

APICAL MICROLEAKAGE EVALUATION IN MONOBLOCK AND CONVENTIONAL SEALERS

THE SHORT TITLE: MICROLEAKAGE IN MONOBLOCK VS. CONVENTIONAL SEALERS

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Introduction

Microleakage is the clinically undetectable passage of bacteria, fluids, molecules, or ions between a tooth and its restorative material [1]. In endodontics, apical microleakage occurs when bacteria and their by-products penetrate voids in the root canal filling. Persistent bacterial infiltration inside the root canal may trigger an inflammatory response, initiating or exacerbating periapical lesions and ultimately leading to endodontic treatment failure [2].

Various materials and obturation techniques have been developed to reduce apical microleakage. In an effort to apply adhesive dentistry principles to endodontics, resin-based sealers were combined with resin-coated gutta-percha cones. This approach aims to create a dense, void-free mass that fully adapts to the root canal walls, forming what is referred to as a “monoblock” within the root canal system [3].

EndoRez (Ultradent Products Inc, South Jordan, UT, USA) is a hydrophilic, urethane dimethacrylate-based sealer that creates a monoblock when mixed with resin-coated gutta-percha cones [3]. RealSeal SE (SybronEndo, Orange, CA, USA) is a root canal obturation material that uses a self-etching methacrylate-based sealer and Resilon cones (Resilon Research LLC, Madison, CT, USA) as an alternative to traditional gutta-percha cones [4]. This is also the first obturation system reported to generate a mono-block between the canal wall and the obturation material [5]. A glass ionomer-based monoblock system is represented by ActiV GP system (Brasseler USA, Savannah, GA, USA), which combines a glass ionomer sealer with gutta-percha cones coated in glass ionomer particles [4].

The objective of this study was to evaluate the apical microleakage of three monoblock obturation systems EndoREZ, RealSeal SE, and ActiV GP using the penetration method in combination with the clearing technique. Furthermore, the sealing ability of these systems was compared with the conventionally used epoxy-based sealer AH Plus (Dentsply, Konstanz, Germany) in combination with standard gutta-percha cones.

Patients and methods

The research was approved by the Ethics Committee of the Faculty of Dentistry, Sarajevo (09-522-2/2013).

Sample selection

A total of 140 extracted permanent maxillary and mandibular incisors and canines were used in this study. Teeth with root fractures or cracks, incomplete root development, prior to endodontic treatment, calcifications, or signs of resorption were excluded. Data on gender, age and the reason for extraction were not recorded.

Sample preparations

The crowns were removed and root lengths standardized to 15 mm using calipers. A #10 K-reamer was inserted into the canal until it reached the apical foramen. This length was transferred to an endometer, reduced by 1 mm, and recorded as the working length. Root canal instrumentation was performed using Mtwo® rotary files (VDW GmbH, Munich, Germany), with the final file size being 40/.04. During instrumentation, canals were irrigated with 1.5% sodium hypochlorite (NaOCl), and the smear layer was removed using an 18% EDTA solution (Ultradent, South Jordan, USA).

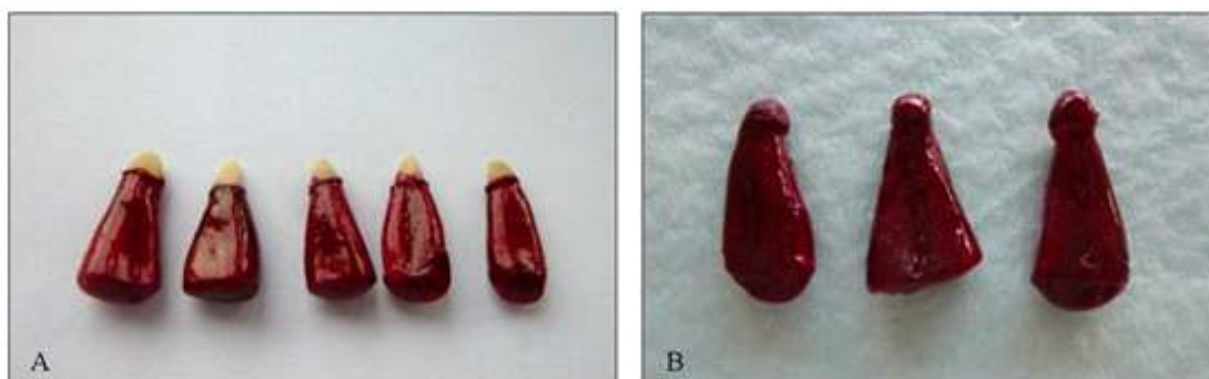
Sample distribution

The 140 samples were divided into four experimental groups and two control groups.

