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ORIGINAL ARTICLE / ARAŞTIRMA MAKALESİ

In Vitro Volumetric Evaluation Of Oval-Shaped Root Canals Filled With Five Different Obturation Techniques

Beş Farklı Obturasyon Tekniği İle Doldurulmuş Oval Şekilli Kök Kanallarinin İn Vitro Hacimsel Değerlendirilmesi

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ABSTRACT

Objectives: This *in vitro* study aimed to compare the volumes of unfilled areas in oval-shaped root canals filled with five different obturation techniques after minimally invasive root canal shaping using cone beam computed tomography (CBCT).

Materials and Methods: 50 extracted mandibular premolars with oval-shaped root canals were used. Root canals were instrumented with K3 files (Kerr, USA) to size #30.04. Then, the samples were randomly distributed into five groups and obturated with different techniques; single cone technique with AH plus (Group A), single cone technique with BIO-C® SEALER (Group B), modified lateral condensation technique with AH Plus using 0.04 GP (Group C), conventional lateral condensation technique with AH Plus using 0.02 GP (Group D) and continuous warm compaction with AH plus (Group E). All teeth were scanned using CBCT before and after obturation. Volume of voids was calculated in each third of the root canal using 3D Doctors software. Kruskal-Wallis and post hoc Dunn tests were used for statistics ($p<0.05$).

Results: Group E showed the least mean volume percentage of voids, whereas Group A showed the highest mean volume percentage of voids in the coronal third, the middle third and overall. However, in the middle and apical thirds, there was no statistically significant difference between the groups regarding the mean volume percentage of voids ($p>0.05$).

Conclusion: The obturation technique effected the quality of obturation minimally in the middle and apical thirds of oval-shaped root canals. The single cone techniques had a higher percentage volume of voids than the continuous wave compaction technique.

Keywords: Obturation techniques, Oval-shaped canals, Cone-beam computed tomography, Volumetric evaluation

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ÖZ

Amaç: Bu in vitro çalışma, minimal invaziv kök kanal şekillendirilmesi sonrası beş farklı obturasyon tekniği ile doldurulmuş oval şekilli kök kanallarındaki doldurulmamış alanların hacimlerini konik ışınlı bilgisayarlı tomografi (KIBT) kullanılarak karşılaştırmayı amaçlamıştır.

Gereç ve Yöntemler: Oval şekilli kanala sahip 50 adet çekilmiş alt küçük azı dişi kullanılmıştır. Kök kanalları 30.04'e kadar K3 eğeler (Kerr, USA) ile şekillendirilmiştir. Daha sonra örnekler rastgele 5 gruba dağıtılmış ve beş farklı teknikle doldurulmuştur; AH Plus ile tek kon tekniği (Grup A), BIO-C® SEALER ile tek kon tekniği (Grup B), AH Plus ile modifiye lateral kondansasyon tekniği 0.04 taper master güta kulanılarak (Grup C), AH Plus ile lateral kondansasyon tekniği 0.02 taper master güta kullanılarak (Grup D) ve AH Plus ile devamlı ısı ile kompaksiyon tekniği (Grup E). Obturasyon öncesi ve sonrası tüm dişler KIBT ile görüntülenmiştir. 3D Doctors yazılımı ile kanalın her bir üçlüsündeki boşlukların hacmi hesaplanmıştır. Kruskal-Wallis ve post hoc Dunn testleri istatistik için kullanılmıştır ($p<0.05$).

Bulgular: Koronal üçlü, orta üçlü ve toplam olmak üzere, Grup E en az ortalama boşluk hacmi yüzdesini gösterirken Grup A ise en yüksek ortalama boşluk hacmi yüzdesini göstermiştir. Ancak, orta ve apikal üçlüde gruplar arasında ortalama boşluk hacmi yüzdesi açısından istatistiksel olarak anlamlı bir faklılık yoktur ($p>0.05$).

Sonuç: Obturasyon tekniği, oval şekilli kök kanallarının orta ve apikal üçlüsündeki obturasyon kalitesini minimum etkilemiştir. Tek kon teknikleri, devamlı ısı ile kompaksiyon tekniğine göre daha fazla boşluk hacim yüzdesine sahiptir.

