Review Article

Sealing Ability and Micro Leakage of AH26 and AH Plus Root Canal Sealers: A Systematic Review

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Abstract

One of the main reasons endodontic therapy fails is the microleakage of the treated teeth. An effective apical seal is vital to the endodontic treatment outcome. Because of the ancillary canals and variances in the root structure, accurately sealing the root canal is a challenging and delicate process. The improper and partial obturation account for 60% of endodontic failures. According to other research, a poor seal is caused by insufficient flow of gutta-percha and its inability to bond to the walls of the dentin. Different techniques and materials have been studied to enhance and compare the sealing capabilities of root canal materials when new sealers are introduced to the market.

In summary, these studies suggest that both AH Plus and AH26 root canal sealers have some degree of microleakage, but the extent of leakage can be influenced by factors such as obturation methods and other experimental conditions. AH26 showed slightly higher bacterial leakage compared to AH Plus in one study, but it also exhibited greater resistance to Enterococcus faecalis in another study. The choice of sealer and specific characteristics may affect their performance in terms of microleakage and cytotoxicity.

Keywords: AH plus, AH 26, Endodontic sealer, Microleakage

Introduction

One of the main reasons endodontic therapy fails is the microleakage of the treated teeth. An effective apical seal is vital to the endodontic treatment outcome. Because of the ancillary canals and variances in the root structure, accurately sealing the root canal is a challenging and delicate process. According to Kelmendi *et al*. improper and partial obturation account for 60% of endodontic failures [1]. According to other research, a poor seal is caused by insufficient flow of gutta-percha and its inability to bond to the walls of the dentin [2, 3]. Different techniques and materials have been studied to enhance and compare the sealing capabilities of root canal materials when new sealers are introduced to the market. The findings are conflicting; none of the sealers developed to date can fully satisfy the criteria for a flawless root canal seal [4-6].

Using computerized fluid filtration, Cobankara *et al*. investigated the apical sealing capabilities of Rocanal 2, RC sealers, AH Plus, and Sealapex; Sealapex offered a superior seal than the other sealers. The fluid transfer via gutta percha in canals filled without or with RSA (Roekoseal Automix), EWT (Pulp Canal Sealer), and AH26 sealer was assessed in another investigation [5]. The samples without a sealer exhibited the greatest fluid movement rate (leakage) in comparison to the other groups, according to the results. A different investigation found that AH Plus had more micro-leakage than AH26 [4].

Pécora *et al*. investigated the dentine adhesion of root canal sealers by Er: YAG and found that AH Plus outperformed AH26. They also assessed the sealing performance of RSA, AH26, and AH Plus utilizing dye penetration in teeth filled with the Thermafill technique or lateral condensation. The teeth obturated using the Thermafill procedure without a sealer had the greatest dye penetration percentage, according to the results. Nevertheless, there was no discernible statistical variation seen in the average apical dye penetrations of the three distinct sealers [7].

It was observed that there was no discernible difference between RSA, Topseal, and Endometason's sealing

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How to cite this article: Almutairi NM, Aldawsari AA, Alshamrani HS, Fakeeha IA, Alshehri FH, Alshiha AA, et al. Sealing Ability and Micro Leakage of AH26 and AH Plus Root Canal Sealers: A Systematic Review. Arch Pharm Pract. 2023;14(2):140-6. https://doi.org/10.51847/cHptScRjUQ

performance when measured using the cross-section or clearing methods [8]. The adhesive properties of sealers based on epoxy resin are well-known [8-10]. Even when utilized only as the root canal filling, AH26, an epoxy-resin-based material, has excellent sealing ability [11]. This material's extended setting time and flowability prevent fracture development and rapid separation from the dentinal wall [12]. It has excellent texture compatibility, less than 0.5% shrinkage when entering the side channels, and the ability to stiffen in the presence of moisture [12, 13].