- Experimental group 1 (n=30): obturated with the EndoREZ system (EndoREZ sealer and EndoREZ points),
- Experimental group 2 (n=30): obturated with the RealSeal SE system (RealSeal SE sealer and Resilon cones),
- Experimental group 3 (n=30): obturated with the Active GP system (Glass-ionomer sealer and ActiV GP gutta-percha),
- Experimental group 4 (n=30): obturated using AH Plus sealer and standard gutta-percha cones.

The quality and apical extent of root canal fillings were evaluated radiographically.

Two control groups were included:

Figure 1. (A) The samples of the experimental and positive controle groups; (B) Samples of the negative controle groups.

- Positive control (n=10): instrumented but not obturated,
- Negative control (n=10): instrumented but not obturated; apical ends sealed with composite material.

All samples were coronally sealed with composite resin.

Dye penetration and clearing technique procedure

Samples in the experimental and positive control groups were coated with two layers of varnish, leaving the apical 2 mm exposed. Negative control samples were completely covered with varnish (Figure 1). To ensure proper setting and adhesion of the obturation materials, all experimental samples were stored in 0.9% NaCl solution at 37°C in a thermostatically controlled environment for 7 days.

All samples were then immersed in Indian ink dye (Lefranc & Bourgeois, France) for 7 days. Following

dye exposure, the varnish was removed and a clearing procedure was performed.

Demineralization was conducted using 5% nitric acid (Semikem doo, Sarajevo, Bosnia and Herzegovina) for 5 days at room temperature, with daily acid renewal. Samples were then dehydrated in ascending concentrations of ethanol (70%, 96%, and 99%), spending 12 hours in each solution. Finally, samples were immersed in methyl salicylate (Semikem doo) to achieve transparency.

Assessment of apical microleakage

Apical dye penetration was evaluated under a stereomicroscope (Novex RZ-series, Euromex Microscopes BV, The Netherlands) equipped with a micrometer. The extent of microleakage was measured in millimetres from the anatomical apex to the most coronally observed point of dye penetration.

Table 1. T descriptive values of apical microleakage of EndoREZ, RealSeal SE, ActiV GP and AH Plus

Sealer	N	M	SD	Skewness	Kurtosis	Min	Max	Q1	Med	Q3
				SE=0.43	SE=0.83					
EndoREZ	30	1.56	2.11	2.21	4.05	0.00	7.81	0.54	0.91	1.37
RealSeal SE	30	0.84	1.29	1.98	3.35	0.00	4.63	0.00	0.43	0.94
ActiV GP	30	2.31	1.88	1.45	1.73	0.00	7.37	1.17	1.73	2.91
AH Plus	30	0.43	1.31	4.47	21.61	0.00	6.85	0.00	0.00	0.16

N=Sample size; M=Arithmetic mean; SD=Standard deviation; Min=Minimal value in distribution; Max=Maximal value in distribution; Q1=First quartile; Med=Median; Q3=Third quartile; SE=Standard error

Table 2. Differences in apical microleakage among sealers assessed by Mann-Whitney test

