

A Scanning Electron Microscope Analysis of Sealing Potential and Marginal Adaptation of Different Root Canal Sealers to Dentin: An *In Vitro* study

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ABSTRACT

Aim: The present study aimed to evaluate the sealing potential and marginal adaptation of different root canal sealers to dentin.

Materials and methods: A total of sixty human lower premolars of the permanent dentition that were extracted were used for this study. The visible debris and calculus were removed from the extracted teeth ultrasonically and were kept for 2 hours in 2.5% sodium hypochlorite and stored in normal saline till next use. A low-speed diamond disc was used to section all the teeth samples at the cemento-enamel junction. Later, cleaning and shaping of the canals was done. Based on the sealer used, the samples (each group consisting of 20 samples) were divided randomly into three groups: group I—bioceramic sealer, group II—resin-based sealer, group III—MTA-based sealer. All split samples were visualized under scanning electron microscope (SEM) at apical and coronal thirds of root canal, the marginal gap at root dentin and sealer interface were assessed.

Results: The highest marginal adaptation (5.60 ± 0.12) was demonstrated by EndoSequence BC sealer, followed immediately by ProRoot MTA sealer (4.48 ± 0.12) and EndoREZ sealer (2.10 ± 0.54). A statistically significant difference ($p = 0.001$) was seen between the EndoSequence BC and ProRoot MTA sealer for apical and coronal marginal adaptation. Also, a statistically significant difference ($p < 0.05$) was found between EndoSequence BC sealer vs EndoREZ sealer at coronal and EndoSequence BC sealer vs EndoREZ sealer and EndoREZ sealer vs ProRoot MTA sealer at apical third.

Conclusion: The present study concluded that significant and better sealing ability and marginal adaptation was demonstrated by EndoSequence BC (bioceramic sealer) when compared to ProRoot MTA sealer (MTA-based sealer) and EndoREZ sealer (resin-based sealer).

Clinical significance: Numerous endodontic sealers enter the market with various factors to attain acceptable seal. According to current study bioceramic sealer, is the appropriate sealer that hermetically seals all the margins.

Keywords: Dentinal tubule penetration, Marginal adaptation, Root canal sealer, Scanning electron microscope.

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INTRODUCTION

Restorations are intended for carious teeth, crowns are made to preserve damaged teeth, and endodontic treatment aims at treatment of pulpally involved teeth. The optimal endodontic obturation technique should essentially offer a dimensionally stable and tight apical seal without fluid leakage so as to avoid any communication between the root canals and the adjoining periapical tissues via the apical foramen. The conventional endodontic treatment is reported to be successful in 79–96% of all the cases.¹

The root canals that are not obturated completely contribute to 58% of endodontic failures. The causes for incomplete obturation may be inappropriate obturation technique or incomplete instrumentation. The root canal sealers that are used during obturation technique should function as a lubricant; seal the minuscule gap between the gutta-percha and the canal wall, and support the seating of gutta-percha cones. The root canal sealers should also seal the patent lateral and accessory canals, bury the bacteria within the tubules of dentin and permit repair of the damaged periapical tissue.²

Previously too much unnecessary emphasis has been placed on whether the filling has reached the radiographic apex or not. Nevertheless, enduring success of root canal treatment (RCT) relies on three-dimensional obturation of root canal. The chief factors responsible for successful RCT are lack of apical and coronal micro leakage, extent of penetration of sealers in to the tubules and sealing off the minute gap between canal wall and sealers. In order

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to minimize micro leakage, the adaptations between root canal wall and sealer has to be excellent which would further increase the root canal breaking strength meaningfully.³

Recently in root canal sealers technology, there have been an improvement in the formulation. The traditional zinc oxide eugenol sealers have been replaced with MTA-based, resin-based, bioceramic-based and silicone-based sealers. Mainly, bioceramic-based sealers are getting popularity because of their chemical stability, alkaline pH within the biological environment, more biocompatible and lack of shrinkage.⁴

Furthermore, deep penetration of the sealer into the tubules advances the fracture resistance of root canal. Thus, an ultimate root canal sealer should penetrate up to the entire depth of dentinal tubules and adapt completely with the root canal walls.⁵ Therefore, this study was undertaken to compare the better sealing ability and marginal adaptation of various root canal sealers to dentin.

MATERIALS AND METHODS

This *in vitro* study was conducted in the Department of Conservative Dentistry and Endodontics, Kalinga Institute of Dental Sciences, Bhubaneswar.