Unfortunately, the formaldehyde release and the lengthy (4-week) setting period are drawbacks [14]. It is said that AH Plus offers the benefits of AH 26 but with a quicker setting time and no formaldehyde release. In addition, compared to AH26, there seems to be less microleakage and more radiopaque [15, 16]. A new version of AH Plus called AH Plus Jet is supplied in mixing syringes that may be administered straight into canal orifices. Its usage is efficient and conducive to infection management because of the changeable syringe tip.

Materials and Methods

A systematic literature review was conducted from 2000 to 2023 using Science Direct, Medline, and PubMed databases. AH 26, AH plus, root sealer, and microleakage were used as keywords. The PRISMA flowchart was utilized to describe the choice process of the reviewed articles **(Figure 1)**.

Inclusion Criteria

- Randomized control and case-control studies
- Publication year between 2000 and 2023
- Published in English
- Study on humans (In vivo)

Exclusion Criteria

- Meta-analyses, Systematic reviews, Narrative reviews, or expert opinions
- The study is based on a survey
- Articles outside the specified time frame
- Articles whose language was not English
- In vitro

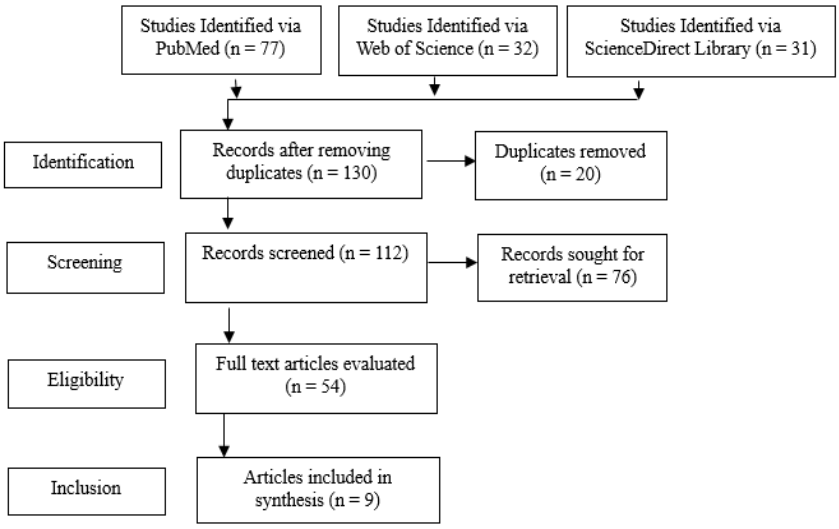

Figure 1. PRISMA Flow Diagram

Bias Assessment Risk

Cochrane risk of bias assessment method was utilized to evaluate the quality of the included studies **(Table 1)**.

Table 1. Cochrane Risk Summary of Bias Assessment

Study	Selection Bias/Appropriate control selection/baseline characteristics similarity	Selection bias in randomization	Selection bias in allocation concealment	Performance-related bias in blinding	Reporting bias/Selective reporting of outcomes	Detection bias Blinding outcome assessors	Accounting for confounding bias
Miletic *et al*. (2002)	+	+	+	-	+	+	+

De Moor *et al*. (2004)	-	+	+	+	-	+	+
Huang *et al*. (2000)	+	+	+	+	+	+	+
Masoud *et al*. (2005)	+	+	+	+	+	+	+
Akhavan *et al*. (2011)	+	+	+	+	+	+	-
Hasheminia *et al*. (2011)	+	-	+	-	+	+	+
Ashraf *et al*. (2020)	+	+	+	-	+	+	+
Rishi *et al*. (2015)	+	+	+	+	+	-	+
Schäfer *et al*. (2002)	+	-	+	+	+	+	+

Results and Discussion

The study was conducted by Miletic *et al*. (2002) [8] to assess the amount of bacteria, either alone or in combination, that can penetrate gutta-percha-filled root canals and one or more root canal sealers, such as AH PlusandAH26. Eighty teeth were separated at random into two groups of forty teeth each, and either the AH26 or the AH Plus sealer was used to obturate the teeth with gutta-percha. Nail varnish was applied in two coats to the exterior surface of every root, with the apical 2 mm exception. The teeth were placed into sterile Schaedler broth-filled glass vials and suspended in Eppendorf plastic tubes. Twenty teeth filled with AH26 and twenty filled with AH Plus had their access cavities filled with Lactobacillus acidophilus, Prevotella melaninogenica, Streptococcus mitis, and Streptococcus mutans. In the experimental teeth, leakage occurred from day 14 to day 87. Of all the samples, 47% had leaks. Fungi and bacteria escaped from samples containing AH26 at a rate of 60% and bacteria from those with AH Plus at a rate of 50%. Between the sealers, there was no statistically significant variation in the amount of fungus and bacteria that penetrated.

