

Comparative Evaluation of Rheological and Radiographic Properties of Three Endodontic Sealers: An *In Vitro* Study

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Objective: To compare and evaluate the rheological and radiographic properties of AH Plus, Endoflas FS, and Pulpdent root canal sealers using a two-plate system and digital imaging technique.

Methods: The rheological and radiological properties of endodontic sealing materials were evaluated according to ANSI/ADA Specification No. 57. The two-plate method was used to evaluate the flow properties and film thickness, and the digital imaging technique was used to evaluate the radiopacity.

Results: The results show that all three root canal sealers comply with ANSI/ADA Specification No. 57 requirements for all tests conducted for rheological and radiographic properties. There were statistically significant differences among the three test materials. In all of the tests, the AH Plus root canal sealer showed better rheological and radiographic properties than Endoflas FS and Pulpdent.

Conclusion: AH Plus root canal sealer had better rheological and radiographic properties than Endoflas FS and Pulpdent root canal sealers.

Key words: AH Plus sealer, flow, film thickness, radiopacity

Successful root canal treatment depends on the thorough debridement of the root canal system, the elimination of pathogenic organisms and finally the complete obturation of the canal. Complete obturation is achieved by the adhesion and stability of the sealer to the canal walls, which, amongst other factors, is affected by its rheological properties¹. The rheological properties of a material, such as flow, are related to molecular mobility². The ideal endodontic sealer should flow along the entire canal wall surface and should have a sufficiently small film thickness to fill even the smallest voids and discrepancies between gutta-percha and canal walls³.

Radiopacity is one of the essential properties of endodontic sealers, as it imparts radiographic clarity to the root canal filling and thereby its presence and extent can be detected⁴. Many different root canal sealers are currently being used in combination with gutta-percha to fill the root canal after biomechanical preparation. Zinc oxide-based sealers, such as Endoflas FS and Pulpdent, have been widely used in root canal treatment. These sealers are tissue compatible and provide an adequate seal. With regard to resin-based sealers such as AH Plus, these have the ability to bond to the canal walls. Studies have shown that these resin-based sealers are stable, biocompatible and have good sealing ability⁵. However, all types of endodontic sealers should fulfil certain general requirements, such as good chemical, physical and radiographic properties suitable for clinical use⁶. The solubility, adhesion and antibacterial properties of different types of root canal sealer have been studied for many years. However, the rheological and

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Fig 1 Load placement on glass plate containing sealer.

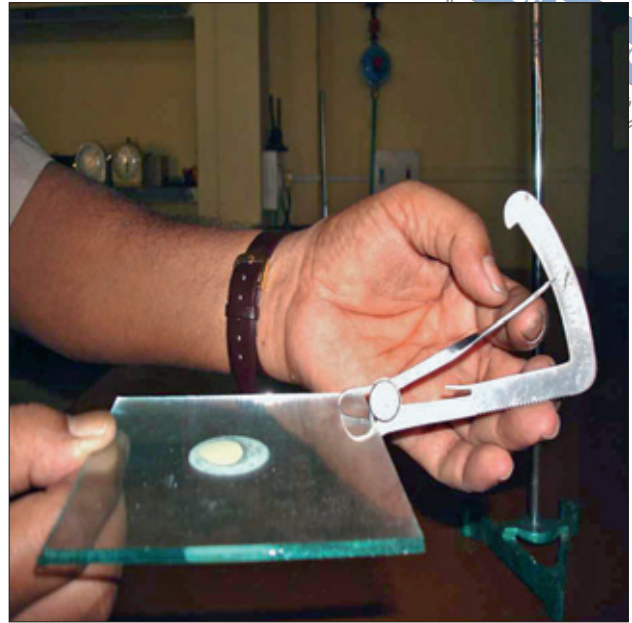


Fig 2 Rheological evaluation of sealers.

radiographic properties of sealers have seldom been studied.

Therefore, the objective of this study was to compare and evaluate the flow, film thickness and radiopacity of Endoflas FS, AH Plus and Pulpdent root canal sealers.

Materials and Methods

Three root canal sealers were evaluated in this study: AH Plus™ (Dentsply), Pulpdent® (Pulpdent Corporation) and Endoflas FS (Sanlor). The experimental tests included: test 1, flow capacity; test 2, film thickness; test 3, radiopacity. Six samples of each root canal sealer were used in each of the three tests. Therefore, 18 samples were used in each test.

All of the tests followed American National Standards Institute/American Dental Association (ANSI/ADA) Specification No. 57, which indicates test methods and establishes minimal requirements of flow, film thickness and radiopacity of endodontic sealers³.

