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BASIC RESEARCH:

Quality Assessment of Matching Single-Cone Obturation in Canals Shaped with Different NiTi Systems: A Micro-CT Study

Evaluación de la calidad de la obturación de conductos radiculares con cono único: un estudio de micro-CT

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ABSTRACT: This study is aimed to evaluate the compatibility of single-cone filling technique in reciprocal and rotationally formed canals in using Micro-CT (Micro-computed tomography). The samples were split into two groups according to the kinematics system used. In both groups, one canal of the shaped roots was filled with the lateral compaction and the other one with a matched single-cone technique with a bioceramic root canal sealer, BioRoot RCS. The percentage of voids in the canal were evaluated by micro-CT radiograph before and after obturation. Regardless of the kinematics used, the single-cone technique left significantly fewer voids than the lateral compaction. In the kinematics comparison, the group shaped with the reciprocal system and filled with the single-cone system had the best results. The reciprocal nickel-titanium (NiTi) system with a matching single-cone gutta percha filling technique was found to be more effective in terms of reducing voids in root canal filling.

KEYWORDS: Single-cone; Rotational; Reciprocal; Matching cone; Micro-CT.

RESUMEN: Este estudio evaluó la compatibilidad de la técnica de obturación de cono único mediante el uso de Micro-CT (microtomografía computarizada). Las muestras se dividieron en dos grupos según el sistema rotatorio utilizado. En ambos grupos, el conducto se obturó con compactación lateral y el otro con una técnica de cono único combinada con el cemento biocerámico BioRoot RCS. El porcentaje de espacios vacíos en el conducto se evaluó mediante micro-CT antes y después de la obturación. Independientemente de la cinemática utilizada, la técnica de cono único dejó significativamente menos espacios que la compactación lateral. El grupo conformado con el sistema recíproco y obturado con el sistema de cono único obtuvo los mejores resultados. El sistema recíproco con una técnica de obturación de gutapercha de cono único es más eficaz en términos de reducir los espacios vacíos en el conducto radicular.

PALABRAS CLAVE: Cono único; Rotación recíproca; Micro-CT.

INTRODUCTION

The objective of root canal treatment is to seal the root canal space in three dimensions and remove any residual pulp, dentin, and microorganisms from the canal space using an efficient chemomechanical preparation. Voids that occur between the root canal filling material and dentine in the root canal space could negatively affect the success of the endodontic treatment due to microleakage (1, 2). Studies have reported that the anatomy of the root canal has a very complex structure, which makes it very challenging to obtain a 3-dimensional root canal filling (3, 4). Despite improvements in shaping systems and obturation techniques, the root canal system cannot be filled completely with root canal filling materials (5, 6).

Root canal fillings with matching single-cone gutta-percha have become incredibly popular as a result of the widespread use of reciprocal and rotational single-file systems. Manufacturers of single-file NiTi systems have produced single cones that have similar dimensions to their files and recommend using matching single cones for obturation (7, 8). This technique has some advantages: it is easy to use, provides more gutta-percha volume in a shorter time, and is economical. The single-cone technique is especially prominent in root canal fillings that use bioceramic root canal sealers.

Matching gutta-percha cones are expected to achieve compatibility with their own files (9). The development of bioceramic root canal sealers and instructions for their use combined with single-cone gutta-percha have supported the advancement of this technique. However, cold lateral compaction is still a commonly used technique (10). Numerous studies have shown that lateral compaction technique obtains comparable results to other warm and cold gutta-percha obturation techniques (11, 12).

Many techniques have been used for evaluation of root canal obturation quality. One of the most common and nondestructive techniques is micro-computed tomography (micro-CT). According to researchers, this technique is more accurate than previous studies by Angerame *et al*. (13), Hammad *et al*. (14) and Moinzadeh *et al*. (15). In this study, we aimed to compare the formation of voids between the lateral compaction and matching single-cone techniques for NiTi files manufactured to be used with different kinematics (reciprocal or rotational).

