuous wave obturation reduced the bond strength of calcium silicate-based sealers, potentially because of heat-related alterations to sealer properties [17]. In contrast, Monticelli et al. reported significantly greater leakage in a single-cone obturation group when compared with a continuous wave condensation group obturated with thermoplasticized gutta-percha and AH Plus sealer [7]. These findings suggest that both obturation technique and sealer selection may influence long-term sealing ability.

Following root canal therapy, placement of an intraradicular post may be indicated—typically within the largest canal—to improve retention of the core build-up and definitive restoration [18]. To preserve the integrity of the apical seal, approximately 4–6 mm of GP is generally retained apically while the coronal portion is removed to create post-space preparation. Multiple post-space preparation techniques have been described. One method involves completing obturation with CWC to the canal orifice followed by removal of the coronal GP using a post drill (PD). Alternatively, in SC obturation, the coronal GP may be removed using a heated plugger (HT). A third method, referred to as the sectioning (SEC) technique, involves pre-sectioning the GP cone approximately 95% through at a point 5 mm from the tip prior to insertion; after placement, the cone is twisted to separate and remove the coronal segment.

The influence of post-space preparation methods—particularly pre-sectioning of the GP cone—on apical sealing ability when used in conjunction with bioceramic sealers remains unclear. Specifically, it is not well understood whether these techniques disrupt the sealer interface at the apical level, thereby compromising or improving sealing effectiveness.

Therefore, the aim of the present study was to evaluate the apical sealing ability of three combinations of obturation and post-space preparation techniques using a standardized bioceramic sealer: SC+SEC, SC+HT, and CWC+PD. It was hypothesized that obturation and post-space preparation technique would significantly influence apical sealing ability despite the use of a consistent sealer, with CWC+PD expected to provide the most effective apical seal.

Materials and Methods

A total of 35 extracted human single-rooted premolars with straight canals were selected for this in vitro study. Teeth were decoronated to a standardized root length of 15 mm. Working length (WL) was established by introducing a size 10 K-file until visible at the apical foramen and subtracting 1 mm.

Cleaning & Shaping

Root canals were instrumented using nickel-titanium rotary files (Vortex Blue rotary system, Dentsply Sirona, Ballaigues, Switzerland) to a final apical size of 40/.04. Irrigation was performed using 2 mL of 6% sodium hypochlorite (NaOCl) delivered with a 30-gauge side-vented needle prior to instrumentation, followed by 1 mL of 6% NaOCl after each successive file. Final irrigation consisted of 2 mL of 17% ethylenediaminetetraacetic acid (EDTA) followed by 2 mL of 6% NaOCl. Canals were dried with sterile absorbent paper points corresponding to the final preparation size.

Specimens were randomly assigned to four groups consisting of three experimental groups (n = 10 each) and one negative control group (n = 5).

Obturation/ Post Space Preparation

Group 1 served as the negative control and was not obturated.

In Group 2, canals were obturated using GP and BC sealer with a SC technique. Post space was created using a sectioning technique in which the GP cone was pre-sectioned extraorally approximately 5 mm from the apex to 95% of its diameter, after which the remaining material was removed by twisting motion (SC+SEC).

In Group 3, canals were obturated using GP and BC sealer with a SC technique. Post space was created by searing the GP to a level 6 mm from the apex using a heat tip set at 200°C (SC+HT) (Woodpecker Fi-G heat tip system, Guilin, Guangxi, China).

In Group 4, canals were obturated using a CWC technique with GP and bioceramic sealer. A heat tip set at 200°C was used to sear the material 6 mm from the apex, and the remaining canal was backfilled with an obturation gun (Woodpecker Fi-P obturation gun, Guilin, Guangxi, China) set at 180°C using GP pellets (Woodpecker Fi-G gutta-percha pellets, Guilin, Guangxi, China) followed by vertical compaction. Post space was subsequently prepared using a size 4 (1.00 mm diameter) post drill (ParaPost drill, Coltene/Whaledent, Altstätten, Switzerland).

Dye Procedure:

Following obturation, all root surfaces were coated with three layers of nail polish except for the canal orifice and apical foramen. Specimens were immersed in methylene blue dye solution for 72 hours to assess apical microleakage. Following immersion, specimens were rinsed in tap water, and the nail polish was then removed using cotton applicators and acetone.

