Keywords
Bioceramic sealer, Resin-based sealer, Single cone technique, Lateral compaction, Obturation quality, Stereomicroscopy, Voids

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Stereomicroscopic evaluation of quality of obturation in single cone and lateral compaction technique using bioceramic and resin-based sealer: an in vitro study

Abstract

Objectives: To stereomicroscopically evaluate and compare the quality of obturation using single cone and lateral compaction techniques with bioceramic and resin-based sealers.

Methods: In vitro experimental study was carried out on extracted single-rooted human teeth. Samples were made, standardized and separated into four groups, according to obturation technique and sealer type. After obturation, longitudinal sections of the specimens were performed and analyzed using a stereomicroscope to determine adaptation and the presence of voids. The analysis of the data was conducted with one-way ANOVA with the level of significance being $p < 0.05$.

Results: Bioceramic sealer groups demonstrated significantly fewer voids compared to resin-based groups. The lateral compaction technique showed better adaptation and reduced void formation than the single cone technique. The combination of bioceramic sealer with lateral compaction exhibited the fewest voids, while resin-based sealer with a single cone showed the highest void incidence.

Conclusions: Both sealer type and obturation technique significantly influence obturation quality. Bioceramic sealers and the lateral compaction technique provide superior results.

Clinical Relevance: Selection of appropriate sealer and technique is critical for achieving optimal sealing, minimizing voids, and improving long-term endodontic treatment success.

INTRODUCTION

The success of endodontic therapy in the long run heavily relies on the capacity of the obturation material to establish a proper seal in the root canal system [1]. The objective of a good obturation is to entrap remaining microorganisms, coronal, and apical microleakage, and the preservation of the intact periapical tissues in the long term [2]. The filling material should be properly adapted, or there should be no voids in the obturation mass, as this can hamper treatment and put the tooth at risk of reinfection [3].

Root canal sealers are important in ensuring a hermetic seal by sealing gaps between gutta-percha and the dentinal walls. A perfect sealer must exhibit good flow, maintenance of the dimensions when set, a high level of adhesion on dentin, radiopacification, and biocompatibility with periapical tissues [4]. Several sealer formulations have been launched over the years, of which resin-based and bioceramic sealers are regularly employed in modern endodontics.

Particularly, epoxy resin formulations and resin sealers have been extensively used because of their good handling qualities, acceptable sealing capacity, and near conformity to the canal walls [5]. These sealers are highly insoluble and compatible with tissues, but their hydrophobic properties and dependence on mainly micromechanical retention instead of chemical bonding can hamper their use in wet root canal systems [6].

Bioceramic sealers are calcium silicate-based materials that are pre-packaged, ready-to-use systems that are placed in the presence of moisture. Their hydrophilic properties, bioactivity, and the formation of hydroxyapatite in the sealer- dentin interface lead to chemical bonding with the dentin [7]. Also, these sealers have low shrinkage, favorable flow properties, and high biocompatibility, and can improve the adaptation of these products to canal walls and minimize the formation of voids [8].

Another factor of importance in determining the quality of the root canal seal is the obturation technique. Lateral compaction with cold has been considered to be a dependable method because of its capacity to give a compact obturation; nevertheless, it is a technique-sensitive method and time-consuming [9]. When combined with modern sealers, the single cone obturation method, which is a less invasive method, can be used to provide a simpler and less invasive method, with the sealer significantly contributing to the adaptation of the canal walls [10].

Although improvements have been made in obturation materials and methods, the existence of voids in the obturation mass or at the sealer- dentin interface is still a major issue of concern because it could jeopardize the success of endodontic treatment in the long run. Obturation quality has been assessed by various techniques, including radiography, cone-beam computed tomography and micro-computed tomography but stereomicroscopic assessment has been a viable and dependable technique of direct observation of the quality of adaptation and distribution of voids in in vitro research. Thus, a comparative evaluation based on this method can be useful in determining the efficacy of various sealers and obturation tools.