Anahtar Kelimeler: Obturasyon teknikleri, Oval şekilli kanal, Konik ışınlı bilgisayarlı tomografi, Hacimsel değerlendirme

INTRODUCTION

Three-dimensional (3D) hermetic obturation of the canal space is a critical stage of root canal therapy that impacts treatment outcomes (Kojima et al., 2004; Schaeffer et al., 2005). Voids within the root canal system may cause treatment failures. The proliferation of microorganisms resistant to chemomechanical preparation or having secondary access to the root canal system in these unfilled spaces results in the re-infection of periapical tissues (Whitworth, 2005; Schilder, 2006). Therefore, the quality of endodontic obturation directly influences the treatment success and depends on the level and density of the filling (Clinton&Van Himel, 2001; Al-Ashou et al., 2021).

A wide variety of obturation techniques with different filling materials have been proposed to ensure the hermetic sealing of the root canal system so far (Zan&Demir, 2021). Due to its simplicity and low cost, the most known and widely used obturation technique is the lateral condensation, which is also considered a reference method for evaluating other techniques (Whitworth, 2005; Kalantar Motamedi et al., 2021). The conventional lateral condensation technique is based on the condensation of an ISO-standardized master guta which fits the size of apical constriction and additional auxiliary cones applied to the root canal with a spreader (Kalantar Motamedi et al., 2021). However, voids may occur between accessory gutta-percha (GP) cones and root canal walls because these cones cannot be fully adapted to the irregularities of the root canal walls. Moreover, this technique is time-consuming (Collins et al., 2006; Kalantar Motamedi et al., 2021). To overcome these disadvantages, the lateral condensation technique can be modified by using a more tapered master gutta (0.04 or 0.06 taper) which requires fewer auxiliary cones to fit closely into the prepared root canal space (Kalantar Motamedi et al., 2021).

In a single cone technique, a more tapered master GP matching the size of the final shaping instrument is inserted into the root canal with a sealer. Although being a simple technique with a short working time, the increase of sealer thickness in oval-shaped canals may result in void formation due to the dimensional shrinkage of the sealer during the setting (Whitworth, 2005; Kalantar Motamedi et al., 2021). Recently bioceramic sealers have been suggested for this method due to their sealing ability and slight expansion after setting (Al-Ashou et al., 2021). Besides cold techniques, several thermo-plasticized GP obturation methods have been suggested with their superiority in producing well-dense GP compared to cold techniques (Bhandi et al., 2021).

The recent focus of endodontics is to clean and shape the root canal space while preserving the strength of the tooth. Utilizing low-tapered nickel-titanium (Ni-Ti) files for the conservative preparation of root canals have been suggested to maintain the structural integrity of peri-cervical dentin as much as possible (Gluskin et al., 2014). Even in minimally invasive root canal preparation with minimal taper, current irrigant activation techniques appear to adequately clean the middle and coronal thirds of the root (Plotino et al., 2019).

There have been many studies demonstrating that it is challenging to instrument and fill the root canals entirely in oval-shaped canals (Ozawa et al., 2009). As far as we know, no studies have been done to see how different filling techniques affect the quality of obturation in oval-shaped canals that were shaped using a minimally invasive instrumentation approach. Therefore, this *in vitro* study aimed to compare the volume of unfilled spaces in oval-shaped root canals filled with five different obturation techniques; single cone with AH plus, single cone with BIO-C® SEALER, modified lateral condensation with master GP 0.04 taper, conventional lateral condensation with AH Plus using master GP 0.02 taper, continous warm compaction (Eighteeth Fast pack, Fast Fill) with AH plus. The null hypothesis of the study was that there would be no significant difference regarding the percentage volume of voids between the canals obturated with five different techniques.

