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Can activation of root canal sealer enhance the penetration into lateral canals?

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Purpose: This study aimed to compare the efficacy of a resin-based canal sealer and a bioceramic canal sealer in obturating lateral canals, with and without the use of activation methods.

Methods: Lateral canals were created at apical positions of 3, 5, and 8 mm in eighty 3D-printed maxillary central teeth. After root canal preparation, the teeth were embedded in 1.5% agar agar to simulate periodontal tissues. The teeth were divided into two main groups based on the type of root canal sealer and further categorized into four subgroups for activation methods: Conventional, EDDY, EndoActivator, and Passive Ultrasonic. Root canals were filled using the single cone technique, and images were captured at 17× magnification. Sealer penetration into lateral canals was measured using ImageJ software. Activation methods were compared using the Kruskal-Wallis test; root levels were compared using the Friedman test, and comparisons between sealers were made with the Mann-Whitney U test at a 95% confidence level.

Results: Activation methods had no significant impact on sealer penetration for both types of sealers. In ultrasonic activation groups, the bioceramic sealer exhibited significantly higher penetration than the resin-based sealer at all root levels. In sonic activation groups, the bioceramic sealer showed significantly superior penetration, especially at the middle root level.

Conclusion: Activation methods did not significantly alter sealer penetration into lateral canals. Bioceramic-based root canal sealer demonstrated enhanced penetration compared to resin-based sealer, especially with ultrasonic and sonic activation.

Keywords: Bioceramic root canal sealer; EDDY; EndoActivator; passive ultrasonic activation.

Introduction

The long-term success of endodontic procedures relies on effectively sealing all openings of the root canal system to prevent bacterial infiltration (1,2). However, anatomical variations such as ramifications and lateral canals can pose challenges in achieving the goals (3,4). Lateral canals are formed due to interruption of Hertwig epithelial root sheath, such as a blood vessel emerged from the dental sac to dental papilla during the development of the dental root (5). The prevalence of lateral canals varies widely, ranging from 27.4 to 99% (3,6,7). Bacteria can potentially harbor in lateral canals, and these lateral canals also serve as a pathway to periodontal tissues for both bacteria and their byproducts, which can incite infection (4,8). Consequently, lateral canals may contribute to the failure of

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endodontic treatment (9-11). Filling the ramifications and lateral canals with sealers can enhance the success of endodontic treatment.

The flowability of the root canal sealer plays a crucial role in filling irregularities and voids within the root canal system, ultimately contributing to the achievement of a hermetic root canal filling (12). The acoustic energy generated by sonic and ultrasonic activation reduces the viscosity of the root canal sealer, increases its fluidity, and enhances its penetration into the canal walls and voids (13,14). Arslan et al. (15) demonstrated that the application of sonic and ultrasonic activation to epoxy-amine resin-based sealer increases their effectiveness in penetrating lateral canals.

There are studies available that evaluate the penetration of different root canal sealers into lateral canals (16-19). However, there is no study in the literature that examines the penetration of bioceramic-based root canal sealers into lateral canals following the application of activation. The aim of this study was to compare the effectiveness of various activation methods applied to two distinct root canal sealers concerning their penetration into the lateral canals. The null hypothesis posited that there would be no differences among the activation techniques.

Materials and Methods

Based on the findings of Wiesse et al. (13) and utilizing one-way ANOVA analysis, G*Power software (version 3.1, Heinrich-Heine-Universität Düsseldorf, Düsseldorf, Germany) with $\alpha = 0.05$, power $(1-\beta) = 0.95$, effect size = 0.7308 and a mean standard deviation of 0.48, the required sample size for each group was determined to be 10. A total of eighty resin-based 3D printed maxillary central teeth, which have anatomic structure derived from real tomographic images of natural teeth, were utilized to assess the flow of filling materials.

The access cavity was created using a high-speed handpiece equipped with #4 carbide round burs. The working length was determined by using ISO #15 K-files, with 1 mm subtracted from the measured length at the point where the file first emerged from the apex. Root canals were instrumented up to Protaper X4 (Dentsply, Maillefer, Ballaigues, Switzerland).