Considering the variations in material properties and obturation techniques, an objective evaluation of obturation quality is essential. Therefore, the present in vitro study was designed to stereomicroscopically evaluate and compare the quality of obturation achieved using single cone and lateral compaction techniques in combination with bioceramic and resin-based sealers. The aim of this study was to compare and evaluate the quality of obturation using single cone obturation and lateral compaction techniques with bioceramic and resin-based sealers.

MATERIALS AND METHODS

Study Design and Setting

This in vitro experimental study was conducted in the "Department of Conservative Dentistry and Endodontics, KMCT Dental College, Calicut", in collaboration with "NIT Calicut". The study was carried out over a period of two weeks under standardized laboratory conditions.

Sample Selection

Extracted human single-rooted teeth with fully formed apices were selected for the study. Teeth exhibiting cracks, resorption, calcifications, or previous endodontic treatment were excluded. All samples were cleaned to remove debris and soft tissue remnants and stored in an appropriate solution until use. The selected samples are shown in Figure 1.

Figure 1: Selected extracted single-rooted human teeth samples used in the study

Tooth Preparation

The teeth were decoronated approximately 1 mm above the cementoenamel junction using a diamond disc under a low-speed handpiece with continuous water irrigation (Figure 2A).

Working length was determined by introducing a file into the canal until it reached the apex, and 0.5 mm was subtracted from this length (Figure 2B) [11]. Biomechanical preparation was then completed using standard instrumentation protocols, followed by irrigation and drying with paper points (Figure 2C).

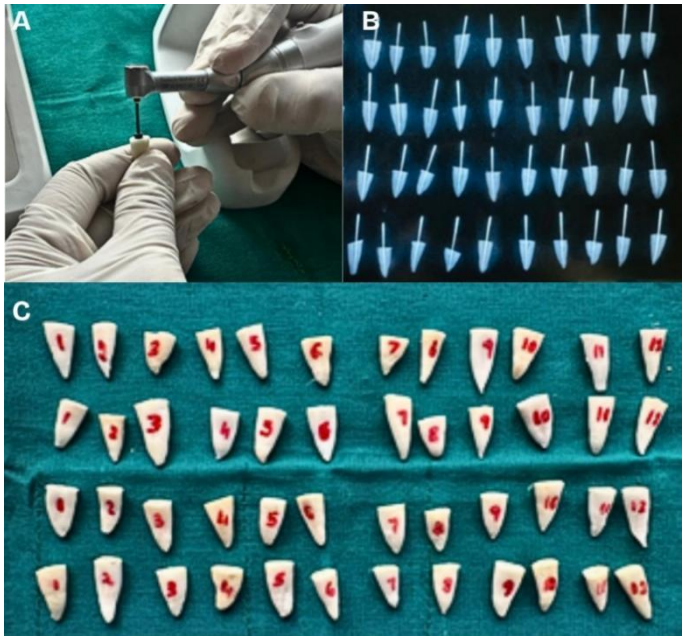

Figure 2: Tooth preparation steps: (A) decoronation of the tooth; (B) working length determination; (C) canal preparation and drying.

Grouping of Samples

Following canal preparation and drying, the samples were randomly divided into four experimental groups as illustrated in Figure 3:

- Group 1: "Single cone obturation with resin-based sealer" (Figure 3A)
- Group 2: "Lateral compaction technique with resin-based sealer" (Figure 3B)
- Group 3: "Single cone obturation with bioceramic sealer" (Figure 3C)
- Group 4: "Lateral compaction technique with bioceramic sealer" (Figure 3D)