De Moor *et al*. (2004) [9] conducted research to assess and contrast the sealability of root fillings in dental extractions utilizing three distinct obturation methods in combination with AH 26 and AH Plus. Procedure and supplies: 940 single-rooted teeth had their root canals prepared to use the crown-down/step-back method (with Flle-Eze and 2.5% NaOCI) before obturation with Thermafil or hybrid condensation and lateral condensation of the gutta-percha. At any point throughout the monitoring period, there were no statistically significant variations in apical leakage between the two sealer groups or between the AH Plus and AH 26 groups. At one day, one week, and two weeks, Thermafil dramatically increased coronal leakage in comparison to hybrid condensation for both AH Plus and AH 26. Thermafil was the only medication that showed more coronal leakage after one week as compared to lateral condensation for hybrid and AH 26 condensation for AH Plus.

The work done by Huang *et al*. (2000) [10] aimed to examine the lactate dehydrogenase (LDH) leakage from rat hepatocytes after in vitro root canal sealer treatment with AH26 and AH Plus. Male Sprague-Dawley rat hepatocytes were used to evaluate the cytotoxicity of AH26 and AH Plus. One-way ANOVA was used to quantify and assess the lactate dehydrogenase leakage values that were both dose- and time-dependent. The results demonstrated that rat hepatocytes are toxic to both AH26 and AH Plus. Rat hepatocytes were more sensitive to AH26 than AH Plus at low concentrations.

The research performed by Masoud *et al*. [11] compared three different root canal sealers' apical sealing capabilities. One hundred single-rooted teeth were utilized to assess the apical sealing capacity of three other root canal sealers: AH Plus, AH26, and ZOE (zinc-oxide eugenol). Every tooth's coronal portion was extracted, located around 2 mm above the cemento-enamel junction. Using hand files and Gates Glidden drills, the "Step-Back" method was used to instrument the root canals. 2.5% sodium hypochlorite was used as an irrigation fluid. The teeth were filled using gutta-percha points and test sealers using the cold lateral condensation method. The teeth were separated into three groups of thirty teeth each. Ten sets of teeth—five negative and five positive—were used as control groups. For three days, the teeth were submerged in 2% methylene blue. After that, the teeth were divided lengthwise, and their linear apical dye penetration was assessed. There were statistically significant ($P<0.05$) variations in leakage between ZOE [5.41mm; SD 0.274], AH Plus [3.64mm; SD 0.182], andAH26 [2.08mm; SD 0.215]. In the study's settings, there was some leakage experienced by all three sealers. Compared to ZOE, there was noticeably reduced leakage with both epoxy resin sealers (AH26, AH Plus). Compared to AH Plus, there was much reduced leakage with AH26.

Akhavan *et al*. (2011) [12] in his research, compared the sealing capabilities of three different kinds of resin-based sealers was the aim of this investigation. This research employed 87 human single-canal removed teeth in an experimental laboratory setting. Following root canal preparation and smear layer removal, the teeth were randomly assigned to 5 groups: 2 positive and negative control groups, 3 experimental groups, and 1 positive group. In the first experimental group, gutta-percha and AH26 sealer were used, followed by AH Plus Jet sealer and gutta-percha in the second group and gutta-percha and TGad seal sealer in the third group. Following that, the teeth were

subjected to a 90-day microbial microleakage examination, during which each sample's daily turbidity occurrence time was noted. After a day, every sample in the positive control group had an infection. After ninety days, none of the models in the negative control group showed any signs of contamination. No statistically significant difference was observed among the three experimental groups in microbial leakage (P-value = 0.611).

