Comparison of bioceramic and epoxy resin sealers in terms of marginal adaptation and tubular penetration depth with different obturation techniques in premolar teeth: A scanning electron microscope and confocal laser scanning microscopy study

Reza Najafzadeh¹, Mahta Fazlyab²,³, Ehsan Esnaashari⁴

¹Post Graduate Student, Endodontics Department, Faculty of Dentistry, Tehran Medical Science, Islamic Azad University, Tehran, ²Assistant Professor, Head of Post-Graduate Department of Endodontics, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, ³Iranian Center for Endodontic Research, Research Institute of Dental Sciences, Dental School, Shahid Beheshti University of Medical Sciences, Tehran, ⁴Assistant Professor, Endodontics Department, Member of Dental Material Research Center, Faculty of Dentistry, Tehran Medical Sciences, Islamic Azad University, Tehran, Iran

Abstract

Introduction and Objective: The proper performance of a sealer in root canal treatment depends on its physical properties. The aim of this study was to investigate the effect of two bioceramic and epoxy resin sealers in terms of marginal adaptation and tubular penetration depth in different obturation methods of human premolar teeth. Materials and Methods: A total of 82 premolar teeth extracted due to caries and gum disease were used in the present *in vitro* experimental study. Two types of sealers, epoxy resin (AH-Plus, Dentsply, Germany) and bioceramic (Endosequence BC sealer, Brasseler, Savannah, GA, USA), were used in this research. Lateral compaction and single-cone techniques were used for filling the teeth. Marginal adaptation and tubular penetration depth were measured by scanning electron microscopy (SEM) and confocal laser scanning microscope (CLSM), respectively. Statistical analysis of data was performed by repeated-measures ANOVA. The significance level was considered as \( P < 0.05 \). Results: The marginal adaptation and tubular penetration depth in all three coronal, middle, and apical regions were better in bioceramic sealer \((P < 0.001)\). The marginal adaptation and tubular penetration depth in all regions were not affected by the filling method and the interaction between the sealer type and the obturation technique. Conclusion: Based on the results of this study, the use of bioceramic sealer caused better depth of tubular penetration and marginal adaptation compared to epoxy resin. Further studies and the use of different filling techniques are necessary to achieve a three-dimensional sealing in curved root canals.

Keywords: Bioceramic, depth of penetration, epoxy resin, lateral compaction and single cone, marginal adaptation, sealer

Introduction

Damage of the pulp due to various reasons causes an urgent need for root canal treatment. The various stages of...
endodontic treatment (root canal therapy) include diagnosis, accurate canal cleansing, and complete filling of the root canal space.\(^\text{[1]}\) Neutralizing the bacterial invasion and destroying the bacterial biofilm formed within the complex anatomy of the canal is necessary to achieve the ideal treatment.\(^\text{[2]}\) Therefore, the apical and coronal areas should be completely blocked to remove all leakage pathways from the tissues around the root into the canal.\(^\text{[3]}\) Sealers fill the small spaces between the canal wall and the main filler and form an impermeable seal.\(^\text{[4]}\) Most sealers can be effective in microbial control by entering the lateral canals.\(^\text{[5]}\) In addition, saliva remaining between the sealer and the walls of the root canal, especially in the presence of a smear layer, can reinfest the root canal.\(^\text{[6]}\)

Available sealers include zinc oxide-eugenol-based sealers, epoxy resin-based sealers, calcium hydroxide-based sealers, and glass ionomer-based sealers.\(^\text{[7]}\) The effectiveness of a sealer depends on its physical properties, such as its seal strength, setting time, solubility, and water absorption in the mouth and surrounding tissues.\(^\text{[8]}\) Epoxy resin sealers have always been considered due to their low solubility and suitable apical seal, but due to their cytotoxicity and genotoxicity, they are less used nowadays.\(^\text{[9]}\) Bioceramic sealers as a new generation of endodontic sealers that due to their small particle size (less than 2 micrometers), non-toxicity, high tissue compatibility, high hydrophilicity, and very small dimensional changes have been considered by many dental professionals.\(^\text{[10]}\) The results of previous studies show that epoxy resin sealers can cause deeper tubular penetration and more marginal adaptation; however, in some other studies, bioceramic sealers have increased deeper tubular penetration.\(^\text{[11]}\) It has also been reported that the type of root obturation technique can be effective in sealer thickness and apical microleakage.\(^\text{[12]}\) Therefore, the present study aimed to investigate the effect of two bioceramic and epoxy resin sealers in terms of marginal adaptation and tubular penetration depth in different methods of obturation for human premolars, including lateral compaction and single cone filling methods by scanning electron microscopy (SEM) and confocal laser scanning microscopy (CLSM).