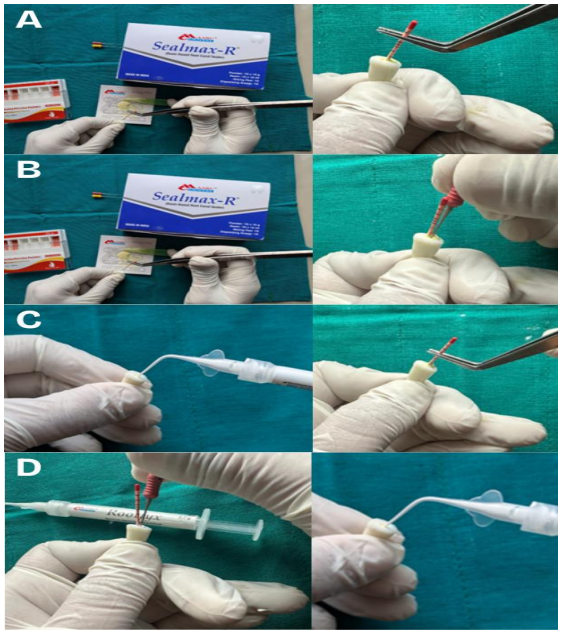

Figure 3: Distribution of samples into experimental groups showing obturation procedures- (A) Group 1: "single cone technique with resin-based sealer"; (B) Group 2: "lateral compaction technique with resin-based sealer"; (C) Group 3: "single cone technique with bioceramic sealer"; (D) Group 4: "lateral compaction technique with bioceramic sealer".

Obturation Procedure

In Groups 1 and 3, obturation was performed using the single cone technique, where a master gutta-percha cone corresponding to the canal size was coated with the respective sealer and placed up to the working length (Figure 3A, 3C).

In Groups 2 and 4, obturation was carried out using the cold lateral compaction technique. A master cone coated with sealer was placed, followed by lateral condensation using a finger spreader and insertion of accessory cones until complete obturation was achieved (Figure 3B, 3D). All procedures were performed under standardized conditions to minimize variability.

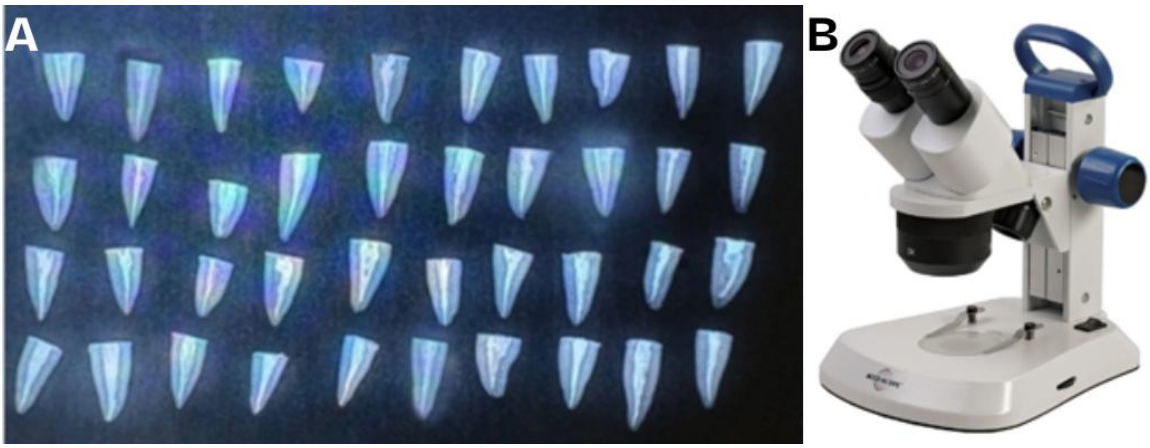

Figure 4: Evaluation procedures - (A) longitudinally sectioned specimens showing obturated canal space; (B) stereomicroscope used for evaluation.

Sectioning and Microscopic Evaluation

After obturation, the samples were longitudinally sectioned along the long axis using a diamond disc to expose the obturated canal space (Figure 4A). The sectioned specimens were examined under a stereomicroscope to evaluate the adaptation of the obturating material and the presence of voids (Figure 4B) [12].

Void Analysis

Voids were identified as empty spaces either within the obturating material or between the material and the canal wall. Stereomicroscopic images of the sectioned samples were used to qualitatively assess the presence and distribution of voids within the obturation mass [11].

Statistical Analysis

All statistical analyses were done with the help of "Statistical Package of Social Sciences" (SPSS) version 20.0. Before the study, power analysis (80%) was carried out. Mean and standard deviation were used to describe the quantitative variables, whereas percentages were used to describe the qualitative variables. There was the application of "one-way ANOVA" to determine differences among groups, and a p-value of less than 0.05 was deemed significant.