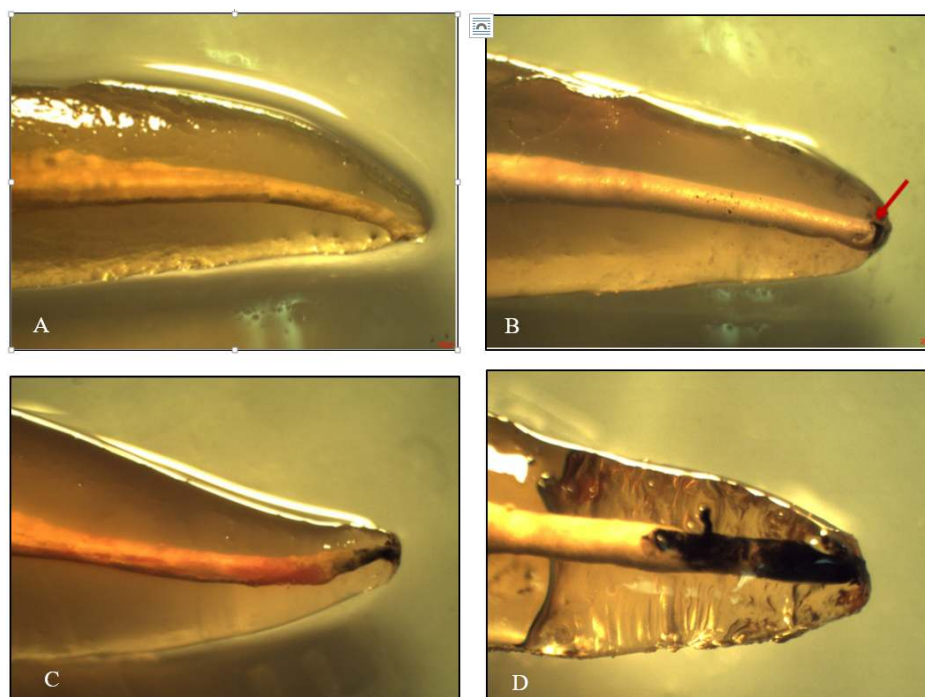
Sealer	N	Mean range	Sum of ranks	Mann-Whitney U	Z	p
EndoREZ	30	35.35	1060.50	304.50	-2.192	0.28
RealSeal SE	30	25.65	769.50			
EndoREZ	30	24.03	721.00	256.00	-2.872	0.00408
ActiV GP	30	36.97	1109.00			
EndoREZ	30	39.53	1186.00	179.00	-4.254	0.000021
AH Plus	30	21.47	644.00			
RealSeal SE	30	21.53	646.00	181.00	-4.015	0.000594
ActiV GP	30	39.47	1184.00			
RealSeal SE	30	35.17	1055.00	310.00	-2.366	0.18
AH Plus	30	25.83	775.00			
ActiV GP	30	42.37	1271.00	94.00	-5.464	0.00
AH Plus	30	18.63	559.00			

Results

Statistical analysis of the results was performed in the Statistical Package for Social Science (SPSS) program, version 20. Stereomicroscopic examination showed complete dye penetration along the full length of the root canals in the positive control group, while no dye penetration was observed in the negative control group. The extent of leakage differed

among the materials in experimental groups (Figure 2).

According to the descriptive statistics (Table 1), ActiV GP demonstrated the highest mean leakage value (2.31 ± 1.88 mm), indicating the greatest extent of microleakage among the tested materials. In contrast, AH Plus sealer exhibited the lowest mean leakage value (0.43 ± 1.31 mm). EndoREZ and RealSeal SE showed intermediate levels of leakage, with mean values of 1.56 ± 2.11 mm and 0.84 ± 1.29 mm, respectively.

**Figure 2.**

Different apical microleakage values observed in the experimental groups.

(A) A sample from the AH Plus group showed no detectable leakage;

(B) Minimal dye penetration was evident in a RealSeal SE specimen;

(C) The EndoREZ group exhibited leakage confined to the apical third;

(D) The sample from RealSeal SE group with significant microleakage.