During each file change, the canals were irrigated using 2 ml of 2.5% NaOCl (Cerkamed, Stalowa Wola, Poland) solution. Lateral canals were created on the mesial and distal surface at apical 3 mm, 5 mm, and 8 mm using a #15 engine-driven reamer.

The 3D-printed teeth were placed in 2 ml Eppendorf tube filled with 1.5% agar agar to simulate periodontal tissues. The teeth were randomly divided into two groups, one for resin-based root canal sealer (AH plus, Dentsply Maillefer, Germany) and the other for bioceramic-based root canal sealer (Bioserra, Dentac, Türkiye). Each group was further subdivided into four subgroups for different activation methods.

Before canal filling, the canals were irrigated once more with a NaOCl solution, and ultrasonic activation was performed for two cycles of 20 seconds each. After irrigation, the canals were dried with paper points. ProTaper X4 gutta-percha cones, positioned 2 mm shorter than the working length, were used to transfer the root canal sealer into the root canal. Sealer activations were then applied for each sealer group as described below.

Conventional Activation: A ProTaper X4 gutta-percha cone was positioned 2 mm shorter than the working length. Activation was performed using back-and-forth movements, repeated 10 times to ensure the penetration of the sealer into the lateral canals.

EDDY Activation: An EDDY polyamide tip (size 25/06, VDW, Munich, Germany) was mounted to the TA-200 (Micron, Tokyo, Japan) device and operated at 6000 Hz. The tip was inserted into the root canal, positioned 2 mm shorter than the working length, and activation was applied for 20 seconds, repeated twice.

EndoActivator Activation: An EndoActivator tip size (35/04, Dentsply, Maillefer, Ballaigues) was mounted to the EndoActivator device, and activation was applied for 20 seconds, positioned 2 mm shorter than the working length, repeated twice.

Passive Ultrasonic Activation: A size 25# ultrasonic tip (Woodpecker, Japan) was mounted to the VDW Ultra (VDW, Germany) device, and activation was applied for 20 seconds, positioned 2 mm shorter than the working length, and repeated twice.

After placing and activating the sealer, a ProTaper X4 gutta-percha cone was inserted into the root canal up to working length. Any excess of the gutta-percha cone was removed using a heated instrument, and the access cavities were sealed with temporary filling material.

Images of the teeth were captured using a dental operating microscope (OMG 2350, Zumax, Suzhou, China) at 17x magnification. Photographic images displaying the lateral canal fillings in each specimen were imported into Image Tool software (ImageJ software, version: 2.0.0-rc-43/1.51e, National Institutes of Health, Bethesda, USA). By using the measure tool of ImageJ software, the depth of sealer penetration into each lateral canal was measured and documented as the lateral canal filling percentage by an experienced endodontist (ES) who assessed the sealer penetration into the simulated lateral canals.

Statistical Analysis

Given that the data did not exhibit a normal distribution, as confirmed by the Shapiro-Wilk test, comparisons among activation methods were carried out using the Kruskal-Wallis test, while comparisons between root levels were conducted using the Friedman test. For comparisons between root canal sealers, the Mann-Whitney U test was employed, with a confidence level of 95% (p=0.05). All statistical analyses were performed using IBM SPSS Statistics 20 software (IBM SPSS Inc., Chicago, IL, USA).

Results

A total of 480 lateral canals from 80 teeth were assessed to evaluate root fillings. The primary root canals of all specimens were adequately filled. Therefore, this analysis focused solely on the fillings within the simulated lateral canals. The percentages of root canal sealer penetration into lateral canals at various levels are presented in Tables 1 and 2. In both groups of root canal sealers, activation of the root canal sealer did not yield a significant difference in terms of its penetration into the lateral canals. The localization of lateral canals did not significantly affect obturation ability, except in the passive activation group of the bioceramic canal sealer. The penetration of bioceramic root canal sealers was notably superior to that of resin-based root canal sealers. Particularly in the ultrasonic activation groups, the bioceramic root canal sealer exhibited statistically significantly higher penetration compared to the resin-based root canal sealer at all root canal levels (the p-values were 0.034, 0.000, and 0.027 for the coronal, middle, and apical levels, respectively). In the sonic activation groups, the bioceramic root canal sealer demonstrated significantly greater penetration compared to the resin-based root canal sealer at the middle root levels (p=0.013).