RESULTS

The statistically significant differences between the quality of obturation of the four experimental groups were identified through stereomicroscopic analysis. The number of voids in specimens obturated with bioceramic sealer groups (Groups 3 and 4) was significantly less than that of resin-based sealer groups (Groups 1 and 2) ($p < 0.05$).

The single cone obturation groups, including Group 3 ("bioceramic sealer using single cone technique") and Group 1 ("resin-based sealer using single cone technique") showed a significantly lower number of voids compared to the former (Group 3).

In the comparison of the obturation methods, the lateral compaction groups (Groups 2 and 4) adapted to the canal walls better and contained fewer voids in comparison with their respective single cone counterparts (Groups 1 and 3). The fewest voids were in Group 4 ("bioceramic sealer and lateral compaction technique"), and the most voids were in Group 1 ("resin-based sealer and single cone obturation technique").

Stereomicroscopic Evaluation of Groups

Representative stereomicroscopic images of the four experimental groups are presented in Figure 5.

- Group 1: "Obturation with the single cone technique with resin-based sealer had more incidence of voids and relatively poor adaptation to canal walls" (Figure 5A).
- Group 2: "Resin-based sealer with lateral compaction technique exhibited better adaptation and fewer voids than Group 1" (Figure 5B).
- Group 3: "Bioceramic sealer single cone obturation showed better adaptation and reduced voids than Group 1" (Figure 5C).
- Group 4: "Group 4 had the best adaptation with the fewest number of voids and showed adaptation with bioceramic sealer using the lateral compaction technique" (Figure 5D).