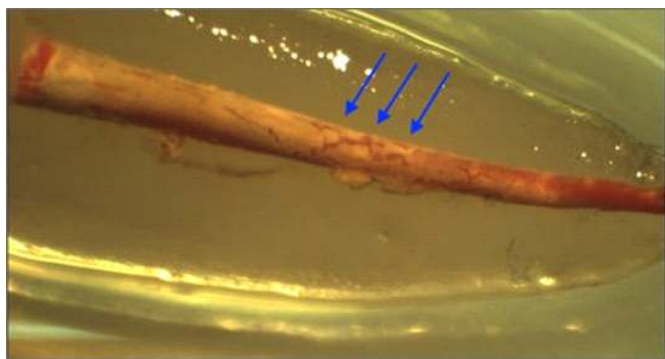


Figure 3. Specimen obturated with the EndoREZ system. The arrows point to cracks within the sealer matrix likely caused by polymerization shrinkage.

Further analyses revealed significantly higher apical microleakage in ActiV GP group compared to other experimental groups ($p < 0.05$). EndoREZ also demonstrated significantly greater leakage compared to the AH Plus/gutta-percha group ($p < 0.0005$). No other statistically significant differences were found among the remaining experimental groups (Table 2).

Discussion

The idea that certain root canal filling materials can form an endodontic monoblock, extending uniformly from one dentinal wall to the other, has attracted considerable attention. Creating a true monoblock through effective sealer bonding could eliminate or significantly reduce microleakage.

All specimens were subjected to the same protocols for canal preparation, dye penetration, and clearing procedure. The only variable was the tested obturation systems.

As stated in the Results section, statistical analysis using the Mann-Whitney U test revealed that ActiV GP had significantly higher apical leakage than all other evaluated materials. The results were statistically significant when compared to EndoREZ ($p = 0.00408$), RealSeal SE ($p = 0.000594$), and AH Plus ($p < 0.0001$).

Several studies have shown that the ActiV GP system tends to have weaker sealing properties compared to other root canal filling materials. Khanvilkar et al. [6] and Kassar et al. – [7] reported the sealing performance of ActiV GP was significantly lower than AH Plus/gutta-percha and RealSeal/

Resilon systems. In a similar in vitro study, Muhammed [8] found that the AH Plus/gutta-percha demonstrated the least apical leakage when compared to ActiV GP and GuttaFlow2. Likewise, Monticelli et al. [9] found a significantly higher leakage value in the ActiV GP system relative to AH Plus/gutta-percha, in line with the present study's outcomes. Although Fransen et al. [5], did not find statistically significant differences among groups, the AH Plus/gutta-percha combination again showed reduced leakage compared to ActiV GP.

The weak apical sealing ability of ActiV GP may be attributed to several factors. Due to its glass-ionomer composition, ActiV GP is prone to water sorption and the gradual leaching of its components [10]. Previous research has shown that glass-ionomer materials tend to undergo slight dimensional changes as they transition from a gel-like phase to a hardened state. This shrinkage during setting may result in microcracks forming at the interface between the sealer and the root canal dentin [7,9]. Additionally, the manufacturer permits adjustment of the powder-to-liquid ratio, which may lead to inconsistency in the sealer's composition and physical properties across different applications.

In our study, EndoREZ exhibited significantly higher apical leakage compared to AH Plus, with a p -value of 0.000021. These findings are consistent with those reported by Rai et al. [11], who used the same methodology as in our study, as well as by Ersahan et al., [12] who used the fluid filtration technique. In study published by Leal et al. [13], statistical differences were not found, but EndoREZ presented inferior sealing ability compared to AH Plus and Apexit Plus sealers. Similarly, Schäfer et al. [14] found that AH Plus exhibited lower solubility, higher radiopacity, and longer bonding time than EndoREZ and RealSeal SE. Conversely, Ballullaya et al. [15] reported lower leakage with EndoREZ compared to AH Plus sealer, likely due to methodological differences and sample size variation.

Our findings are consistent with those of Kim et al. (16), who reported lower microleakage in the AH Plus/gutta-percha combination compared to RealSeal SE, using the glucose penetration method. Veríssimo et al. [17] found superior sealing ability of the Resilon/Epiphany system (chemically identical to Resilon/RealSeal) over AH Plus, attributing this to the formation of a hybrid layer. However, in our study,

no significant difference was observed between AH Plus and RealSeal SE, which may be explained by the larger sample size and the use of a different obturation technique.

