

Evaluation of Apical Sealing Ability of Different Endodontic Sealers: A Stereomicroscopic Study

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ABSTRACT

Introduction: The introduction of the adhesive dentistry concept has allowed materials to bond and provide intimate contact with the dentin walls of the root canal. Bondable root canal sealers, such as methacrylate resin sealer, can form a monobloc system within the root canal space, which improves the seal and fracture resistance of the filled canals. Recently, bioceramics have become one of the most popular biomaterials used in Endodontics after the clinical success of Mineral Trioxide Aggregate (MTA).

Aim: The present study aimed to evaluate the sealing ability of three endodontic sealers (AH Plus, MTA Fillapex and Bio-C sealer) through an in-vitro dye leakage test.

Materials and Methods: The present in-vitro study was conducted in Bharati Vidyapeeth Deemed to be University Dental College and Hospital, Pune, Maharashtra, India, from April 2024 to September 2024. Thirty intact single-rooted single-canaled teeth extracted for orthodontic/periodontal reasons were used in this study. These teeth were decoronated, chemomechanical preparation was done till size F3, and they were divided into three groups of 10 each. The samples in Group A were obturated with F3 Gutta-Percha (GP) cone and AH Plus sealer, in Group B, MTA Fillapex sealer was used, and in Group C, Bio-C sealer was used.

The apical microleakage was measured microscopically using the linear dye penetration method. The intergroup comparisons of microleakage were made using the One-way Analysis of Variance (ANOVA) test, followed by a post-hoc Tukey test for pairwise comparisons. A p-value of less than 0.05 was considered statistically significant.

Results: The MTA Fill-apex sealer group exhibited the highest level of microleakage, with a mean value of 1.48 mm, followed by the Bio-C sealer, which had a mean microleakage of 0.78 mm. In contrast, the AH Plus sealer group showed the lowest microleakage, with a mean of 0.59 mm. The differences in microleakage among the three groups were statistically significant at $p \leq 0.05$. Specifically, a significant difference was observed between AH Plus and MTA Fill-apex ($p=0.002$), as well as between MTA Fill-apex and Bio-C ($p=0.015$). However, the difference between AH Plus and Bio-C was not statistically significant ($p=0.702$).

Conclusion: The present study findings indicated that AH plus sealer exhibited superior sealing ability compared to MTA Fillapex and Bio-C sealer. Hence, it can be concluded that AH Plus provides more effective sealing, making it a more reliable option during obturation procedures and contributing to better long-term treatment outcomes.

Keywords: AH Plus sealer, Bio-C sealer, Dye penetration, MTA Fill apex sealer, Microleakage, Obturation, Resin sealer

INTRODUCTION

Root canal therapy involves chemomechanical preparation and three-dimensional obturation of the root canals [1]. The successful result of this procedure depends on the thorough removal of bacteria from the root canal. However, completely achieving this can be challenging because of the complex anatomical features of the root canal system. Therefore, an optimal sealing of the root canal is essential for preventing the infiltration of bacteria from the oral cavity and for containing any residual microorganisms [2]. The Gutta Percha cone is used with an endodontic sealer to obturate the root canal [1,3]. Despite the existence of several obturation procedures, there is a continuous need to create simpler and more efficient materials and methods. With the increasing usage of rotary nickel-titanium (Ni-Ti) instruments, the single-cone obturation technique has gained popularity [4]. Sealers eliminate any irregularities that GP cannot fill, such as lateral depressions and grooves. Since GP is impermeable, leaks happen at the interface between the sealer and the tooth, and the sealer and GP [5]. An ideal endodontic sealer should exhibit excellent flow characteristics, allowing it to smoothly coat the entire surface of the canal walls. It must effectively infiltrate and fill every void found between the root filling material and the surrounding dentin, ensuring a comprehensive seal. Additionally, they serve as a lubricant and facilitate the formation of a strong bond with both the dentin and GP, creating a reliable barrier against

bacterial leakage and promoting long-term success in root canal treatments [5-8].

A broad range of root canal sealers are commercially available and can be classified into specific categories based on their chemical composition [3]. These groups are determined by the principal ingredient present in each sealer, which includes: Sealers containing zinc oxide eugenol, iodoform, calcium hydroxide, resin, polyacrylic acid, silicone, Mineral Trioxide Aggregate (MTA), Bioceramic sealers that incorporate calcium-silicate-phosphate [7].

AH Plus (Dentsply Maillefer in Ballaigues, Switzerland) is an epoxy-amine resin-based sealer and is widely acknowledged for its superior properties. This product is distinguished by its advantageous physical and chemical properties, which contribute to its effective sealing capabilities [9]. AH Plus shows significant adhesive properties to root dentin and effectively penetrates micro irregularities, thereby improving the mechanical interlocking between the sealer and the dentin [6].