### Materials and Methods

In the present in vitro experimental study, a total of 80 premolar teeth (mandibular first and second single canal and single-root premolar teeth) were used, which were extracted due to caries and gum disease. Two teeth were also considered as a control group to observe the absence of a smear layer on the dentin wall. Inclusion criteria were single-root, single-canal premolars that had no calcification, internal or external resorption, and additional canals along their root canal system. Exclusion criteria included teeth with internal or external resorption, root caries, immature apex, and previous endodontic treatment. Canal preparation was performed using RaCe rotary system (FKG Dentaire, La Chaux de, Fonds, Switzerland) with the size of 30.06 at the speed of 650 RPM and torque of 1.5 NCm according to the manufacturer’s instructions. The canals were washed using 5 ml of 5.25% NaOCl solution during the preparation of the canals. Further, 17% EDTA solution for 2 min and then 5.25% NaOCl solution for 1 min were used to smear layer removal after preparation. Two types of epoxy resin (AH-Plus, Dentsply, Germany) and bioceramic (Brasseler, Savannah, GA, USA) sealers were used in this study. The teeth were randomly divided into four groups before filling the canals: 1) epoxy resin sealer and lateral compaction filling method, 2) epoxy resin sealer and single cone filling method, 3) bioceramic sealer and lateral compaction filling method, and 4) bioceramic sealer and single cone filling method. In the lateral compaction method, after preparing the canal, a master cone from AH-Plus, Dentsply, Germany or Brasseler, Savannah, GA, USA sealer with the size of 30.04 was impregnated with the walls of the canal and spreader with a size of 20.04 and a length of 1–2 mm were placed along the canal and next to the master cone. After that, the accessory gutta-percha (15.04) was placed inside the canal with pressure (until the spreader entered one-third of the coronal canal) and was filled with normal gutta-percha. In the single cone filling technique, be paired with the canal wall. All gutta percha cones in bioceramic groups were ceramic coated. Finally, the gutta-percha used in the CEJ area were amputated and the teeth were repaired using resin composite, Z250 3M, ESPE and Single Bond, 3M bonding agent (3M, Irvine, California, USA) A3.

In the next step, to complete the setting of the sealers, the teeth were placed in a wet incubator for 2 weeks with a relative humidity of 95% and a temperature of 37°C. All teeth were cut horizontally in three areas, namely coronal, middle, and apical, to check the marginal adaptation by acrylic mounted and using the Mecatome T210 high-speed circular saw (PRESI, Grenoble, France) device. Also, an ultrasonic bath of 17% EDTA solution was used for 2 min; then, an ultrasonic bath of 5.25% NaOCl was used for 1 min to remove the debris created in the teeth after cutting them. The marginal adaptation between the filled material and the canal wall was recorded at the minimum and maximum distances in different areas, including coronal, middle, and apical, by using the Hitachi S-4160 scanning electron microscope (Hitachi, Tokyo, Japan). A confocal laser scanning microscope (CLSM, LSM 5 Exciter, Zeiss, Germany) was used to measure the minimum and maximum of the sealer penetration into the tubules in different areas, including coronal, medial, and apical. Finally, the recorded data related to the mean marginal adaptation and the depth of tubular penetration were statistically analyzed using repeated measure ANOVA. The significance level was considered as $P < 0.05$.

### Results

As shown in [Table 1], in all three areas, including coronal, medial, and apical, the marginal adaptation was not affected by the interaction between the sealer type and the obturation method ($P > 0.05$).

Marginal adaptation of the three areas was not affected by the obturation method, but the amount of marginal adaptation in
all three areas was better in the bioceramic sealer ($P < 0.001$). In comparison between the groups, it was observed that in both types of sealers and both types of obturation methods including single cone and lateral compaction, the marginal adaptation in the coronal area was more than the other two areas and in the middle area was more than the apical area ($P < 0.001$). The depth of tubular penetration in any of the three areas, including coronal, medial, and apical, was not affected by the interaction between the sealer type and the obturation method ($P > 0.05$). Tubular penetration depth in all three areas when using bioceramic sealer was significantly higher than epoxy resin sealer ($P < 0.001$). However, the depth of penetration was not affected by the type of root obturation method ($P > 0.05$). The results presented in [Table 1] show that in both types of sealers and both types of filling methods, the depth of tubular penetration in the coronal area was higher than the other two areas as well as in the middle area was higher than the apical area ($P < 0.001$).