Demineralization / Dehydration / Clearing process:

Specimens underwent a clearing protocol based on the method described by David Robertson et al. [19], including decalcification in 5% nitric acid for 5 days with daily solution changes, followed by rinsing under running water for 4 hours. Dehydration was performed in ascending concentrations of ethyl alcohol (80% for 12 hours, 90% for 2 hours, and 100% for 2 hours), after which samples were rendered transparent by immersion in methyl salicylate.

Imaging / Data Collection:

Microleakage was evaluated using a digital stereomicroscope at 20× magnification, and images were captured for analysis. See Figure 1. The maximum linear extent of apical dye penetration was measured from the apex to the most coronal extent of dye penetration using ImageJ software (National Institutes of Health, Bethesda, MD, USA). See Table 1.

Statistical analysis was conducted using two-tailed independent-samples t-tests for pair-wise comparisons between groups. Statistical significance was established at $p < 0.05$.

Figure 1. Sample of Specimen Analysis

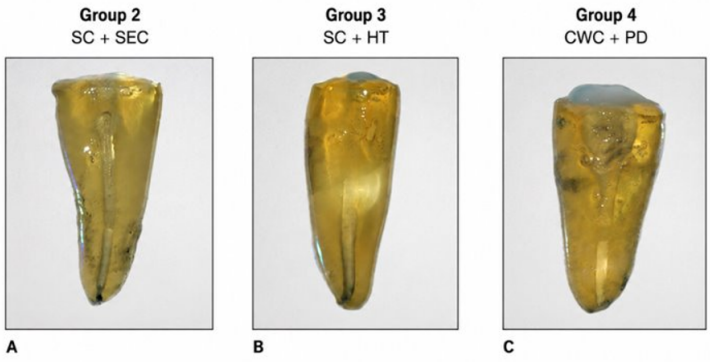

Fig. 1. 20× images of specimens after obturation and post-space preparation after being immersed in MB dye and cleared. (A) Group 2 (SC + SEC); (B) Group 3 (SC + HT); (C) Group 4 (CWC + PD).

Table 1. Dye leakage distance (mm)

Specimen	Obturation Method			
	1 Control	2 SC+SEC	3 SC+HT	4 CWC+PD
1	4.46	0.49	0.49	0.94
2	1.51	1.22	2.08	0.67
3	11.96	0.28	2.40	0.90
4	3.57	0.29	2.68	0.71
5	2.25	1.53	0.28	0.25
6	—	1.56	1.73	0.88
7	—	2.32	1.22	0.57
8	—	3.83	3.21	0.90
9	—	2.60	3.94	0.91
10	—	0.98	5.74	0.78
Mean	**4.75**	**1.51**	**2.38**	**0.75**
SD	4.19	1.14	1.64	0.22

— *Not applicable.*

Results

Group 1 (negative control) demonstrated the greatest extent of dye penetration and the highest variability. Among the obturated groups, Group 3 (SC+HT) exhibited the greatest dye penetration, followed by Group 2 (SC+SEC), whereas Group 4 (CWC+PD) demonstrated the least dye penetration. See Chart 1.

Variability in dye penetration followed a similar pattern, with Group 3 exhibiting the greatest variability, followed by Group 2, while Group 4 demonstrated the least variability.

Statistical analysis demonstrated that Group 4 differed significantly from both Groups 2 and 3 ($p < 0.05$), whereas no statistically significant difference was observed between Groups 2 and 3.

Overall, Group 4 (CWC+PD) demonstrated the lowest level of dye penetration and the most consistent results, suggesting superior apical sealing ability compared with the other experimental groups.

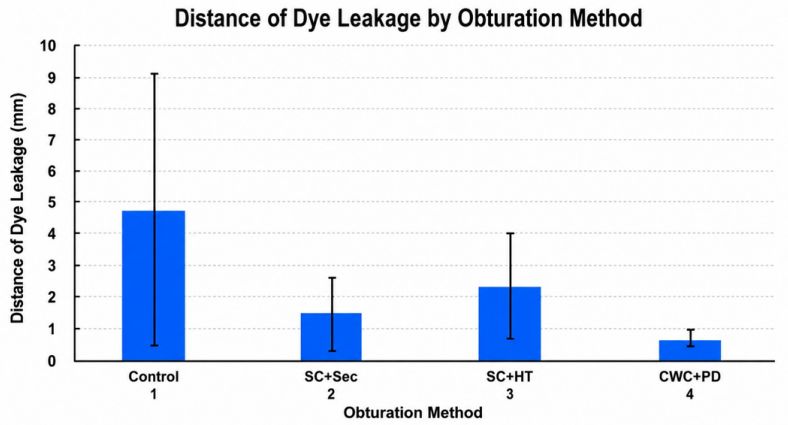

Chart 1: Mean measurement in millimeters and standard deviation values of depth of dye penetrability from apical to coronal.