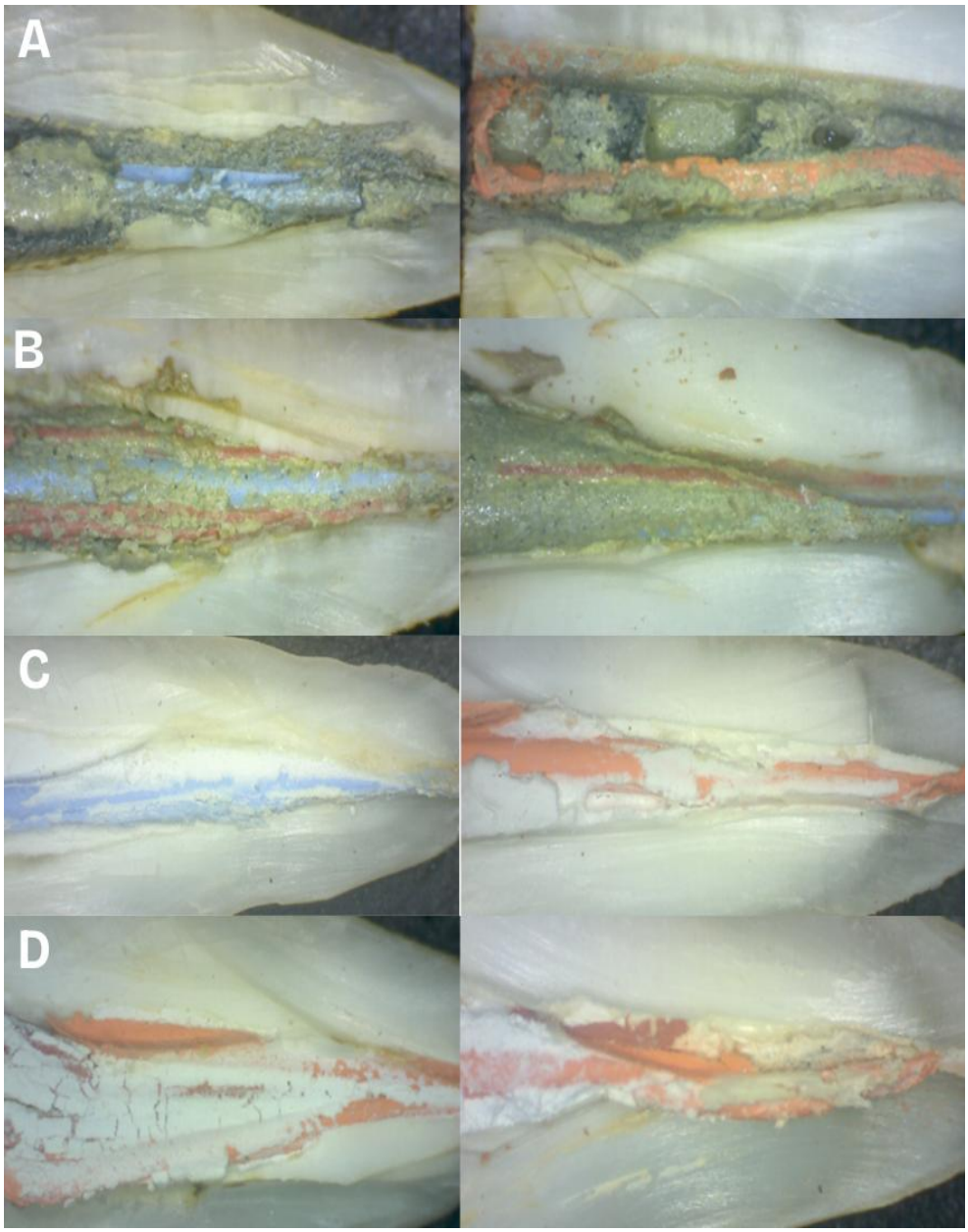

Figure 5: Stereomicroscopic evaluation of obturation quality in different groups - (A) Group 1: "single cone technique with resin-based sealer"; (B) Group 2: "lateral compaction technique with resin-based sealer"; (C) Group 3: "single cone technique with bioceramic sealer"; (D) Group 4: "lateral compaction technique with bioceramic sealer".

Quantitative Analysis of Voids

The statistical analysis was done in "Statistical Package of Social Sciences" (SPSS) version 20.0. Analysis of mean void values in the four experimental groups by the "one-way ANOVA" showed that there were statistically significant differences ($p = 0.001$).

The mean void in the different groups was greatest in "Group 1" (RB-SCO), then "Group 2" (RB-LC), and "Group 3" (BC-SCO), and the least value was found in "Group 4" (BC-LC). The decreasing void formation was found to be gradual between "resin-based sealer groups" and "bioceramic sealer groups"

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In each type of sealer, the lateral compaction method recorded lower mean values of voids than the single cone method. "Group 4" ("bioceramic sealer using a lateral compaction technique") had the lowest value of void formation, which means it adapts better, but "Group 1" ("resin-based sealer using a single cone obturation technique") had the largest value of voids.

Table 1 contains the detailed statistical comparison of mean values, standard deviation, and 95% confidence intervals, and Figure 6 is the graphical representation of the mean values of the voids between the groups.

Table 1: Comparison of mean void values among the four experimental groups with standard deviation and 95% confidence interval

Group	N	Mean	Std. Deviation	95% CI (Lower)	95% CI (Upper)	p-value
RB-SCO	12	554.27	31.76	534.09	574.45	0.001*
RB-LC	12	496.17	160.57	394.15	598.19	
BC-SCO	12	449.41	142.17	359.08	539.74	
BC-LC	12	198.07	58.30	161.03	235.11	