MATERIALS AND METHODS

This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Istanbul University, Faculty of Dentistry. (Date: 31/07/2019, No:2019/71)

SAMPLE SELECTION

In this study, the mesial roots of mandibular molars with an average root inclination of 20º were used. The inclusion criteria of the selected samples were; completed root development, open canal path, absence of resorption, fractures, or cracks, and the termination of the mesiobuccal and mesiolingual canals with two separate foramen (Vertucci IV) (16). The coronal parts of the samples were removed and standardized to obtain a 16-mm root length. The endodontic working length was determined until the tips of the #10 K-files (Mani Inc., Tochigi-Ken, Japan) inserted in the canal appeared visible at the apex 0.5 mm from this length. All samples were micro-CT scanned before the treatment. The CTVol v.2.2.1 (Bruker, Kontich, Belgium) program was used to create three-dimensional modeling for the micro-CT analysis prior to shaping.

ROOT CANAL PREPARATION

All procedures were performed by a single operator, and each instrument was used only once. The OneFlare file (25/0.09) (MicroMega, Besançon, France) was initially used for coronal enlargement. The file was moved through the canal using a 2- to 3-mm in-and-out motion to create the coronal opening. As instructed by the manufacturer, the OneG file (14/0.03) (MicroMega) was used to prepare the glide path. A 1- to 2-mm in-and-out motion was used in the canal to apply the file along its length. Thirty teeth were divided randomly into two groups after the glide route were created, Group 1 and 2 (https://www.randomizer.org/). Group 1 was prepared with the HyFlex EDM (HEDM) OneFile system (25/0.08) (Coltene, Langenau, Germany). Group 2 was prepared with the WaveOne Gold (WOG) Primary system (25/0.07; Dentsply Maillefer; Ballaigues, Switzerland). One mesial canal of each root was filled using the matching single-cone technique, and the other was filled using the lateral compaction technique, creating 2 subgroups for each group.

- Group 1a (n=15): Canals shaped with HEDM and filled with lateral compaction technique.
- Group 1b (n=15): Canals shaped with HEDM and filled with single-cone technique.
- Group 2a (n=15): Canals shaped with WOG and filled with lateral compaction technique.
- Group 2b (n=15): Canals shaped with WOG and filled with single-cone technique

In both the mesiobuccal and mesiolingual canals of the roots in Groups 1 and 2, the HEDM system was shaped with the X-Smart Plus (Dentsply Maillefer) endodontic motor at a speed of 400rpm and a torque of 2.5Nm with rotational movement according to the manufacturer's recommendations. The file was inserted approximately 2-3mm into the canal and shaped using a pecking motion along the working length without applying pressure.

In both mesial canals in Group 2, the WOG system was used in a reciprocal motion by applying the X-Smart endodontic motor's "WAVE ONE GOLD" mode according to manufacturer's recommendations. It was applied in an in-and-out motion three times along the working length.

During the preparation, apical patency was controlled with a #10 file after each file usage. After each file, a 2.5% sodium hypochlorite (NaOCl) solution was applied to the root canals by attaching a 30-gauge NaviTip needle (Ultradent, South Jordan, ABD) to the tip of a syringe. The final irrigation procedure was applied to remove the smear layer after preparation. First, 5ml of 17% ethylenediaminetetraacetic acid (EDTA) was used for 1 minute. The irrigation process was then finished using 5ml of a 2.5% NaOCl solution and 2.5ml of distilled water. All canals were dried using paper points. All samples were scanned using micro-CT.

ROOT CANAL FILLING

Two different techniques were used to fill the two mesial canals of the shaped roots. Half of the mesiobuccal canals were filled using a matching single-cone filling technique, and the other half were filled using a lateral compaction technique (n=15 each). Both canal filling methods used a #25 Lentulo (Mani Inc.) at 300rpm to apply the bioceramic root canal sealer (BioRoot RCS; Septodont, Saint Maur des Fossés, France) into the root canal.