MATERIALS and METHODS

The protocol of this in vitro study was approved by the Ethics Committee of Istanbul Aydın University (Protocol no: B.30.2.AYD.0.00.00-050.06.04/146). Human extracted mandibular premolar teeth due to periodontal or orthodontic indications were collected for the study and stored in saline. Initially, bucco-lingual and mesio-distal views of each tooth were obtained using digital periapical radiographs. Teeth with single canal having a ratio of long to short diameter of more than 2, at the 5 mm level and a root curvature less than 10°, as determined by the Schneider's technique were included in the study (Schneider, 1971). Teeth with immature apices, endodontically treated teeth or teeth with root caries, root resorption, root canal obstruction or restorations and fractured teeth were excluded from the study. Based on periapical images, a total of 50 mandibular premolar teeth were deemed suitable for the study.

Tooth preparation

After preparing access cavity, working length was determined using the visual method by inserting10-K file into the root canal until the tip reached the apical foramen. The distance between the reference point to the tip of the instrument was measured and the working length was recorded as 1 mm less than that distance (Olczak et al., 2022). The specimen was placed in a red wax from the cemento-enamel junction to apical foramen to stimulate in vivo conditions. Then, they were embedded into cold-cured acrylic resin blocks. All canals were instrumented with K3 files (Kerr, USA) to size #30.04 taper and irrigated with 2.5% sodium hypochlorite between each file, finally with 17% EDTA for 1 minute and normal saline (5 mL). After all, the canals were dried out with paper points.

Volumetric evaluation before obturation

Biomechanically prepared root canals were scanned with the exposure parameters of 90 kV, 5 mA, 30.8 sec, 250 µm voxel size and field of view (FOV) of 40x40 mm using the 3D Accuitomo 170 system (J. Morita, Kyoto, Japan). Then, images were transferred into the 3D Doctor software (Able Software Corp., Lexington, MA, USA) for 3D volumetric analysis. Before obturation, the volume of the root canal was measured in each third of the root canal (coronal, middle, apical).

Obturation of root canals

After instrumentation of the canals, teeth were randomly distributed into 5 groups (n=10):

1. **Group A :** A 30.04 GP cone was placed into the canal in the working length. Then, the apical third of GP was coated with resin based sealer (AH Plus, DENTSPLY) and was placed into the canal. An endodontic plugger was used gently to condensate the coronal part of the GP.
2. **Group B :** A 30.04 GP cone was placed into the canal in the working length. Then, Bio ceramic sealer (BIO-C® SEALER angulus) was delivered into the apical third of the root canal using an intracanal tip. Also, the apical third of GP was coated with the sealer and gently inserted into the canal, and an endodontic plugger was used gently to condensate the coronal part of the GP.
3. **Group C:** A 30.04 GP cone was inserted to the working length into the canal. Then, the apical third of GP was coated with resin based sealer (AH Plus, DENTSPLY) and was placed into the canal. A #25 spreader (Mani, Tochigi, Japan) was inserted into the canal adjacent to the master cone at a 2 mm distance from the working length. Accessory GP points were placed in the space created by the spreader immediately after its removal.
4. **Group D:** A 30.02 GP cone was placed into the canal in the working length. Then, the apical third of GP was coated with resin based sealer (AH Plus, DENTSPLY) and placed into the canal. A #25 spreader (Mani, Tochigi, Japan) was inserted into the canal adjacent to the master cone at a 2 mm distance from the working length. Accessory GP points were placed in the space created by the spreader immediately after its removal. The canal was filled until a size 25 finger spreader (VDW, Antaeos, Munich, Germany) could not go deeper than 3 mm.
5. **Group E:** A 30.04 GP cone was placed into the canal to the working length. The GP cone was down-packed using a continuous wave obturation technique with 04-50 heating condenser attached to Fast pack (Eighteeth China), leaving 3-4 mm of the remaining GP mass in the apical section. The remaining GP mass was vertically condensed with a size 30 hand plugger. Then, 2-3 mm of thermoplasticized warm GP was injected into the canal in 3 stages for backfill process using Fast fill (Eighteeth China) back fill obturation system with a 23-gauge needle tip.

Finally, a bonding agent (G-Premio bond, GC Corp., Tokyo, Japan) and a composite resin (Beautifil Flow, Shofu Inc., Kyoto, Japan) were used to seal the access openings of the teeth and all samples were kept at a relative humidity of 100% and 37°C for 7 days.