MTA Fillapex (Angelus, Londrina, Brazil), a MTA-based sealer, offers significant benefits. Composed of synthetic Portland cement with dark gray nodular materials, MTA Fillapex is noted for its high radiopacity, extended setting time, sufficient working time, optimal flow for filling accessory canals, low solubility, and ease of removal in the event of re-entry. Its design facilitates user convenience, particularly with the use of small auto-mixing tips [10].

Bio-C sealer (Angelus, Londrina, Brazil), presents a valuable option as a calcium silicate-based endodontic sealer. The product is available in a premixed injectable format, which effectively addresses the specific requirements and preferences of dental practitioners [11]. A stereomicroscope, also known as a dissecting microscope, is an optical magnifying instrument that allows the viewer to see an item in three dimensions. It has distinct target focal points and eyepieces. The unique viewpoints from the left and right eyes generate a three-dimensional (3D) image. Stereomicroscope uses mirrored/reflected light from the object being examined [12].

Ongoing research is focused on exploring alternative sealers that demonstrate adherence to dentin along with various filling materials. To assess the effectiveness of the newly developed sealer as a potential replacement for traditional options in root canal fillings, it is essential to conduct more comprehensive long-term studies. The most widely used method for evaluating the sealing ability of a root canal sealer is the dye penetration technique. This study aimed to evaluate the sealing ability of three different commercially available sealers through a stereomicroscopic analysis of dye penetration.

MATERIALS AND METHODS

The present in-vitro study was conducted in Bharati Vidyapeeth Deemed to be University Dental College and Hospital, Pune, Maharashtra, India, from April 2024 to September 2024, following the approval from the Institutional Ethics Committee (Registration number EC/NEW/INST/2021/MH/0029). Thirty mature human teeth recently extracted, (due to orthodontic and periodontal reasons), were selected for the study.

Inclusion criteria: Intact, non-carious, single-rooted and single-canaled teeth devoid of canal aberrations.

Exclusion criteria: Teeth with root cracks, internal root resorption, caries, restorations and previous endodontic treatment.

Sample size calculation: The sample size was estimated using the data obtained from a previous study by Mohamed El Sayed MAA et al., [4]. Considering the mean scores of the two out of three groups to be 1.52 & 0.74, the pooled standard deviation of the two groups to be 0.65, the number of pairwise comparisons to be 3, keeping the α error at 0.05 and power at 99%, the sample size estimated was 10 per group. The teeth were immersed in a 3% sodium hypochlorite (NaOCl) solution (Prime Dental) for two hours. Subsequently, they were stored in regular saline until required for further use.

Study Procedure

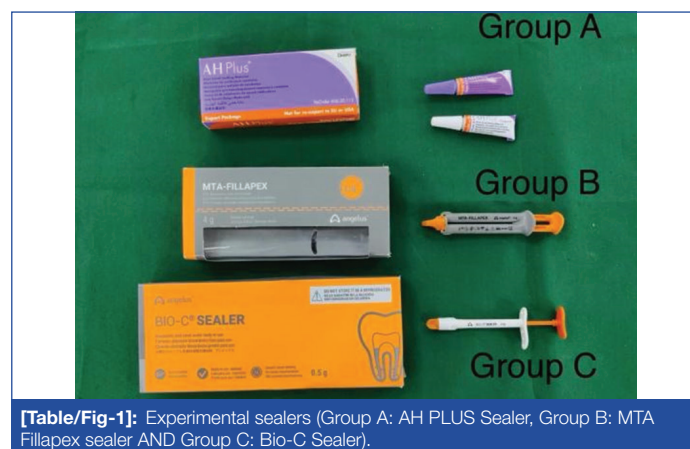
With adequate water cooling, the teeth were cut to obtain a consistent root length of 15 mm using a flexible diamond disc. The working length of a 10 K file (Mani Inc.) was calculated by extending it slightly past the apical foramen and then deducting 1 mm from its length. Chemomechanical preparation was carried out using ProTaper Universal NiTi rotary files (Dentsply Maillefer, Ballaigues, Switzerland) successively from S1 to F3, and irrigation was done with 3% NaOCl and normal saline. The canals were then dried with sterile paper points.

Group A (AH Plus): The samples in this group were obturated using the F3 ProTaper GP cone and AH Plus sealer. Using a Lentulo spiral, the sealer was applied into the canals in compliance with the manufacturer's recommendations. For the single-cone obturation method, AH Plus sealer was lightly coated on the tip of the appropriately sized master cone. After that, a vertical pumping action was used to push the cone into the root canal until the complete working length was achieved. Radiographic evaluation was used to gauge the obturation's quality [Table/Fig-1].