The aim of the research conducted by Hasheminia *et al*. (2011) [13] was to evaluate the chemical and physical characteristics of Resil, an experimental endodontic resin sealer, in comparison to AH-26 and AH-Plus. From day 1 to day 30, all three groups had a considerable growth (P<0.05). The AH-Plus and experimental sealers had significantly different mean dimensional changes (P=0.020). The pH of the experimental sealer (Resil) two hours after mixing was substantially higher than AH-26 (P<0.001) and significantly lower than AH-Plus (P<0.001). The experimental sealer exhibited considerably greater antibacterial activity both before and after setting compared to the other two sealers (P<0.001).

The study executed by Ashraf *et al*. (2020) [14], compared and investigated the apical sealing capabilities of AH Plus Jet, AH Plus, and AH26, using the fluid filtration model.

Seventy single-rooted teeth were removed from the cemento-enamel junction for this experimental investigation. ProTaper rotary system and manual K-files were used to prepare the canals, while 17% EDTA and 5.25% NaOCl were used for irrigation. The control group consisted of ten teeth, split into five positive and five negative controls. After dividing into three groups of 20, the remaining samples were filled with gutta-percha using the lateral compression method.

One of the following: AH Plus Jet, AH Plus, or AH26was added to each sample group. On days two and thirty, the quantity of air bubble movement inside the capillary glass tube that was attached to the root was used to measure microleakage. Although AH Plus had the highest rate and AH Plus Jet had the lowest value of microleakage; statistically, the differences were not significant.

Rishi *et al*. [15] presented their study to compare AH plus, Apexit, Zinc Oxide Eugenol sealer, and AH 26's resistance to Enterococcus faecalis along obturated root canals with unsuccessful coronal sealing. Before being needed for the investigation, 52 excised human lower premolars were gathered, kept in saline, and then split into 5 groups of 10. Conventional methods were used for the root canal treatment, and distinct sealers were used for each group's obturation. Control group (group 0): teeth that were obturated without the use of a sealer. Groups 1 and 2 are AH Plus, Zinc Oxide Eugenol, and AH 26, while Group 4 is Apexit. As a consequence, ZOE (GROUP 1), APEXIT (GROUP 4), and AH PLUS (GROUP 2) were all outperformed by AH 26 (GROUP 3). Finally, AH 26 demonstrated the strongest defense against E. faecalis.

This research was set out by Schäfer *et al*. (2002) [16] to evaluate the seal achieved in both curved and straight root canals filled with Thermafil obturators or laterally compacted gutta-percha. Every method was combined with three distinct sealants (AH Plus, RSA Roeko Seal, and AH 26). There were 14 test groups, each consisting of 16 teeth, using Thermafil obturators in the sealer absence. As either positive or negative controls, sixty teeth were used. 142 removed teeth with straight root canals, and another 142 with curved root canals were included in the research. Up to size 40, all channels were expanded. Filling material extrusion was substantially higher in canals filled with Thermafil obturators than in canals filled with lateral compaction ($p < 0.01$). In both straight and curved canals, Thermafil without sealer demonstrated significantly higher dye penetration than all other groups ($p < 0.05$). Thermafil-obturated seals were comparable to lateral compaction in terms of dye penetration, provided a sealer was applied. The mean apical dye penetration for each of the three sealers did not vary statistically. For every group, the variations in dye penetration between curved and straight tubes were not statistically significant ($p > 0.05$).

Table 2. Study findings summary

Author's name	Purpose	Method and Materials	Key Findings
Miletic *et al*. (2002) [8]	Evaluate Candida albicans and bacterial penetration through root canals filled with AH Plus and AH26 sealers.	80 teeth were divided into two groups filled with either sealer. Candida albicans and bacteria were introduced. Leakage observed.	In 47% of samples, leakage occurred between 14 and 87 days. No significant difference was reported in penetration between sealers.
De Moor *et al*. (2004) [9]	Compare sealability using AH Plus and AH 26 with various obturation techniques.	940 single-rooted teeth prepared using various techniques and sealed with either sealer. Leakage observed.	No significant differences in apical leakage within and between sealer groups. Coronal leakage varied based on the obturation technique.
Huang *et al*. (2000) [10]	Assess cytotoxicity of AH26 and AH Plus on rat hepatocytes.	Rat hepatocytes were treated with sealers, and lactate dehydrogenase leakage was measured.	Both sealers were toxic to rat hepatocytes. AH26 had higher toxicity at low concentrations.