Mahdi et al. [18] investigated the leakage of AH Plus/gutta-percha, EndoREZ, and RealSeal using the fluid transport method, reporting no significant differences among the tested systems. Similarly, our study found no statistically significant difference in leakage between RealSeal SE and the AH Plus/gutta-percha. In contrast to Mahdi et al., [18] our results revealed a statistically significant difference between EndoREZ and AH Plus/gutta-percha.

El Sayed et al. [19], using the glucose penetration method, found significantly lower microleakage in the RealSeal SE group compared to the AH Plus sealer, suggesting the superior sealing ability of RealSeal SE. Our study showed no statistically significant difference between these two techniques, although mean microleakage values were descriptively lower in the AH Plus/gutta-percha group. Tay et al. [20] concluded that the chemical bonding between methacrylate-based sealers and Resilon is relatively weak, and significantly lower than the bond strength observed in composite resin systems. This is attributed to the suboptimal concentration of dimethacrylate in Resilon, which reduces its potential for forming strong chemical bonds with methacrylate-based sealers [20]. Opposite results were found in study by Eldeniz and Østravik [21] where Epiphany (chemically identical to RealSeal) prevented leakage significantly better than AH Plus and EndoREZ.

It is apparent that the evaluation of apical microleakage across different studies involved a wide range of techniques and methodologies that are difficult to interpret. Despite mixed results in previous studies, gaps and voids have been observed in root canal fillings using resin-based sealers, including both monoblock systems (such as EndoREZ and RealSeal SE) and conventional resin-based sealers like AH Plus. Apical microleakage in these obturation systems can be attributed to several contributing factors, including polymerization shrinkage, the high configuration factor (C-factor), structural differences in the apical root dentin, and biological degradation.

During polymerization, resin materials shrink as monomers form chains [22,23]. The polymerization contraction can exceed the adhesive bond strength, causing cracks, typically between the resin-coated

gutta-percha and the resin sealer [24]. In our specimens, shrinkage-induced cracks were clearly observed under stereomicroscopic examination (Figure 3).

The configuration factor (C-factor) represents the ratio between bonded and unbonded surfaces [25]. A higher C-factor indicates a increased shrinkage due to reduced material flow during polymerization. In the root canal system, the C-factor can reach high values [25], since nearly every dentin wall has an opposing wall, leaving few free interfaces. The root canal geometry creates an unfavorable conditions that promotes polymerization shrinkage [26]. Unlike direct composite restorations, where incremental layering techniques can be used to minimize volumetric shrinkage, such approaches are not feasible in the root canal [25]. Consequently, the use of a sealer in a thin layer is a logical and clinically recommended strategy, as it helps to reduce the overall polymerization contraction [26,27].

In the apical third of the root, dentinal tubules are less numerous and often sclerotic which limits the formation of resin tags and limits the penetration of resin-based sealers. The differences in the composition and microstructure of root dentin can compromise the sealing ability in apical region and contribute to apical leakage [28].

Previous studies report that Resilon undergoes significant degradation [29,30]. Payne et al. [30] found 78% degradation in nonhealed cases filled with Resilon, compared to 0% with gutta-percha. According to Payne et al. [30], this degradation is related to cholesterol esterase activity, an enzyme secreted by macrophages commonly present in periapical granulomas of infected teeth. The susceptibility of methacrylate-based fillings to bacterial degradation [31] may compromise apical seal by promoting porosity and structural irregularities.

The findings of this study favor AH Plus over EndoREZ, RealSeal SE, and ActiV GP. Its superior performance may be attributed to properties such as low solubility, high flow, minimal polymerization shrinkage, and good adaptation to canal walls [32].

Study limitation

This study was conducted under in vitro conditions, and assessed short-term sealing ability of tested materials.

Conclusion

Monoblock obturation systems have not demonstrated superior sealing ability compared to the conventional AH Plus sealer combined with gutta-percha. Although developed to improve the quality of root canal obturation, these systems have not fulfilled expectations. Consequently, the AH Plus/gutta-percha combination remains a reliable and clinically relevant option in current endodontic practice.

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