A total of 60 human lower premolars of the permanent dentition that were extracted for orthodontic purpose were used for this study. The extracted teeth were excluded if they had severe curvatures, resorption, incomplete apex formation and/or craze lines. The visible debris and calculus were removed from the extracted teeth ultrasonically and were kept for two hours in 2.5% sodium hypochlorite as extracted teeth must be decontaminated to prevent spread of infection. And then they were stored in normal saline till next use. A low-speed diamond disc was used to section all the teeth samples at the cemento-enamel junction. A K-file #10 (Dentsply Meillefer, OK, USA) was introduced into the root canal to the length until its tip was visible at the tooth apex. In order to attain the working length during the root canal preparation, this length was reduced by 1 mm. A step-back system was followed with hand K-files starting with an initial K-file #25 to master apical file #40. The shaping was continued up to K-file #80. The paper points (DiaDent, Seoul, South Korea) were used to dry the root canals.

Based on the sealer used, the samples (each group consisting of 20 samples) were divided randomly into three groups:

Group I—Bioceramic Sealer [EndoSequence BC (Brasseler, Savannah, GA, USA)]

A syringe tip was used to place the premixed bioceramic sealer up to 2/3rd of the root canal. After dipping the gutta-percha cone in the sealer, it was inserted in the root canal with slow up and down motion until it reaches the full working length. The cone was later seared off at the level of the orifices.

Group II—Resin-based Sealer [EndoREZ (Ultadent Products, Inc)]

Prior to the placement of sealer, the canal has to be moist and not dried. A skin syringe with a mixing tip at the back is used to express the EndoREZ sealer. Gutta-percha point smeared with sealer was inserted up to the working length. The gutta-percha cone was then seared off at the orifice level.

Group III—MTA-based Sealer [ProRoot MTA (Dentsply, Tulsa, OK, USA)]

A self-mixing tip attached to a syringe was used to mix the sealer. The sealer was then applied to root canal space ProTaper. The gutta-percha point layered with sealer was introduced up to the

working length. The gutta-percha cone was then seared off at the orifice level.

Evaluation of Marginal Adaptation Using Scanning Electron Microscopy

The obturated teeth were stored for 1 week at 100% humidity and a temperature of 37°C. The teeth samples were cut vertically using a hard tissue microtome so as to minimize the chances of formation of crack in both the tooth structure and the material. The marginal gap at root dentin and sealer interface was evaluated at apical and coronal third of root canal under SEM.

All the samples were viewed under SEM after being mounted on an aluminum stub which was sputter coated with gold. A single examiner measured the highest gap width as the highest distance between root canal dentin and obturated material with a magnification of $\times 2,000$ (Figs 1 and 2).

Statistical Analysis

A Statistical Package for Social Sciences (SPSS) of version 20 (SPSS Inc. Chicago, IL, USA) was applied to analyze data. The significant difference was evaluated using Kruskal–Wallis tests and Mann–Whitney *U* test. A *p* value of <0.05 was considered to be statistically significant.

RESULTS

The mean and standard deviation of three different sealers was shown in Table 1. The highest marginal adaptation (5.60 ± 0.12) was demonstrated by EndoSequence BC sealer, followed next by ProRoot MTA sealer (4.48 ± 0.12) and EndoREZ sealer (2.10 ± 0.54).

The difference between the apical and coronal marginal adaptation was statistically significant ($p = 0.001$) with EndoSequence BC and ProRoot MTA sealer respectively. However, EndoREZ sealer did not show any difference between the apical and coronal marginal adaptation that was significant (Table 2).

At Table 3, coronal third comparison was done using a Mann–Whitney *U* test. EndoSequence BC sealer vs EndoREZ sealer showed statistically significant difference ($p < 0.05$).

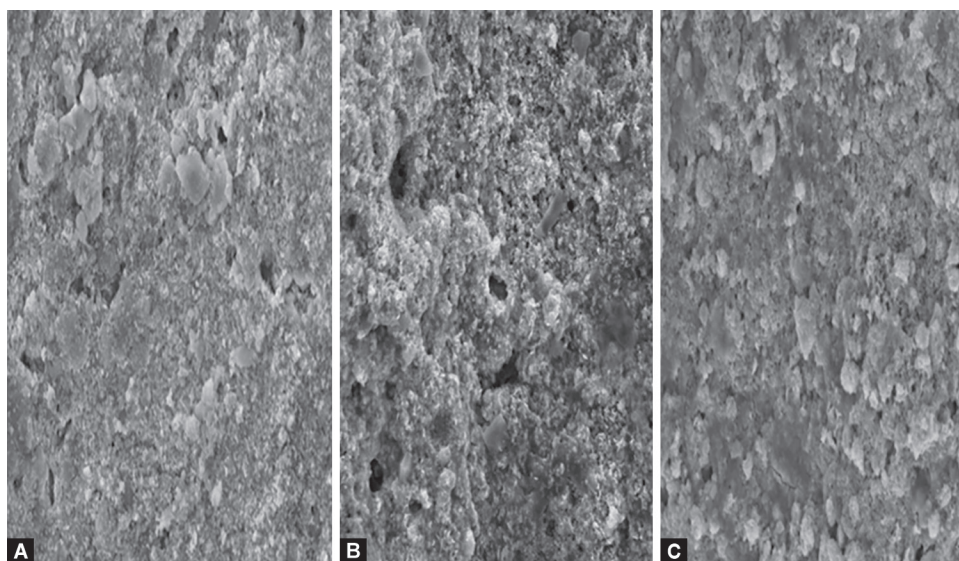
As shown by Table 4, the inter group comparison for the apical third was done. A statistically significant difference ($p < 0.05$) was found for EndoSequence BC sealer vs EndoREZ sealer and EndoREZ sealer vs ProRoot MTA sealer.