Discussion

During endodontic treatment, anatomical variations such as lateral canals can significantly impact the disinfection, filling, and overall success of root canal procedures (9-11). The effectiveness of lateral canal filling is influenced by the selection of root canal filling techniques and the type of root canal sealer, in addition to their specific characteristics (17-22). In the literature, numerous studies have been conducted to investigate the quality of lateral canal filling in teeth using various root canal filling techniques and sealers (12,15-23). In these studies, researchers either utilized pre-existing lateral canals present in extracted teeth (18) or artificially created lateral canals in these

Table 1. The mean, standard deviation, and quartile values of lateral canal fillings for epoxy-resin based root canal sealer.

	Coronal	Middle	Apical	p
Conventional	81.59 (13.51)	82.74 (18.37)	82.03 (22.36)	
	84.80 (77.42 – 92.45)	84.60 (79.25 – 92.4)	89.00 (77.30 – 96.77)	0.354
EDDY	65.73 (28.44)	79.92 (17.22)	72.20 (29.94)	
	74.90 (42.25 – 86.87)	86.20 (70.50 – 91.62)	82.55 (48.07 – 97.45)	0.186
EndoActivator	78.53 (17.72)	70.82 (25.76)	73.05 (20.85)	
	86.80 (69.95 – 89.97)	80.70 (54.20 – 88.8)	80.10 (61.87 – 85.87)	0.287
Passive Ultrasonic	71.70 (22.98)	78.56 (17.63)	70.42 (23.47)	
	78.70 (61.82 – 87.65)	76.30 (90.02)	77.60 (68.80 – 84.02)	0.819
p	0.241	0.259	0.054	

Table 2. The mean, standard deviation, and quartile values of lateral canal fillings for bioceramic root canal sealer.

	Coronal	Middle	Apical	p
Conventional	66.17 (34.86)	87.43 (11.21)	89.44 (7.97)	
	84.29 (26.73–93.08)	89.63 (82.45–96.23)	90.52 (83.77–95.03)	0.029
EDDY	70.16 (29.33)	89.01 (12.03)	81.41 (20.72)	
	80.62 (51.06–90.67)	92.66 (80.20–99.86)	87.41 (74.58–96.42)	0.262
EndoActivator	84.76 (18.54)	88.12 (9.23)	81.83 (20.98)	
	89.96 (81.26–95.61)	89.94 (83.81–95.35)	89.53 (78.25–95.10)	0.951
Passive Ultrasonic	79.42 (27.67)	90.14 (15.09)	77.26 (30.65)	
	91.42 (73.30–97.39)	94.31 (88.61–97.49)	94.06 (52.21–98.95)	0.157
P	0.219	0.476	0.760	

teeth (15,16,19,21). Additionally, transparent resin blocks (22,24) and plastic teeth (20,23) have been employed in experimental investigations. In this study, resin-based 3D printed teeth, which have anatomic structure derived from real tomographic images of natural teeth, were used due to the challenges associated with achieving standardization in terms of natural teeth's root dentin thickness and the lengths of the lateral canals. Lateral canals were created on resin teeth via a #15 engine-driven reamer because current 3D printing technology faces challenges in forming adequate narrow canals below 0.3 mm in diameter. However, a previous study revealed that only a tiny percentage of teeth have lateral canals wider than a #15 reamer, and in fact, over fifty percent of them have a smaller diameter than #10 reamer (25). In this study, we used a #15 reamer due to its similarity in dimensions to natural lateral canals and its stability and durability during the drilling of lateral canals in specimens.