In the canals of Groups 1a and 2a, where the lateral compaction filling technique was used, 30/0.02 gutta-percha (DiaDent Group International Inc., Vancouver, BC, Canada) was placed along the length of the canal, and a space was created for the accessory cones with the help of a #20 spreader (Mani Inc.) at a 0-2mm distance from the working length. Accessory gutta-percha cones (15/0.02) were immediately inserted in the space that was created from the spreader. A heated instrument was used to remove the excess gutta-percha. A plugger was applied to help with vertical compaction.

Matching single-cone of HEDM gutta-percha (25/0.08) was used in Group 1b and the WOG matching single-cone gutta-percha (25/0.07) was used in Group 2b in accordance with the working length of the root canal. A heated instrument was used to remove excess gutta-percha in the coronal part. A plugger was used to help with vertical compaction. The samples were stored in an incubator at 37°C and 100% humidity for 1 week after the canal filling procedure, and then all samples were scanned with micro-CT.

MICRO-CT ANALYSES

The SkyScan 1172 instrument (Bruker) was used to scan specimens before preparation, after preparation, and after obturation. Specimens were photographed using an 11-MP camera operating at 80kV. Cross sections (13.68µm) and slices (2,000×1,330 pixels) were obtained for each specimen. A camera exposure length of 2,400ms was used for scanning (360 rotations around the vertical axis), with 2×2 binning and a rotation step of 0.5. Horizontal sections of specimens were analyzed using the NRecon software (version 1.6.4; Bruker). Beam hardening was performed with smoothing set to 2 and an attenuation factor of 0.09. The reconstructed images were imported into CTAn software (version 1.18.8; Bruker) for three-dimensional calculations. Dentine, filling, and void volumes were measured by micro-CT for each specimen; filling and void percentages were determined for all thirds and for the entire canal.

STATISTICAL ANALYSES

The filling qualities of the lateral compaction technique and single-cone gutta-percha technique prepared with two different NiTi systems (HEDM and WOG) were evaluated in terms of voids. SPSS software (ver. 25.0; IBM Corp., Armonk, NY, USA) was used for statistical analyses. The Kolmogorov-Smirnov test and histograms were used to determine whether variables were normally distributed. Descriptive statistics, including means, standard deviations, medians, and interquartile ranges, were generated. Comparisons of non-normally distributed (nonparametric) variables were performed using the Mann-Whitney U test (for two groups) or Kruskal-Wallis test (for three or more groups). A p-value threshold of <0.05 was presumed to indicate statistical significance.

RESULTS

Table 1 shows the percentage of voids and fillings in the root canal filling, both along the canal and separately in the apical, middle and coronal thirds regardless of the kinematics used. When the voids formed along the root canal are compared by considering the entire root canal space, it was found that the samples filled using the single cone technique (Groups 1b and 2b) had significantly fewer voids than the samples filled using the lateral compaction technique (Groups 1a and 2a) ($p<0.05$). There were no statistically significant differences in the percentage of voids in the apical third between the two filling techniques ($p>0.05$). However, there were significantly fewer voids in the groups filled using the single-cone technique (Groups 1b and 2b) compared to the lateral compaction technique (Groups 1a and 2a) in the middle and coronal thirds ($p<0.05$).