Masoud *et al*. (2005) [11]	Compare the apical sealing ability of ZOE, AH Plus, and AH26on single-rooted teeth.	Teeth filled with test sealers, and apical dye penetration evaluated.	AH26 and AH Plus showed significantly less leakage than ZOE.
Akhavan *et al*. (2011) [12]	Assess microbial microleakage in teeth filled with AH26, AH Plus, and tgad seal.	Teeth were filled with different sealers and examined for microbial leakage.	No significant difference in microbial leakage between the experimental groups.
Hasheminia *et al*. (2011) [13]	Evaluate chemical and physical properties of Resil, AH-26, and AH-Plus sealers.	Changes in dimensional stability and pH were measured. Antibacterial activity assessed.	All three sealers showed significant expansion. Resil had a lower pH and higher antibacterial activity.
Ashraf *et al*. (2020) [14]	Compare the apical sealing ability of AH Plus Jet, AH Plus, andAH26.	Teeth were filled with different sealers, and microleakage was assessed using fluid filtration.	The lowest microleakage was for AH Plus Jet, while the highest ratewas for AH Plus, although the differences were not significant.
Rishi *et al*. (2015) [15]	Evaluate resistance against bacterial microleakage in teeth filled with various sealers.	Teeth were filled with different sealers and resistance against Enterococcus faecalis was assessed.	AH26 performed better than ZOE, APEXIT, and AH Plus in resisting bacterial leakage.
Schäfer *et al*. (2002) [16]	Assess the seal obtained in straight and curved root canals filled with different obturation techniques and sealers.	Teeth were filled using various techniques and sealers, and dye penetration was evaluated.	Thermafil obturators without sealer showed greater dye penetration. No significant differences in apical dye penetration among sealers.

The findings of this investigation demonstrated that the dimensional alterations of the Resil experimental sealer were larger than those of the other two sealers. Its pH was between that of the other two sealers, with an alkaline value. Its antibacterial activity was higher than that of AH-PlusandAH-26. In contrast to AH-26 and AH-Plus, the physical and chemical characteristics of resilience were evaluated in this research. Because of their great popularity among the resin sealers on the market, the latter two sealers were chosen. Furthermore, Resil's chemical structure was shown to be comparable to that of AH-26 and AH-Plus in a prior investigation on its characterization [5, 6]. Resil experimental sealer is suitable for clinical usage since it has physical and chemical characteristics similar to AH-26; if it resembled AH-Plus, it would be the gold standard [17, 18].

In comparison to AH-26, Resil had a quicker setup time (about 11 hours) and less cytotoxicity, according to prior research [5, 6]. All sealers had expansion from day 1 to day 30, according to our study's assessment of the dimensional changes of Resil, AH-26, and AH-Plus. There was a substantial difference in the mean dimensional changes between Resil and AH-Plus.

It was also shown by a few more research [7, 8, 19] that AH-26 and AH-Plus showed setting expansion [20]. AH-Plus's expansion makes up for its polymerization shrinkage. It is ideal for sealers and root-filling materials to have appropriate growth or dimensional stability. Nonetheless, there is always a chance of root fracture because of the forces brought on by sealant expansion. It should be mentioned that other elements, like the dentin's tensile strength and the root filling material's modulus of elasticity, also matter in this regard [7]. Due to its low modulus of elasticity, gutta-percha somewhat reduces the pressures brought on by the sealer's expansion. Conversely, shrinking the sealer is not as desirable since it results in gaps at the interface between the root canal wall and sealer, as well as microleakage. Consequently, compared to a little expansion, sealing shrinking offers a higher chance of therapy failure [7, 18].