Volumetric evaluation after obturation

Obturated root canals were scanned with the same exposure parameters using the 3D Accuitomo 170 system (J. Morita, Kyoto, Japan). Then, the volume of filling material after obturation was measured in each third of the root canal (coronal, middle, apical) using the 3D Doctor software (Able Software Corp., Lexington, MA, USA) (Fig.

1). Void volume was calculated by subtracting the volume of filling material from the volume of root canal. Also, the percentage volume of voids was recorded.

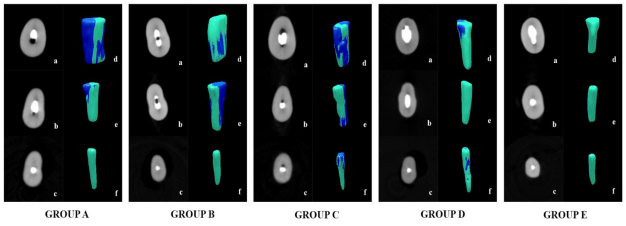

Figure 1: Axial CBCT sections (a: Coronal third, b: Middle third, c: Apical third) and 3D reconstruction models (d: Coronal third, e: Middle third, f: Apical third) of mandibular premolar teeth after filled with five obturation techniques. In 3D models, filling materials are in the green color and voids are in the blue color

Statistical analysis

The data were analyzed using the Statistical Package for the Social Sciences (SPSS, version 22; Armonk, NY: IBM Corp.). Normal distribution of parameters were determined using Shapiro Wilks and Kolmogorov-Smirnov tests. Kruskal-Wallis Test was performed to verify differences between the groups and Dunn's test was performed for post hoc evaluation. The intra-observer reliability in measuring the volume of root canals was calculated using intra-class correlation coefficient (ICC). The statistical significance level was set to $p< 0.05$.

RESULTS

The ICC's revealed high intra-observer reliability for volume measurements before and after obturations (Table 1).

Table 1: Intra-observer reliability for volume measurements

	ICC	%95 CI	p
Before obturation	0.999	0.996-1.000	0.001*
After obturation	0.996	0.989-0.999	0.001*

ICC, Intraclass Correlation Coefficient; *CI,* Confidence interval *$p<0.05$

Regarding the mean volume percentage of voids, in the coronal third, the middle third and overall, group E showed the least mean volume percentage (0.22±0.68, 0.11±0.15, 0.35±0.58; respectively) whereas Group A showed the highest mean volume percentage (22.67±20.42, 8.83±16.23, 16.66±17.48; respectively). However, in the apical third, the mean volume percentage of voids was the highest in Grup C (11.23±17.9) and the lowest in Group D (1.29±2.6) (Table 2).

Table 2: Mean and standart deviations of percentage volume of voids (%) in the study groups

	Coronal third	Middle third	Apical third	Overall
	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)	Mean±SD (median)
Group A	22.67±20.42 (21.8)^{a}	8.83±16.23 (0)^{a}	3.2±5.26 (0)^{a}	16.66±17.48 (11.6)^{a}
Group B	12.38±13.14 (4.3)^{a}	2.44±7.73 (0)^{a}	2.18±6.61 (0)^{a}	8.71±8.2 (6.6)^{a}
Group C	7.09±11.75 (0.7)^{ab}	3.71±8.06 (0)^{a}	11.23±17.9 (0)^{a}	6.71±9.92 (1.8)^{ab}
Group D	0.55±1.25 (0)^{b}	1.09±2.8 (0)^{a}	1.29±2.6 (0)^{a}	0.76±1.07 (0.2)^{bc}
Group E	0.22±0.68 (0)^{b}	0.11±0.15 (0)^{a}	2.07±4.89 (0)^{a}	0.35±0.58 (0)^{c}
p	0.001*	0.188	0.644	0.001*

Kruskal Wallis Test *$p<0.05$

Note: Different superscript letters in each column indicate significant difference.

Overall, the mean volume percentage of voids in Group A and Group B were statistically higher than group D (p=0.002; p=0.009, respectively) and group E (p=0.001). Also, Group C had significantly higher mean volume percentage of voids than Group E (p=0.028) (Table 2).