Upon examining the previous studies, it becomes evident that various methods have been employed to create lateral canals. Fernández et al. (17) prepared artificial lateral canals using a 10-engine reamer at distances of 3, 6, and 10 mm from the apex. In the creation of artificial lateral canals, Arslan et al. (15) used an 8 K-file at distances of 2, 4, and 6 mm from the apex, while Candeiro et al. (12) utilized 6 and 10 K-file. In a separate study that employed decalcification techniques, artificial lateral canals were established at distances of 3, 6, and 10 mm from the root apex by introducing a #10 K-file perpendicular to the external surface (21,26). Almeida et al. (16) employed a 0.1 mm drill to create artificial lateral canals in teeth, positioning them at distances of 3 mm and 6 mm from the root apex. Karabucak et al. (23) created lateral canals on the mesial surface at apical positions of 2 mm, 6 mm, and 10 mm, as well as on the distal surface at apical positions of 4 mm, 8 mm, and 12 mm, using a Quantac file (15/0.2) in plastic teeth. In another study that utilized plastic teeth, prefabricated lateral canals with a width of 0.2 mm were established at distances of 2 mm, 5 mm, and 7 mm from the apex within the teeth (20). The dimensions of lateral canals in natural teeth have been defined in prior studies (6,16,27). Considering the dimensions mentioned in previous studies, artificial lateral canals were formed using a 15 K engine reamer, resulting in lateral canals with an approximate width of 150 µm. These lateral canals were established at distances of 2 mm, 5 mm, and 8 mm from the root apex.

ImageJ is a powerful image processing and analysis software developed in Java. It is highly regarded in scientific research due to its unique capabilities. It can operate on any available operating system. Additionally, it is open-source and free to use. ImageJ can display, edit, analyze, process, save, and print 8-bit to 32-bit images in various formats, including TIFF, JPEG, BMP, GIF, DICOM, FITS, and raw files. The software supports a range of standard image processing functions, including contrast manipulation, sharpening, smoothing, edge detection, and median filtering. It can also compute area and pixel value statistics for user-defined selections, measure distances and angles, and generate density histograms and line profile plots (28). In this study, the software's measure tool, which was run by using the pixel value of images, was employed to determine the penetration rate of the sealers into the lateral canals.

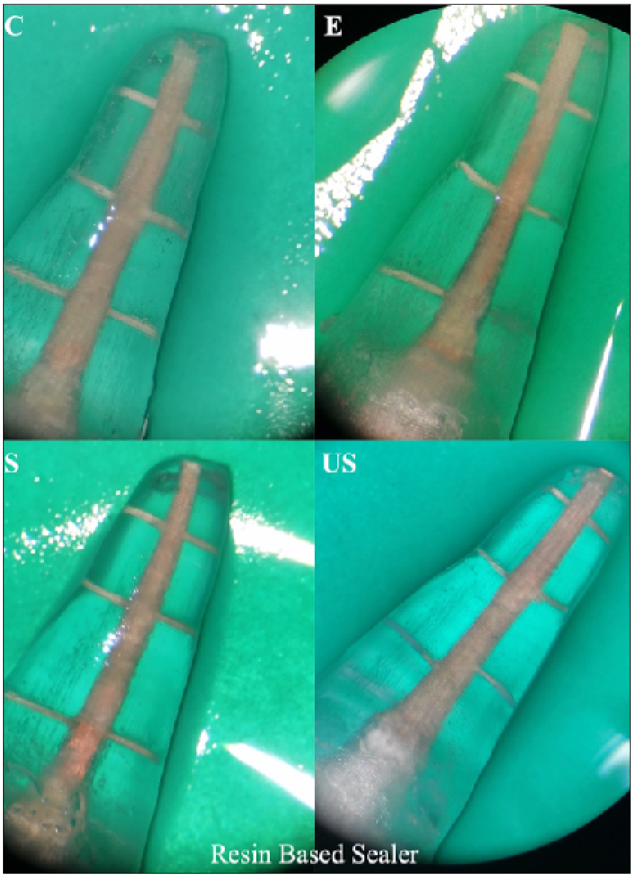

Fig. 1. The images of epoxy-resin based root canal sealer groups (17x). C: conventional activation; E: EDDY activation; S: Sonic activation; US: Ultrasonic activation.