The inference of the present study indicates that the EndoSequence BC (bioceramic sealer) significantly has better sealing ability and marginal adaptation followed by ProRoot MTA sealer (MTA-based sealer) and EndoREZ sealer (resin-based sealer).

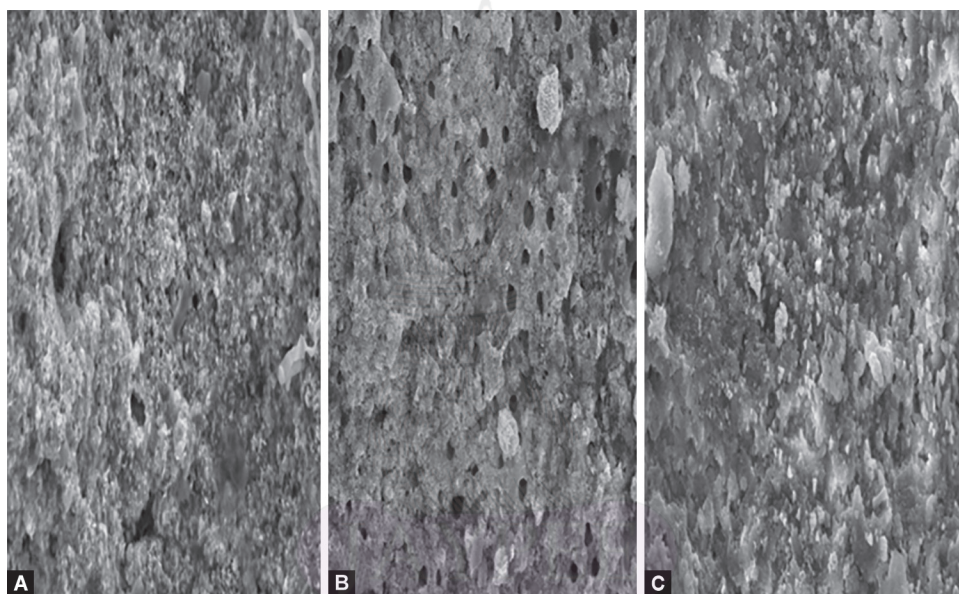
DISCUSSION

The chief objective of obturation technique is to deliver a seal in all three dimensions, thus avoiding the recurrence of infection in root canals and preserve the periapical tissues in a healthy condition. The gold standard in RCTs is obturation of root canals with root canal sealers and gutta-percha. Despite several benefits, root canal sealers have some demerits such as, lack of ability to bond completely with dentin that lines the root canals. On setting, the sealer may also tweak away from the gutta-percha due to its hydrophobic nature.⁶

Previously, several trials have evaluated the sealing ability of the root canal sealers by assessing the extent of microleakage. Yet, there have been disparities in these trials⁷ and the results



Figs 1A to C: Scanning electron microscope images of: (A) EndoSequence BC sealer; (B) EndoREZ sealer; (C) ProRoot MTA sealer at coronal third



Figs 2A to C: Scanning electron microscope images of: (A) EndoSequence BC sealer; (B) EndoREZ sealer; (C) ProRoot MTA sealer at apical third

Table 1: Statistical analysis of mean and standard deviation of three different sealer's marginal adaptations

Sealer's group	<i>n</i>	Mean \pm (SD)
Group I: EndoSequence BC sealer	20	5.60 \pm 0.12
Group II: EndoREZ sealer	20	2.10 \pm 0.54
Group III: ProRoot MTA sealer	20	4.48 \pm 0.12

Table 2: Sealing potential and marginal adaptation of different sealers at coronal and apical levels

Type of sealer	Coronal (mean \pm SD)	Apical (mean \pm SD)	KANOVA value	<i>p</i> value
EndoSequence BC sealer	2.30 \pm 0.01	3.30 \pm 0.11	26.00	0.001
EndoREZ sealer	0.96 \pm 0.04	1.14 \pm 0.50	24.80	0.084
ProRoot MTA sealer	1.68 \pm 0.09	2.80 \pm 0.03	25.44	0.001