Group B (MTA Fillapex): The samples in this group were obturated using F3 ProTaper GP cone and MTA Fillapex sealer. Using a Lentulo spiral, the sealer was applied into the canals in compliance with the

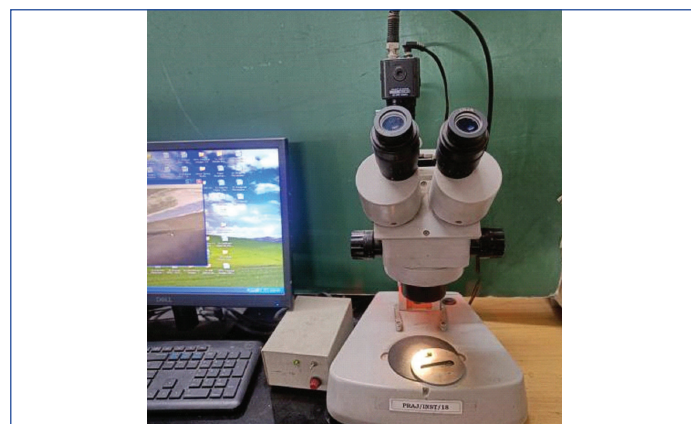
manufacturer's recommendations. The obturation procedure was the same as that of Group A [Table/Fig-1].

Group C (Bio-C): The samples in this group were obturated using F3 ProTaper GP cone and Bio-C sealer. Using the intracanal tip that the manufacturer provides, the Angelus Bio-C sealer was injected straight into the canals, and the obturation was carried out using the previously described procedure [Table/Fig-1].



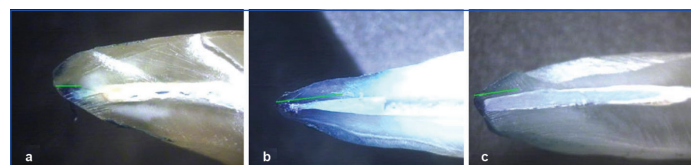
[Table/Fig-1]: Experimental sealers (Group A: AH PLUS Sealer, Group B: MTA Fillapex sealer AND Group C: Bio-C Sealer).

Three coats of nail varnish were applied to the entire length of each sample, leaving the apical 3 mm exposed. The samples were then submerged in 1% methylene blue dye and allowed to soak for 72 hours. After soaking, the samples were thoroughly rinsed under running water and left to dry. A No.11 scalpel blade was used to remove the nail varnish. The samples were longitudinally sectioned using a diamond disc with water cooling, and with a digital stereomicroscope, microleakage in each sample was evaluated [Table/Fig-2].



[Table/Fig-2]: Stereomicroscope (Wuzhou New Found Instrument Co., Ltd., China, Model: XTL 3400E, magnification: 10X).

An image analysis system was used to measure the amount of leakage in millimetres, from the apex to the farthest point of dye penetration (Chroma Systems Pvt., Ltd., India, Model: MVIG 2005). Each sample's dye penetration data was noted. To minimise operator-related variability, a single person handled all testing and preparation [Table/Fig-3a-c].



[Table/Fig-3a-c]: Stereomicroscopic images of the samples stained with 1% methylene blue dye of three experimental sealers: a) AH PLUS sealer; b) MTA Fillapex sealer; and c) Bio-C sealer, 10x magnification.

STATISTICAL ANALYSIS

The data were analysed using Statistical Package for Social Sciences (SPSS) software, version 26.0. To compare microleakage

among the various groups, a One-way ANOVA test was performed after confirming a normal distribution with the Shapiro-Wilk test. For pairwise comparisons, the Tukey post-hoc test was employed. A p-value of less than 0.05 was considered statistically significant.

RESULTS

The MTA Fillapex sealer group demonstrated the highest microleakage, with a mean value of 1.48 mm. This was followed by the Bio-C sealer group, which exhibited a mean microleakage of 0.78 mm. In contrast, the AH Plus sealer group recorded the lowest microleakage, with a mean of 0.59 mm. The differences in microleakage among these groups were statistically significant ($p=0.002$) [Table/Fig-4].

Group	Mean	SD	p-value
AH Plus	0.59	0.41	0.002*
MTA Fillapex	1.48	0.55	
Bio C	0.78	0.59	

[Table/Fig-4]: Microleakage (in millimeters) comparison of three sealers.

*indicates a significant difference at $p \leq 0.05$ in the One-way ANOVA test.

The application of the Post-hoc Tukey test indicated that the microleakage in the MTA Fillapex sealer group was significantly higher than that in the other two groups. Furthermore, there was no significant difference in microleakage between the AH Plus and Bio-C sealer groups (p -value 0.702) [Table/Fig-5].