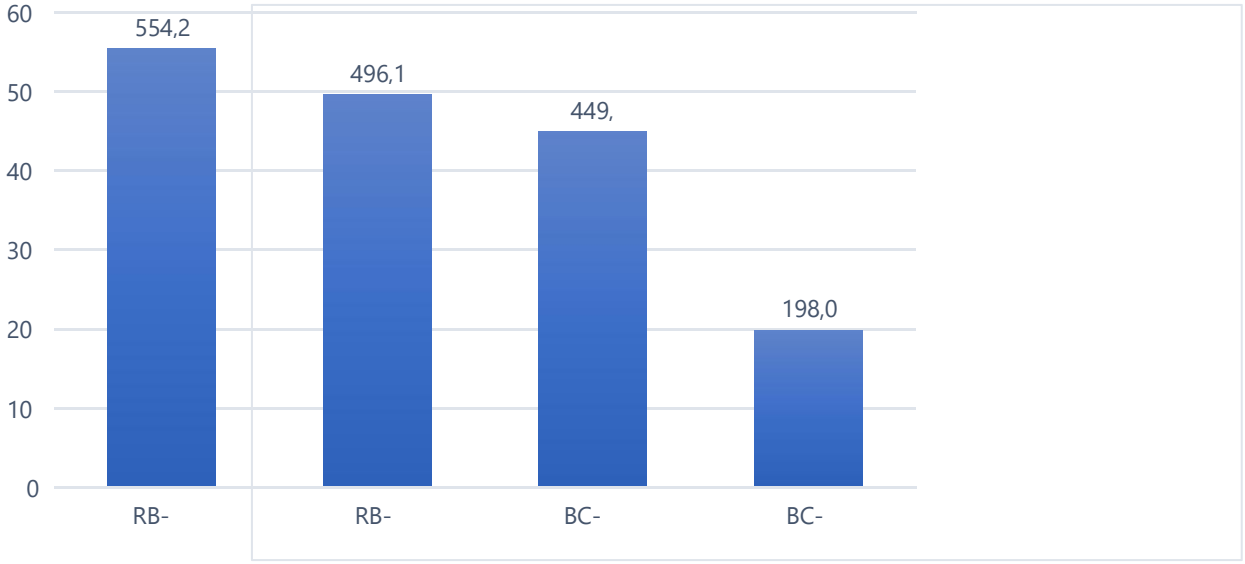

Figure 6: Bar graph representing mean void values among the experimental groups (RB-SCO: "resin-based sealer with single cone obturation"; RB-LC: "resin-based sealer with lateral compaction"; BC-SCO: "bioceramic sealer with single cone obturation"; BC-LC: "bioceramic sealer with lateral compaction").

DISCUSSION

The success of endodontic treatment is closely related to the quality of obturation achieved within the root canal system. A three-dimensional, void-free obturation is essential to entomb residual microorganisms and prevent reinfection by eliminating pathways for microleakage [13]. Despite advances in obturation materials and techniques, the presence of voids within the obturation mass or at the sealer–dentin interface remains a common concern and may compromise the long-term prognosis of endodontically treated teeth [14]. Therefore, continuous evaluation of obturation quality using different techniques and sealers is warranted, which formed the basis for the present study.

Techniques used in obturation are very important in terms of densities and homogeneities of the root canal filling [15]. Cold lateral compaction has long been considered a stable method as it involves a mechanical force of pressing gutta-percha laterally against the sides of canals, which may close any gaps and increase adaptation. Nevertheless, it is time-consuming, technique-sensitive, and the quality of obturation is heavily reliant on the skill of the operator [16]. Conversely, the single cone method is simple, has less chair time, and has low levels of stress on the root dentin. The single cone method has become popular with the introduction of newer sealers with better flow and bonding characteristics, especially when bioceramic sealers are used, which are developed to counter the shortcomings of mechanical compaction [17].

Root canal sealers are part of obturation because they seal irregularities between the core material and dentinal walls and help in the overall seal [1]. Sealers of resin type have been popular because of their good handling characteristics, dimensional stability, and sealing capacity; nevertheless, they have disadvantages such as being hydrophobic, and they are dependent on retention by micromechanical forces, which could inhibit adaptation in the naturally humid root canal [4]. Bioceramic sealers are, on the other hand, calcium silicate-based hydrophilic and bioactive materials that mature in the presence of moisture and form hydroxyapatite at the sealer-dentin interface. This bonding is stronger than with dentin and can lead to better adaptation and less void formation, especially with simplified obturation methods like the single cone method [7].

Multiple techniques have been used to assess voids in root canal obturation, such as periapical radiographs, cone beam computed tomography, micro-computed tomography, scanning electron microscopy, and stereomicroscopy [18]. Stereomicroscopic analysis is a commonly used, practical technique in in-vitro analysis because it provides direct visualization of obturation mass and interfaces at high magnification, and is able to identify and quantify interfaces reliably with a cost-effective technique [19].