Table 3: Intergroup comparison at coronal third

Inter groups	Mean rank	Mann-Whitney U test	<i>p</i> value
EndoSequence BC sealer vs EndoREZ sealer	22.80–6.20	40.20	0.001
EndoSequence BC sealer vs ProRoot MTA sealer	17.58–8.24	14.00	0.38
EndoREZ sealer vs ProRoot MTA sealer	20.03–9.88	37.50	0.06

Table 4: Intergroup comparison at apical third

Inter groups	Mean rank	Mann-Whitney U test	<i>p</i> value
EndoSequence BC sealer vs EndoREZ sealer	24.18–8.30	42.76	0.001
EndoSequence BC sealer vs ProRoot MTA sealer	19.58–8.96	16.10	0.46
EndoREZ sealer vs ProRoot MTA sealer	22.48–1.88	40.88	0.001

have been conflicting.⁸ In the existing study, SEM—a method of histological evaluation has been used to assess the root canal seal quality. Scanning Electron Microscope has greater resolution, improved interface magnification, and superior field depth, which has also been stated by Punithia and Shashikala.⁹

In this study, the highest marginal adaptation was displayed by EndoSequence BC sealer tracked by ProRoot MTA sealer and EndoREZ sealer. Similar findings have been reported by Zhou et al.¹⁰ who demonstrated that EndoSequence BC sealers have reduced film thickness and improved flow. Additionally, Polineni et al.¹¹ described that the sealers may penetrate the dentinal tubules due to alkaline nature of the bioceramic byproducts that denature the collagen fibers of dentin.

EndoSequence BC sealer is a nonaqueous premixed calcium phosphate silicate-based sealer distributed in carriers that are water-miscible and it becomes hard when comes in contact with moist root dentin. In this study, improved marginal adaptation was shown by EndoSequence BC sealer than the other sealers. Hegde and Arora¹² and Pawar et al.¹³ found the hydrophilic sealers to demonstrate increased marginal adaptation and lesser apical micro leakage values. Candeiro et al.¹⁴ established adequate flow values which corresponds with their commendations of ISO 6786/2001.

In our study, EndoREZ sealer demonstrated relatively reduced marginal adaptation. EndoREZ is an UDMA resin-based sealer which has been shown to have hydrophilic characteristics and easy delivery system. This result is unlike those obtained by Mamootil and Messer¹⁵ who found a higher mean maximum adaptation of methacrylate resin-based sealer EndoREZ in their SEM based study. A similar SEM examination was performed by Tay et al.¹⁶ who found a better sealing ability by the EndoREZ sealer in the middle and coronal portions of the root canals.

The most important role of a root canal sealer is to enhance the adaptation of the obturation material to the canal walls and to seal irregularities, without which there would be increased chances of micro leakage and endodontic failures. An optimal root canal sealer should have reduced surface tension to permit improved penetration into irregularities, increased wettability to provide liquid tight seal and must be biocompatible. Insufficient filling of root canal space leads to approximately 60% of endodontic failures. This paved the way for developing novel endodontic substances and obturation techniques.¹⁷

After obturation, the respective sealer samples were kept in humidior to confirm total setting of sealers for 1 week and reduce the sealer's final setting time. In the same way, Nair et al.¹⁸ kept the specimens in humidior for 7 days to permit setting of the sealers. Loushine et al.¹⁹ showed EndoSequence BC to form a more permeable matrix and have increased initial setting time (180 hours) and reduced micro hardness of the set cement with the increase in quantity of water in the course of the setting of sealer.

In a study by Nair et al.¹⁸ the sealing capability of endo sequence and ProRoot MTA was compared using a model based on bacterial leakage and the groups did not show significant difference.

However, the results of current study do not agree with Hirschberg et al.²⁰ who found that the samples in the EndoSequence group leaked significantly more than the samples in the MTA group.

In the current study the teeth samples were cut longitudinally and during this the gutta-percha may get withdrawn from the canals thus modifying the results. Also, the single-rooted teeth that were obturated under ideal conditions in *in vitro* state were used in this study. These above-mentioned factors can be considered

as demerits of our study. It is difficult to clinically reproduce the thin sealer layer caused by obturation. Comparative clinical studies that evaluate the importance of adaptation of root canal sealer to canal walls using with proven adhesion properties are needed in the future.

CONCLUSION

The present study concluded that significant and better sealing ability and marginal adaptation was demonstrated by EndoSequence BC (bioceramic sealer) when compared to ProRoot MTA sealer (MTA-based sealer) and EndoREZ sealer (resin-based sealer).

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