In this study, we compared the effectiveness of various activation methods for root canal sealers regarding their capacity to enhance sealer penetration into the lateral canals (Fig. 1 and Fig. 2). No significant differences were observed among the activation methods for each root canal sealer, leading to the acceptance of the study's null hypothesis. In contrast to our findings, Arslan et al. (15) reported that ultrasonic and sonic activation applied to

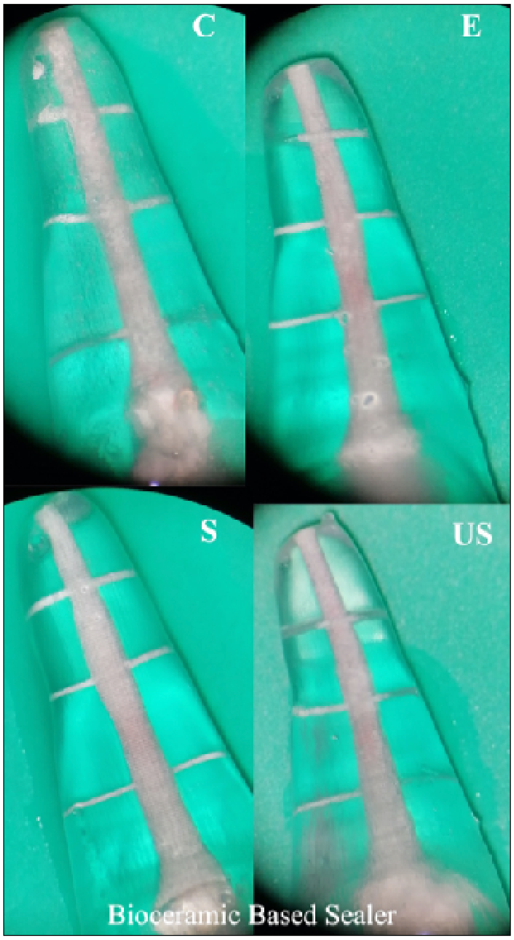

Fig. 2. The images of Bioceramic based root canal sealer groups (17x). C: conventional activation; E: EDDY activation; S: Sonic activation; US: Ultrasonic activation.

epoxy resin-based sealer increased sealer penetration into the lateral canals. We posit that the variation in lateral canal width created in these studies may account for this discrepancy.

Fernández et al. (17) examined the influence of resin and bioceramic-based root canal sealers on penetration into lateral canals. Regardless of the root canal filling technique, they found that resin-based root canal sealers exhibited greater effectiveness. Lopes et al. (14) conducted a study to investigate the penetration effect of resin and bioceramic-based root canal sealers at two different lateral canal widths (19). They reported no significant difference in penetration between the two root canal sealers. However, they observed that an increase in lateral canal diameter, especially when using bioceramic sealers, resulted in improved root canal sealer penetration. In our study, we observed that the penetration of the bioceramic root canal sealer in the sonic activation group (at the middle level) and the ultrasonic activation group (all root levels) was statistically superior compared to the resin-based root canal sealer. We attribute these discrepancies among the studies to potential variations in the diameter of created lateral canals and the choice between using plastic or natural teeth.

While it is indeed more convenient to create narrow canals in resin blocks or plastic teeth, it is essential to recognize that the surface texture can impact the flow properties of both gutta-percha and sealer (24). The use of resin-based teeth represents one of the limitations of this study. Furthermore, it's worth noting that lateral canals with a width of 150 nm were created in this study. Narrower lateral canals, measuring less than 150 nm in width, could potentially yield different outcomes regarding sealer penetration. Conducting further research to assess activation methods at various lateral canal diameters in natural teeth may offer valuable insights in this regard.

Conclusion

This study showed that activation methods and lateral canal location did not significantly affect the penetration of resin and bioceramic sealants into the lateral canals. Notably, in the groups where ultrasonic and sonic activation were applied, the bioceramic-based root canal sealer exhibited superior penetration efficiency into lateral canals compared to the resin-based root canal sealer.

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