Flow test

A two-plate system method was used for the flow test. A volume of 0.5 ml of sealer was mixed according to the manufacturer's direction and was placed at the centre of a glass plate using a graduated syringe and it was covered by an identical plate. The setting times were 8 h for AH Plus sealer, 4 h for Endoflas FS sealer and 2 h for

Pulpdent sealer. Then a load of 100 N was placed carefully and centrally on the top of the glass plates (Fig 1). At 10 min after the commencement of mixing, the load was removed and the maximum and minimum diameters of the compressed disc of sealer were measured with a measurement scale using units of millimetres. If the diameters were less than 1 mm, then the mean of two diameters were recorded; if both of the two diameters were less than 1 mm, the test had to be repeated. Six flow tests were performed for each sealer and the mean value for each of the specimens was calculated in millimetres. A minimum value over 20 mm was required by the ANSI/ADA Specification No. 57.

Film thickness test

A two-plate system method was used for the film thickness test. A volume of 0.5 ml of sealer was mixed according to the manufacturer's direction and placed at the centre of a glass plate using a graduated syringe and it was covered by an identical plate. A load of 150 N was placed carefully and centrally on the top of the glass plates, ensuring that the material filled the entire area between the top and bottom glass plates. At 10 min after the commencement of mixing, the thickness of the two glass plates and the interposed sealer film was measured with a measurement scale. The difference in thickness of the two glass plates, with and without sealer, was taken as the film thickness of the material (Fig 2). Six film thickness

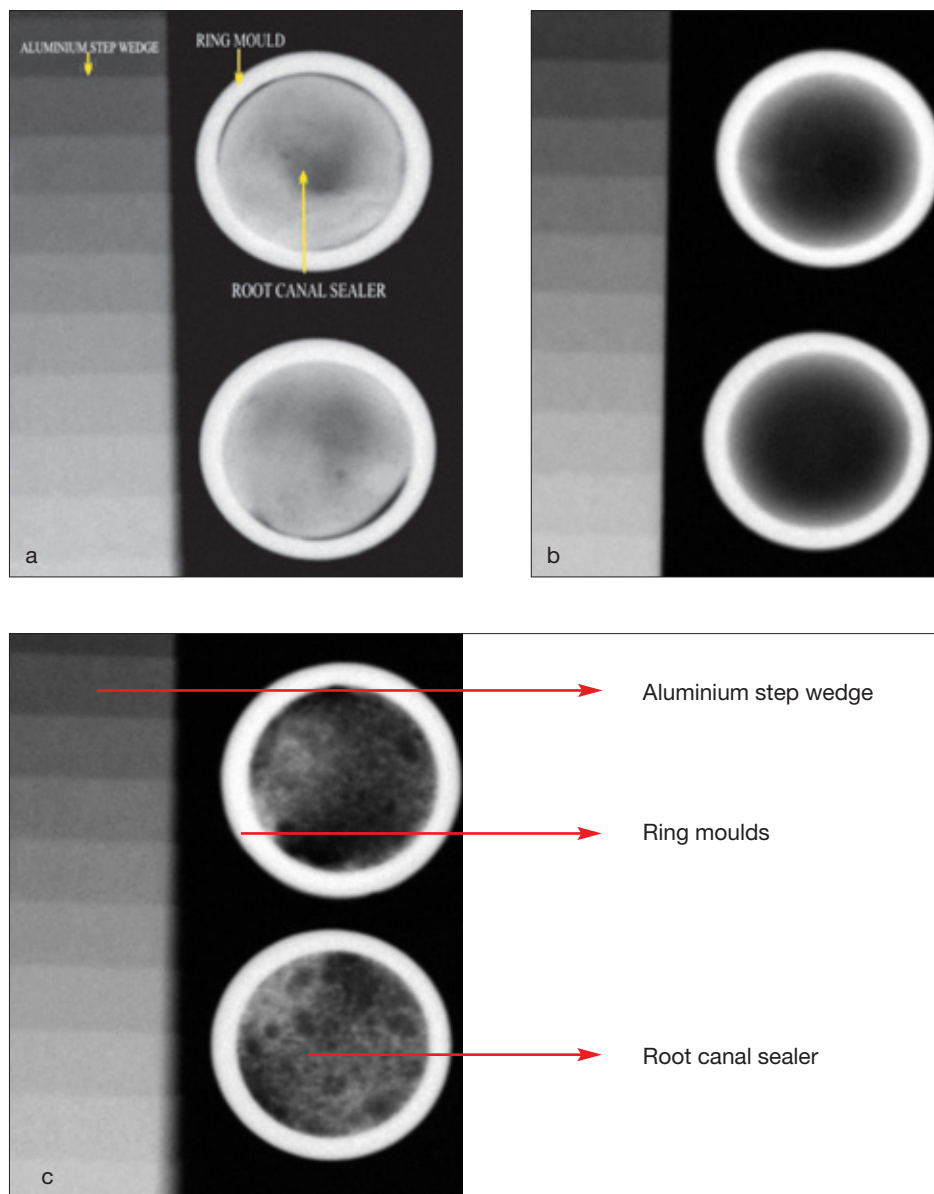


Fig 3 Digital radiographic images of AH plus sealer (a), Endoflas FS sealer (b) and Pulpdent sealer (c).

tests were performed for each sealer and the mean value of each of the specimens was calculated in micrometres. A value lower than 50 μm was required by ANSI/ADA Specification No. 57.