Pairwise comparison	Mean difference	p-value
AH Plus vs MTA Fillapex	-0.89	0.002*
AH Plus vs Bio C	-0.19	0.702
MTA Fillapex vs Bio C	0.70	0.015*

[Table/Fig-5]: Pairwise comparison of microleakage (in mm) among three sealers.

*indicates a significant difference at $p \leq 0.05$ in the Post-hoc Tukey test.

DISCUSSION

The present study was conducted to evaluate and compare the sealing capabilities of three endodontic sealers utilising single-rooted, single-canal teeth that were instrumented with the F3 ProTaper Universal nickel-titanium rotary instrument for standardised assessment of apical leakage. The use of rotary instrumentation ensures consistent and efficient biomechanical preparation [4].

Methylene blue dye, which serves as a potential indicator of microleakage [13-16], was employed to assess apical microleakage. The results indicated that the AH Plus sealer demonstrated the lowest levels of microleakage when compared to both MTA Fillapex and Bio-C. This finding corroborated the results of previous studies conducted by Mohamed El Sayed MAA et al., which highlighted the superior sealing capabilities of AH Plus, an epoxy resin-based root canal sealer derived from AH 26. [4]. De Almeida WA has successfully proved the excellent sealing capabilities of AH Plus, a root canal sealer based on epoxy resin developed from AH 26 [3]. Furthermore, Madakwade S et al., evaluated push-out bond strength and identified that teeth obturated with AH Plus and GP exhibited higher bond strengths, signifying the resilience of the sealer to stress and pressure [17]. Additionally, when the apical sealing ability of Resilon/Epiphany was assessed against GP/AH Plus for 16 months, Paque F et al., recorded a reduction in fluid movement with the combination of AH Plus and GP. This phenomenon may be attributed to the gradual expansion of AH Plus in a liquid medium over time [18].

These findings were consistent with those reported by Sönmez IS et al., who noted that MTA Fillapex presents a lower sealing ability compared to AH Plus [19]. Moreover, a systematic review and meta-analysis by Dioguardi M et al., concluded that epoxy resin-based cements exhibit superior sealing capabilities, as evaluated through bacterial micro-infiltration models, compared to tricalcium silicate-based cements for observation periods lasting longer than

90 days [20]. The robust adhesion properties of AH Plus are likely the result of its capacity to covalently bond with amino groups present in radicular dentin collagen, along with its setting expansion upon application within the root canal, and its ability to penetrate micro-irregularities in dentin walls [4].

In the context of a phosphate buffer, calcium silicate-based bioceramic sealers interact with dentin by chemically absorbing silicon and calcium, which enhances the efficacy of the Bio-C sealer. This interaction leads to the formation of a mineral infiltration zone following the denaturation of collagen fibers, initiated by the alkaline effects of the sealer byproducts. Minerals, including silica, calcium, and carbonate, can infiltrate intertubular dentin through this zone [21]. A study conducted by Fontana CE et al., indicated that Bio-C, an endodontic sealer produced by Angelus, exhibited the highest mean of apical microleakage, performing inferiorly to both AH Plus and hydroxyapatite-based sealers [22]. This suggests that Bio-C may have inherent limitations in its sealing ability, potentially attributable to factors such as setting time or the presence of moisture, aligning with the findings of their study [10].

Rane S et al., executed a similar study at the same institution. Their results demonstrated the superior sealing ability of a bioceramic sealer augmented with chitosan nanoparticles. While the previous study employed the lateral compaction technique for canal obturation, the current investigation utilised the single cone technique. Unlike earlier research, chitosan particles were not incorporated in this study. The principal aim here was to assess the clinical relevance of bioceramic sealers employing the single cone technique to ascertain their effectiveness in achieving an adequate apical seal [23].

Limitation(s)

It is crucial to acknowledge the limitations inherent in this laboratory work. The results are based on a controlled experimental framework that may not accurately reflect the complexities of real-world clinical scenarios. Several factors, including interactions with periapical tissues, dentinal tubules, and moisture conditions, were not considered. Additionally, the assessment of apical leakage via dye penetration affords a limited view of the effectiveness of the sealers in dynamic clinical settings.

CONCLUSION(S)

Despite being primarily utilised as a supplementary component in the root canal obturation, endodontic sealers have been demonstrated to significantly affect the outcomes of endodontic treatments. The ideal root canal sealer should have a precise balance between biocompatibility and sealing efficacy. Within the constraints of the investigation, it was discovered that there were statistically significant differences in the sealing qualities of AH Plus, MTA Fillapex, and Bio C Sealers. According to the results, the MTA Fillapex sealer group had the maximum microleakage, followed by the Bio-C sealer group, while the AH Plus sealer group had the least.

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