Longitudinal sectioning of the specimens was favored in the current study compared to horizontal sectioning because of the ability to have a continuous view of the

obturated canal along its entire length, which enables adaptation and distribution of voids in the coronal, middle, and apical thirds to be analyzed in one section. Horizontal sectioning can be effective in terms of analysis at the level, but it also offers isolated slices and cannot reflect the overall obturation quality [12]. The longitudinal sections also limit the number of cuts to be made on a specimen, and hence structural loss and possible artefactual voids caused during sectioning are minimized [20].

Under stereomicroscopic observations, they were found to be empty spaces either in the obturating material or between the obturation mass and the canal wall. The image analysis was performed on the digital images acquired with the help of the stereomicroscope with the help of ImageJ software, which is a tested image analysis tool widely used in dental studies [21].

The findings of the current research found that obturation that was done with the bioceramic sealer had many fewer voids as compared to the resin-based sealer. Huang et al. reported similar results; they found that calcium silicate-based sealers had lower mean percentages of voids than resin-based sealers with less void volume, especially in the apical third of the canal, although this was attributed to be as a result of final compaction [22].

In the current study, using the single cone obturation method, the bioceramic sealer group had a significantly lower rate of voids in comparison with the resin-based sealer group. This observation is consistent with the results of Silva et al., who suggested the use of the single cone technique, particularly when using calcium silicate-based sealers, since they exhibit good physical and chemical characteristics [23].

The enhanced efficacy of bioceramic sealers can be attributed to the fact that Almeida et al. proposed that the better adaptation of these sealers is associated with the fact that they create a chemical bond with the dentin due to the formation of hydroxyapatite in the setting reaction [24]. Moreover, the lateral compaction method displayed a much lower number of voids as compared to the single cone method, regardless of the sealer employed in the current research. The results are in line with the findings of Nouroloyouni et al., who highlighted that cold lateral compaction still offers a higher quality of obturation compared to the single cone method because of increased mechanical condensation of gutta-percha [11].

In clinical practice, the absence of a void in obturation is needed to achieve the eradication of bacterial leakage and effective long-term treatment. The findings of the present study show that the quality of seals can be significantly influenced by the choice of sealer and obturation technique. Hydrophilic properties of bioceramic sealers and the ability to form a bond with chemicals may be advantageous in a humid canal environment typical of clinical practice. Similarly, techniques with increased mechanical compaction, such as lateral compaction, may enhance the adaptation of obturating materials and reduce the development of cavities. These factors must be considered by clinicians when selecting materials and methods to get the best endodontic outcomes.

Certain limitations of this study should be acknowledged. Longitudinal sectioning can cause sample loss and structural distortion, and certain voids can be artefacts due to sealer handling or sectioning. Moreover, the stereomicroscopic assessment is two-dimensional and thus is not able to analyze the voids volumetrically [19]. New research that includes three-dimensional imaging methods, including micro-CT, and analyzes the long-term clinical outcomes, would yield a more comprehensive view of obturation quality [9]

CONCLUSION

In the constraints of this in vitro experiment, the quality of root canal obturation was revealed to be greatly affected by the nature of the sealer, in addition to the obturation method applied. Stereomicroscopic analysis showed that bioceramic sealer groups adapt better to canal walls and have fewer voids compared to resin-based sealer groups. Lateral compaction continued to perform better than the single cone technique, regardless of the sealer applied, among the obturation techniques. These findings were further confirmed through a quantitative analysis with SPSS that showed statistically significant differences between the groups ($p < 0.05$). The bioceramic sealer with the lateral compaction technique showed the least mean void values, thus indicating that obturation quality was the highest, and the resin-based sealer with the single cone technique presented the highest number of voids. The combination of the bioceramic sealer and lateral compaction technique, though none of the techniques provided a totally void-free obturation, provided the best results. These results indicate that bioceramic sealers could prove a better choice regarding obtaining better sealing capacity due to their better physicochemical characteristics, especially in combination with methods that promote better mechanical adaptation.

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