### Discussion

One of the disadvantages of gutta-percha in the treatment of root canal is the inability to connect to the root dentin, which can be minimized using a sealer due to its compatibility with the root canal.\[^{10}\] Creating a three-dimensional seal through the use of a sealer can prevent reinfection of the root canal and periapical tissues. Nearly two-thirds of unsuccessful root canal treatments are due to incomplete filling of the root canal space. Therefore, this has led to the introduction of new and suitable materials that can be used in the treatment of root canals.\[^{10}\] Among the types of sealers available, epoxy resin is widely used in root canal filling due to its strength and adsorption resistance. Recently, a bioceramic-based sealer has been introduced, which has been considered by dentists in terms of physical, chemical, mechanical, and biological properties.\[^{11}\] In this study, a scanning electron microscope (SEM) was used to assess marginal adaptation. In the evaluation of marginal adaptation by SEM in relation to different methods, defects can be observed at the level of less than one micron with the desired magnification. A confocal laser scanning microscope (CLSM) was also used to assess the tubular penetration depth of the studied sealers. The results of the present study showed that the degree of marginal adaptation in the coronal, middle, and apical regions and in both canal filling methods in the case of using a bioceramic sealer was more than epoxy resin sealer ($P < 0.001$). It was also observed that the degree of marginal adaptation was better in both types of sealers and in both types of filling methods in the coronal region than in the medial and apical regions ($P < 0.001$). Consistent with the results of this study, Polineni et al.\[^{13}\] and Huang et al.\[^{13}\] reported that marginal adaptation was less in all groups based on SEM images in the apical part compared to the middle and coronal parts. Remy et al.\[^{14}\] by evaluation the AH plus sealer, also reported that the marginal adaptation of the apical region was significantly lower than the coronal region. In the present study, it was observed that the depth of tubular penetration was not affected by the filling method; however, it was significantly higher in the use of bioceramic sealer than epoxy resin ($P < 0.001$). The depth of tubular penetration in the coronal area was higher than the apical part in both filling methods and in both types of sealers used ($P < 0.001$). The lower density and diameter of dentinal tubules at the apical surface than at the coronal surface cause less permeability of sealer and as a physical barrier interfere with sealer connection to the root canal dentin.\[^{12}\]

The degree of marginal adaptation and the tubular penetration depth were not affected by the interaction between the sealer type and the obturation techniques ($P > 0.05$). Due to its small particle size, hydrophilicity, and low contact angle, bioceramic sealants can easily chemically bond with the dentin walls of the root canal and fill the lateral microcanals. Therefore, establishing a chemical bond without a gap between the sealer and the dentinal walls of the root in the bioceramic sealer has made it an effective sealer.\[^{14}\] The chemical nature of the sealer plays a major role in tubular penetration. Hydrophilic sealers penetrate deeper than hydrophobic sealers.\[^{10}\] The smear layer is an organic compound that is enclosed in mineral dentin and plays a major role in the penetration of sealers, especially in the apical region. Removal of the smear layer improves the performance of the bioceramic sealer by increasing the bond strength between the sealer and the

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**Table 1: Evaluation of marginal adaptation and penetration depth of different root canal sealers used with different obturation methods in all three regions**

| Groups | Epoxy resin sealer | Bioceramic sealer | Significance$^{1}$ |
|--------|-------------------|------------------|------------------|
|        | Lateral compaction | Single cone | Lateral compaction | Single cone | Sealer | Obturation | Interaction |
| Marginal adaptation, $\mu$m | | | | | | | |
| Coronal | 5.49 | 5.64 | 2.31 | 2.07 | ** | NS | NS |
| Middle | 10.8 | 10.1 | 5.64 | 5.38 | ** | NS | NS |
| Apical | 16.6 | 16.1 | 10.2 | 10.8 | ** | NS | NS |
| Penetration depth, $\mu$m | | | | | | | |
| Coronal | 220.4 | 232.7 | 795.3 | 839.2 | ** | NS | NS |
| Middle | 159.3 | 177.8 | 640.5 | 665.9 | ** | NS | NS |
| Apical | 71.6 | 73.2 | 391.7 | 432.1 | ** | NS | NS |

$^{1}$Significance: ** $P<0.001$; * $P<0.05$; NS, not significant
dentin wall as well as reducing bacterial permeability.\textsuperscript{[13]} Epoxy resin sealer contains an epoxy compound as a catalyst and has good biocompatibility and seal, texture tolerance, and long-term dimensional stability. On the other hand, its silicone oil causes shrinkage between sealer and dentin, which is the main problem of epoxy resin sealer.\textsuperscript{[14]} According to El Hachem \textit{et al.}\textsuperscript{[15]} the bioceramic sealer shows a greater depth of tubular penetration, which may be due to the smaller size of the bioceramic sealer particles than the epoxy resin sealer. The average particle size of a bioceramic sealer is 2 \(\mu m\), and the average particle size of an epoxy resin sealer is 8 \(\mu m\). Therefore, the smaller particle size in the bioceramic sealer increases the penetration into the dentinal tubules and can act as a physical barrier to prevent microleakage of the root canal system. Consistent with the results of the present study, Candeiro \textit{et al.}\textsuperscript{[16]} reported that the penetration capacity of bioceramic sealer in dentin tubules was significantly higher than epoxy resin sealer. McMichael \textit{et al.}\textsuperscript{[17]} and Wang \textit{et al.}\textsuperscript{[18]} also reported that the depth of tubular penetration in the use of bioceramic-based sealers was significantly higher than that of epoxy resin-based sealers in different filling techniques.

**Conclusion**

The main purpose of using different types of sealers is to provide three-dimensional sealing that can prevent reinfection of the root canal and maintain the health of periapical tissues. In the present laboratory study, the degree of marginal adaptation and depth of tubular penetration was better when using a bioceramic sealer than an epoxy resin sealer. The degree of marginal adaptation and the depth of tubular penetration were not affected by the root obturation method. To achieve a three-dimensional sealing in curved root canals, it is necessary to further study using different obturation techniques.

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**Conflicts of interest**

There are no conflicts of interest.

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