In the coronal third, the mean volume percentage of voids in Group A and Group B were statistically higher than group D (p=0.007; p=0.032, respectively) and group E (p=0.002; p=0.011, respectively) whereas there was no significant difference between the other groups (p>0.05) (Table 2).

In the middle third and apical third, there was no statistically significant difference between the groups regarding the mean volume percentage of voids (p=0.188; p=0.644, respectively) (Table 2).

DISCUSSION

This *in vitro* study aimed to compare the volume of unfilled spaces in oval-shaped root canals instrumented with minimally invasive approach and filled with five different obturation techniques. The study's findings revealed a significant difference between the obturation techniques regarding the volume of voids. Thus, the null hypothesis was rejected.

Hermetic root canal filling is crucial to prevent reinfection and is associated with the absence of empty spaces after endodontic treatment (Hammad et al., 2009). Nevertheless the filling quality of the root canals can be affected by the cross-sectional shape of the root canal,

which may differ in round, oval, long oval, flattened or irregular morphologies (Jou et al., 2004; Deus et al., 2006). It has always been challenging to obturate the oval-shaped root canals compared to the root canals with a round cross-section (Ozawa et al., 2009). In recent years, especially with the understanding of the importance of irrigation and the effective use of irrigation activation systems, minimally invasive instrumentation has been recommended in endodontic treatment with the philosophy of improving resistance to tooth fracture by preserving the structural integrity of peri-cervical dentin (Tang et al., 2010). Therefore, the present study was conducted in oval-shaped root canals, which were instrumented with low-tapered Ni-Ti files.

Mandibular premolars were used in this study because they are usually oval-shaped, providing a better test of a technique's ability to fill irregularities (Wu et al., 2001). Mandibular premolar teeth with single canal having a ratio of long to short diameter of more than 2, at the 5 mm level and a root curvature less than 10° were included in the present study, in order to standardize the anatomic variance and create well balanced experimental groups. The same operator performed all procedures and was adequately trained in them. In addition, only one periapical radiograph was taken to confirm the adaptation of GP master cone and to avoid operator bias.

In the present study, canals obturated with single cone technique using Ah Plus sealer (Group A) had a higher mean volume percentage of voids than in those obturated with single cone technique using Bioceramic sealers (Group B), which is smilar to those reported by Zare et al (2021). However, this result is in contrary to the findings of Viapiana et al (2016) and De-Deus et al (2022). The differences of findings between the studies could be explained by variable factors of the methodology employed in the studies including sample selection, quality of instrumentation, whether irrigation activation system is used or not, evaluation method, skill and experience of operators.

During obturation, the single cone technique eliminates the need of additional accessory cones without inducing excessive forces on root canal walls. Additionally, using a larger tapered master cone results in increased amount of GP in the canal. This technique is also simple to apply (Whitworth, 2005). However, the cross-sectional shape of Ni-Ti rotary files is primarily round, and while preparing root canals with Ni-Ti files, the file is located in the widest part of the canal and works in this region (Metzger et al., 2010). If the root canal has a round shape in cross-section, the preparation can entirely enclose the original canal, whereas in oval-shaped root canals, which are quite common, there may be areas that remain untouched after preparation, especially in the buccal or lingual part of the canal (Wu & Wesselink, 2001). Unfortunately, using larger files in the preparation to include these untouched areas may result in excessive thinning of the mesial and distal walls of the root and, subsequently in strip perforation (Rundquist & Versluis, 2006). Therefore, irregularities in the walls of oval-shaped canals may occur due to preparation with the rotary files. Then, these irregularities cannot be filled, and voids may occur in these regions.

De-Deus et al. (2008) found that the GP filled areas after obturation of oval-shaped root canals were significantly higher in thermoplasticized techniques than in the lateral condensation technique. Similarly, group E which is a thermoplasticized technique, showed the least mean volume percentage of voids in the present study. Furthermore, Ozawa et al. (2009) measured the cross-sectional area of sealer cement and GP occupied in the canal space of oval-shaped root canals obturated with three different techniques (single cone, lateral condensation technique, and Thermafil). Among these techniques, in the coronal and middle thirds of the root canal, Thermafil had the lowest percentage of sealer and the highest percentage of filling material. Although the sealer-to-GP ratio was not calculated in the present study, the volume of filling material was greatest in the coronal and middle thirds of root canals obturated with warm GP technique (Group E).