Radiopacity test

A digital imaging technique was used for the radiopacity test. The sealers were prepared according to the manufacturer's directions and placed in two stainless steel ring moulds (diameter 10 mm, height 1 mm). The stain-

less steel ring moulds used in the study were of smaller diameter and consequently smaller surface area available for evaluation. This made it possible to choose a representative homogeneous area for measurement. Each sample was then digitally imaged alongside an aluminium step wedge which was used as a reference. The aluminium step wedge was fabricated by creating several steps of 1 mm thickness in increasing number from a single aluminium block. These steps had the additional benefit of speeding up the measurement process. The images were taken using an RVG sensor (Gendex Visu-

**Table 1** The mean flow, film thickness, and radiopacity properties among the three sealers

Parameter	Mean ± SD		
	AH Plus	Endoflas FS	Pulpdent
Flow (mm)	40.05 ± 0.08*	31.03 ± 0.05#	30.07 ± 0.08
Film thickness (µm)	30.00 ± 0.06*	38.03 ± 0.05#	36.02 ± 0.04
Radiopacity (mm)	10.95 ± 0.08*	6.97 ± 0.05#	5.78 ± 0.04

* $P < 0.001$ versus AH Plus and Endoflas FS

$P < 0.001$ versus Pulpdent

alox, USB) and a dental x-ray machine (Orix, Italy) operating at 70 kVp and 10 mA with a total filtration equivalent to 2.25 mm of aluminium (Fig 3). The exposure time used in this study was 0.6 s, which was sufficient to allow the visualisation of the aluminium alloy and the sealer materials. The digital images were analysed with the Pro Plus 4.1 analytical software system (Media Cybernetics, Silver Spring, USA). The 'bone density' tool was applied to the region of the radiographs containing the sample. Care was taken to analyse only those regions which were free of air bubbles and other anomalies. The bone density tool produced a graph of the grey-scale value of each pixel, 0 (black) to 255 (white), in the analysed segment, which was recorded. Six digital images of each sealer were taken for analysis.

Results

Table 1 shows the mean flow, film thickness and radiopacity values among the three types of root canal sealer. Analysis of variance and the *t* post hoc test of Bonferroni were used for data analysis. The results of this study show that all three of the root canal sealers satisfied the requirements of ANSI/ADA Specification No. 57 with respect to the rheological and radiographic properties. Statistically significant differences in flow, film thickness and radiopacity properties were found among the three sealers ($P < 0.001$). When comparing the properties of the three sealers one by one, AH Plus had the best flow, the lowest film thickness and exhibited the highest radiopacity.

Discussion

Successful endodontic therapy is based on thorough debridement of the canal system, the elimination of pathogenic organisms and the complete obturation of the canal⁷. Filling root canals is currently achieved using a combination of endodontic sealer and gutta-percha. Gut-

ta-percha is widely used owing to its good physical and biological properties, but the lack of adhesiveness to canal walls is a major disadvantage. A satisfactory seal cannot be obtained without the use of a sealer, because gutta-percha does not spontaneously bond to dentine walls³.

An ideal root canal sealer should make a hermetic seal. It should flow efficiently along the entire canal wall surface and fill all voids and discrepancies between the gutta-percha and canal walls. The root canal sealers should be easy to use by a clinician and readily removed if necessary for retreatment. Furthermore, they should be impervious to tissue fluids and should not discolour tooth tissue⁸. However, these ideal properties will be less relevant if the sealer does not have certain rheological and radiographic properties, such as flow, film thickness and radiopacity⁷.

Flow is an essential rheological property of endodontic filling materials. It is defined as 'deformation under a static load, even that associated with its own mass'. Ideally, the root canal sealer with good flow has low surface tension and can be easily placed along the entire root canal. It should wet the canal walls thoroughly and thus provide a well-adapted filling². The film thickness is another rheological feature of root canal sealers and is defined as the 'dimension which is measured after pressure is applied between two flat surfaces that are separated by the cement layer'. A thin film can wet the root canal surface better than a thick film and thus provide a better hermetic seal. The smaller the film thickness, the greater will be the ability of the material to fill even the smallest voids or discrepancies and perhaps enter the dentinal tubules³.