Discussion

The findings of the present study support both the study hypothesis and previous literature demonstrating that warm vertical techniques such as continuous wave compaction (CWC) produce a more densely adapted obturation and may therefore provide an improved apical seal [2,7,8,11,12]. The improved performance observed in the CWC group may be attributed to enhanced thermoplasticized gutta-percha adaptation and reduced interfacial void formation within the canal system. Heating and vertical compaction of gutta-percha likely promoted greater adaptation to canal irregularities and dentinal walls when compared with the single-cone techniques, thereby reducing potential pathways for apical leakage.

Among the single-cone groups, the SC+SEC technique demonstrated less dye penetration than the more commonly utilized SC+HT technique, although the difference was not statistically significant. Despite its limited representation in the literature, the SC+SEC technique may offer potential advantages in non-endodontic settings where specialized equipment is unavailable or when performed by clinicians with limited experience using CWC techniques.

These findings have important clinical implications for practitioners performing root canal therapy. Technique selection is often influenced by clinician training, skill level, and procedural confidence, leading practitioners to adopt methods that are most predictable in their hands. Although many endodontists may prefer the CWC with post drilling technique because of greater familiarity and efficiency with this approach, the two single-cone techniques evaluated in this study represent viable alternatives in select clinical situations and may be particularly attractive to general practitioners.

Several limitations of the present study should be considered when interpreting the findings. First, this investigation was conducted in vitro using extracted human teeth under controlled laboratory conditions, which may not fully replicate the biologic and mechanical variables encountered clinically. Factors such as occlusal loading, temperature fluctuation, moisture contamination, periodontal ligament simulation, and long-term restorative function were not reproduced in this model. Additionally, the relatively small sample size may limit the generalizability of the results and reduce the ability to detect smaller differences between experimental groups.

Another important limitation is the use of dye penetration methodology to evaluate apical leakage. Although dye leakage models are widely utilized because of their simplicity and cost-effectiveness, they primarily assess potential physical pathways of leakage rather than true microbial or endotoxin penetration. Furthermore, the molecular size of methylene blue is substantially smaller than that of bacteria and their byproducts, which may overestimate clinical leakage potential. While useful for comparative assessment of sealing ability, dye penetration studies do not fully account for the biologic complexity associated with microbial invasion and periapical disease. Therefore, the findings of this study should be interpreted cautiously and may not directly predict long-term clinical success. Bacterial leakage models may provide a more clinically relevant alternative because they more closely simulate microbial penetration through compromised restorative interfaces [20].

Further investigation is warranted to evaluate differences among these obturation and post-space preparation methods, particularly with respect to immediate versus delayed post-space preparation. The present study evaluated only immediate post preparation performed within 30 minutes of obturation. In clinical practice, however, post placement may be delayed because of scheduling, restorative considerations, or referral patterns, allowing additional time for sealer setting. EndoSequence BC Sealer has a reported initial setting time of approximately 4–6 hours, with complete setting occurring at approximately 24 hours and potentially extending to 48 hours depending on environmental conditions.

Future studies utilizing bacterial leakage models, fluid filtration methods, or micro-computed tomography (micro-CT) analysis may provide a more clinically relevant evaluation of obturation quality and post-space preparation techniques. Additional research comparing immediate and delayed post-space preparation following complete bioceramic sealer setting may further clarify the influence of timing on apical sealing ability

Conclusion

Obturation and post space preparation techniques influenced apical sealing ability despite consistent sealer use among all groups. Although apical leakage was observed across all techniques evaluated, the continuous wave compaction with post drilling technique demonstrated significantly less leakage and superior apical sealing ability compared with the two single-cone obturation approaches.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgement

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