In a recent micro-computed tomography (micro-CT) study, single cone and lateral condensation techniques showed similar volume percentages of voids (Penha da Silva et al., 2021). Contrary to the aforementioned study, in the present study, it was found that single-cone techniques (Groups A and B) had higher mean volume percentage of voids than conventional lateral condensation technique (Group D). This difference could be explained by taper and tip size difference of master cones utilized in the studies. Although Penha da Silva et al. (2021) used 0.02 taper master cone with apical size 50 in applying single cone technique , the diameter of master cone at the fifth millimeter from the tip was 0.60 mm. However, in the present study 0.04 taper tip size 30 cone was used and at the fifth millimeter from the tip diametrer of cone was 0.46 mm. This means that although the taper size was small, it fills more places than 0.04 taper. In addition, the use of different

brands of bioceramic sealer (Endosequence BC&BIO-C® SEALER angulus) and different evaluation methods (micro-CT&CBCT) may have an impact on the differences between the findings of the studies. The mean percentage volume of voids was found to be higher in the coronal third of the root canal obturated with single cone techniques using either AH Plus or Bioceramic in the present study. According to our observation, the taper of the GP was insufficient to disperse the sealer properly in the cavities.

Despite the various obturation techniques used in the present study, none of them were able to completely fill the root canal space, which was consistent with previous reports (Keles et al., 2014; Kalantar Motamedi et al., 2021; Dhangar et al., 2022). In group E, the middle third of the root canal showed the least volume percentage of voids, which means excellent adaptation of filling material in the middle third. Besides, among the lateral condensation techniques, in the apical region, the mean volume percentage of voids was found to be the highest in Grup C and the lowest in Group D. This result may be due to the inability of lateral cones to be appropriately placed in the apical region next to the more tapered (0.04) master GP cone (Keles et al., 2014).

Micro-CT imaging is considered to be the gold standart for in vitro stuides of root canals (Celikten et al., 2019). However, it cannot be used regularly in clinical routines. Therefore, CBCT has been an alternative to micro-CT due to its applicability in humans, which was the main reason of choosing CBCT as imaging method in the present study. Unfortunately, one of the main limitations in post-endodontic assessment of root canals using CBCT is the presence of artefacts depends on the density of materials such as GP, root canal sealers and/or other hyperdense materials which results in reduced image quality and overestimation of root canal filling volume (Celikten et al., 2019; Rodrigues et al., 2021). Various procedures for reducing artifacts and improving image quality have been proposed in some CBCT devices, including the exposure parameters of higher kVp, higher mA, restricted FOV with the target object in its center or the use of metal artefact reduction algorithms (Rodrigues et al., 2021). Therefore, the exposure parameters were selected with the guidance of previous reports (Celikten et al., 2019; Rodrigues et al., 2021). Additionally, the CBCT device used in the present study was one of the most preferred device, specifically used for post-endodontic evaluations with higher resolution and low metal artefact formation (Celikten et al., 2019). Besides, ICCs of the observer indicated high reliability of the volumetric evaluations. However, clinicians should keep in mind that there have been several sealers with different material compositions, which can result in different artifacts on CBCT images. Therefore, it should be possible to select materials that are affected by artifacts as little as possible (Celikten et al., 2019; Miyashita et al., 2021).

The present study has some limitations. It was difficult to precisely control the pressure applied during GP cone placement, which may have influenced the sealer distribution in empty spaces in the single cone techniques. The operator's familiarity and hand manipulation with the obturation methods might have an impact on the results.

CONCLUSION

Based on our findings, the obturation technique effected the quality of obturation minimally in the middle and apical thirds of oval-shaped root canals. The single cone techniques had a higher percentage volume of voids than the continuous wave compaction technique, which led to better adaptation of GP to the canal space in the coronal and middle thirds.

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