Dental diagnosis relies mainly on radiology. In order to identify and distinguish root canal filling materials from the surrounding anatomical structures, the root canal sealers should be radiopaque. Radiopaque refers to that portion of the radiograph that appears light or white. Radiopaque structures are dense and absorb or resist the

passage of the x-ray beam. The sealer should contribute to the radiopacity of the root filling for visualisation on radiographs and evaluation of obturation of lateral canals and apical ramifications³.

Gutta-percha has been used as a core material with zinc oxide–eugenol-based sealers for many years. Pulpdent root canal sealer is a zinc oxide-based sealer which can fill any irregularities and accessory canals for complete obturation of the root canal system. Endoflas FS is another zinc oxide-based sealer which has antibacterial properties, is hydrophilic in nature and can be used in relatively humid canals. However, zinc oxide-based sealers shrink upon setting and dissolve over a period of time, and this compromises the quality and life expectancy of the apical seal. Studies have shown that no zinc oxide-based sealers bond to the root dentin and prevent apical leakage in the root end⁶. Recently, a few new endodontic sealers have been developed with improvements in sealing and bonding to the root dentin. These improvements depend on the incorporation of resin monomer into the sealer. AH Plus, a two-component paste root canal sealer, is based on the polymerisation reaction of epoxy resin amines. AH Plus has high radiopacity, low solubility, less shrinkage, good tissue compatibility and does not release formaldehyde. The presence of resin monomer and the particle size of the filler component have a significant effect on the rheological properties of the sealers⁹.

A capillary rheometer was used to evaluate the rheological properties, which was time consuming and lacked accuracy⁷. A conventional radiographic method could be used to evaluate the radiopacity. However, this routine radiographic procedure includes chemical processing of radiographic films and it can produce significant variation in the final radiographs, affecting the accuracy⁴. To overcome these limitations, an attempt was made to use a two-plate system and a digital imaging technique to evaluate the rheological and radiographic properties of root canal sealers.

The two-plate method for assessing flow and film thickness is simple to conduct and fulfils the requirements of ANSI/ADA Specification No. 57, and the test gives more accurate and consistent results³. The digital imaging technique is an emerging area of radiology that offers many potential benefits to the endodontic practice. This technique offers computer-based image processing and analysis⁴. The digital radiographic method, compared with the conventional radiographic method, does not need any conventional periodic radiographic film or radiographic chemical processing, thus saving time and decreasing the stages that could interfere with the final radiographic quality. In addition, the digital radiograph-

ic method reduces the operator's exposure to radiation and also provides a detailed analysis of digital images¹⁰. In this study, all tests were conducted according to ANSI/ADA Specification No. 57, which indicates test methods and establishes minimal requirements of flow, film thickness and radiopacity of endodontic sealers. According to ANSI/ADA Specification No. 57, the minimal requirements of flow of root canal sealers should be greater than 20 mm, film thickness should be lower than 50 μm and the radiopacity of the sealer should be equivalent to or more than 3 mm of aluminium³.

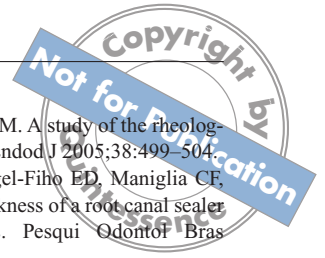
In the test of flow, the results showed that the highest mean flow was observed in AH Plus, followed by Endoflas FS and then Pulpdent. The presence of bisphenol A and bisphenol F epoxy resin in the composition of AH Plus root canal sealer increased the setting time of the sealer (8 h) and can explain its better flow characteristics compared with the other sealers tested¹¹. In the test of film thickness, the results showed that the highest mean film thickness was observed in Endoflas FS, followed by Pulpdent and then AH Plus. AH Plus consisted of finely ground calcium tungstate and zirconium oxide, which have average particle sizes of 8 μm and 1.5 μm respectively. The small particle size of the filler had a significant effect on the film thickness of the AH Plus sealer⁹. In the test of radiopacity, the results showed that the highest mean radiopacity was observed in AH Plus, followed by Endoflas FS and then Pulpdent. The Endoflas FS and Pulpdent root canal sealers consisted of zinc oxide and barium sulphate as radio-opacifying agents. Recently, there has been an addition of newer fillers, like zirconium oxide and iron oxide in AH Plus root canal sealer. This contributes to the greater radiopacity of AH Plus sealer relative to the other sealers tested¹⁰.

Conclusion

The results of the study suggested that all root canal sealers complied with the ANSI/ADA Specification No. 57 requirements in all tests conducted. Among the three root canal sealers, AH Plus sealer provided better rheological and radiographic properties, followed by Endoflas FS and Pulpdent. Thus, AH Plus root canal sealer can be considered as an alternative to current zinc oxide-based sealers.

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