Contrary to what we found, some investigations [20-22] indicated that the pH of AH-26 and AH-Plus rose after setting. However, [23] noted that in only 4 weeks, the pH of AH-Plus dropped from 7.34 to 7.07. Methodology differences might be one cause of the findings' unpredictability. While the pH of the samples was tested after setting in Silva *et al*.'s research and this investigation, [21] submerged the sealers for pH measurement before their setting.

According to the present research, AH Plus Jet showed the least amount of leakage on days two and thirty, whereas AH Plus showed the greatest incidence of microleakage. The leakage of the investigated sealers did not vary statistically significantly.

Fluid filtration, first presented by Wu *et al*. is now the most widely used technique for microleakage evaluation due to its several benefits over the dye penetration approach. Sample reevaluation is not feasible due to tooth structural changes caused by the dye penetration procedure after sectioning. Other drawbacks include the potential for bias resulting from many phases of tooth preparation and the challenge of determining the degree of dye penetration between the gutta-percha and the canal walls in the sectioned areas [24-26]. The fluid filtration assessment approach minimizes tooth structural alteration and allows for long-term sample reevaluation. The method is easy to use, takes less time, and allows for the measurement of microleakage in individual samples throughout many observation periods. In teeth filled

using the lateral compression method, Zemner *et al*. investigated the sealing capabilities of AH26 and AH Plus. Dye penetration was used to measure the microleakage after two, four, and ten days.

In comparison, AH Plus showed significantly higher leakage than AH26. This discrepancy might be explained by the quick setting of AH Plus and the ensuing setting shrinkage. It has also been demonstrated that AH26 had a greater initial growth than AH Plus [26, 27]. An additional investigation evaluated the fluid filtration microleakage of Ketac-endo, Apexit, Diaket, AH Plus, and AH26on sixty obturated teeth. In the first 24 hours after obturation, AH Plus leaked more than AH26. However statistically, no significant difference was reported.

The content of AH26 and AH Plus is the same. The inclusion of silicone and aerosol in the mixture, as well as the removal of formaldehyde release from the latter substance, are what set them apart. the oral cancer cell line (OC2) was exposed to DMSO-immersed AH26 root canal sealer, which caused cytotoxicity and genotoxicity. This harmful effect persisted even after the solution was stored for more than a year. It is believed that other factors were more important and that formaldehyde generation should decrease after a year. the AH26 sealer's epoxy resin component may have contributed to the toxicity. In this investigation, AH26's LDH leakage at 0.1% and 4 hours revealed more LDH leakage than AH Plus [28, 29]. AH26 is more harmful than AH Plus. However, AH Plus also demonstrated hepatocyte damage as treatment duration increased. Formaldehyde may not be released by AH Plus sealer. Still, it is impossible to rule out the possibility of other hazardous chemicals released by DMSO that might be harmful to cells. It is not possible to draw the conclusion that AH Plus outperforms AH26 clinically based on the information above. endodontic sealers that include formaldehyde and eugenol had the strongest antibacterial activity against the microorganisms over the periods under study. In other words, sealer may have a positive antibacterial effect yet be toxic to tissue. The sealer's dosage determines this. In conclusion, rat hepatocytes may become contaminated due to AH26 and AH Plus sealers. Overall, these sealers are still effective endodontic sealers in clinical practice, even if some of their components may have leaked into the periapical tissue and produced discomfort [30].

Conclusion

In summary, these studies suggest that both AH Plus and AH26 root canal sealers have some degree of microleakage, but the extent of leakage can be influenced by factors such as obturation methods and other experimental conditions. AH26 showed slightly higher bacterial leakage compared to AH Plus in one study, but it also exhibited greater resistance to Enterococcus faecalis in another study. The choice of sealer and specific characteristics may affect their performance in terms of microleakage and cytotoxicity.

ACKNOWLEDGMENTS: None
CONFLICT OF INTEREST: None
FINANCIAL SUPPORT: None
ETHICS STATEMENT: None

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