Table 2 displays the regional evaluation results for all study groups (apical, middle, and coronal third). In the comparison between the single-cone groups (Groups 1b and 2b), no significant differences were observed in terms of voids in the middle and coronal thirds ($p>0.05$), but the group shaped with HEDM and filled with the single-cone technique (Group 1b) had significantly more voids than the group shaped with WOG and filled with the single-cone technique in the apical third ($p<0.05$). When the groups using the lateral compaction technique (Groups 1a and 2a) were compared, the group shaped with HEDM and filled with lateral compaction (Group 1a) had significantly more voids than the group shaped with WOG and filled with lateral compaction (Group 2a) in the apical third. There were no significant differences between the remaining spaces in the middle and coronal thirds ($p>0.05$). Groups 1b (HEDM+SC) and 2b (WOG+SC) had the best results in the apical third. The group using HEDM and the lateral compaction technique (Group 1a) had the least desired results. Similar to the apical third, Groups 1b and 2b also had the best results in the evaluation of the middle and coronal thirds, while the worst results were obtained in Group 1a. Group 2b (WOG+single cone) had the best results in the assessment in terms of total canal volume. Examples of voids formed in the root canal filling are shown in the colour green along the entire canal, while example of voids formed in the axial section are also shown with arrows in Figure 1.

Table 1. Comparisons of single-cone and lateral compaction filling techniques.

		Filling Technique				p
		Single-Cone		Lateral Compaction		
		Mean ± SD	Median (IQR)	Mean ± SD	Median (IQR)	
Apical third	Void (%)	1.64±2.20	1.09 (0.3–1.95)	1.39±2.35	0.73 (0.25–1.80)	0.416
	Filling (%)	98.36±2.20	98.91 (98.05–99.70)	98.61±2.35	99.27 (98.20–99.75)	0.416
	Void (%)	0.75±1.31	0.27 (0.07–0.87)	3.92±3.46	2.99 (2.00–4.59)	<0.001
Middle third	Filling (%)	99.25±1.31	99.73 (99.13–99.93)	96.08±3.46	97.01 (95.41–98.00)	<0.001
	Void (%)	0.77±1.27	0.28 (0.13–0.80)	2.78±2.21	2.34 (0.95–4.76)	<0.001
Coronal third	Filling (%)	99.23±1.27	99.72 (99.20–99.87)	97.22±2.21	97.66 (95.24–99.05)	<0.001
	Void (%)	1.05±1.68	0.36 (0.12–1.28)	2.70±2.89	1.86 (0.59–3.96)	<0.001
	Filling (%)	98.95±1.68	99.64 (98.72–99.88)	97.3±2.89	98.14 (96.04–99.41)	<0.001

Table 2. Comparison of all groups between each other (Group 1a: HEDM+lateral compaction; Group 1b: HEDM+single cone; Group 2a: WOG+lateral compaction; Gorup 2b: WOG+single cone).

			Group 1a	Group 1b	Group 2a	Group 2b	Group 1a:1b	Group 1a:2a	Group 1a:2b	Group 1b:2a	Group 1b:2b	Group 2a:2b
Apical	Void %	Mean±SD	2.29±3.10	1.88±1.85	0.50±0.35	1.41±2.55	0.917	0.026	0.271	0.007	0.245	0.561
	Filling %	Mean±SD	97.71±3.10	98.12±1.85	99.50±0.35	98.59±2.55	0.917	0.026	0.271	0.007	0.245	0.561
Middle	Void %	Mean±SD	4.35±4.44	1.05±1.50	3.50±2.18	0.45±1.05	0.004	0.852	0.001	0.001	0.13	<0.001
	Filling %	Mean±SD	95.65±4.44	98.95±1.50	96.50±2.18	99.55±1.05	0.004	0.852	0.001	0.001	0.13	<0.001
Coronal	Void %	Mean±SD	3.34±2.60	1.03±1.69	2.22±1.64	0.51±0.59	0.007	0.29	0.002	0.007	0.604	0.001
	Filling %	Mean±SD	96.66±2.60	98.97±1.69	97.78±1.64	99.49±0.59	0.007	0.29	0.002	0.007	0.604	0.001
Total	Void %	Mean±SD	3.33±3.49	1.32±1.69	2.07±1.99	0.79±1.65	0.001	0.171	<0.001	0.028	0.049	<0.001
	Filling %	Mean±SD	96.67±3.49	98.68±1.69	97.93±1.99	99.21±1.65	0.001	0.171	<0.001	0.028	0.049	<0.001

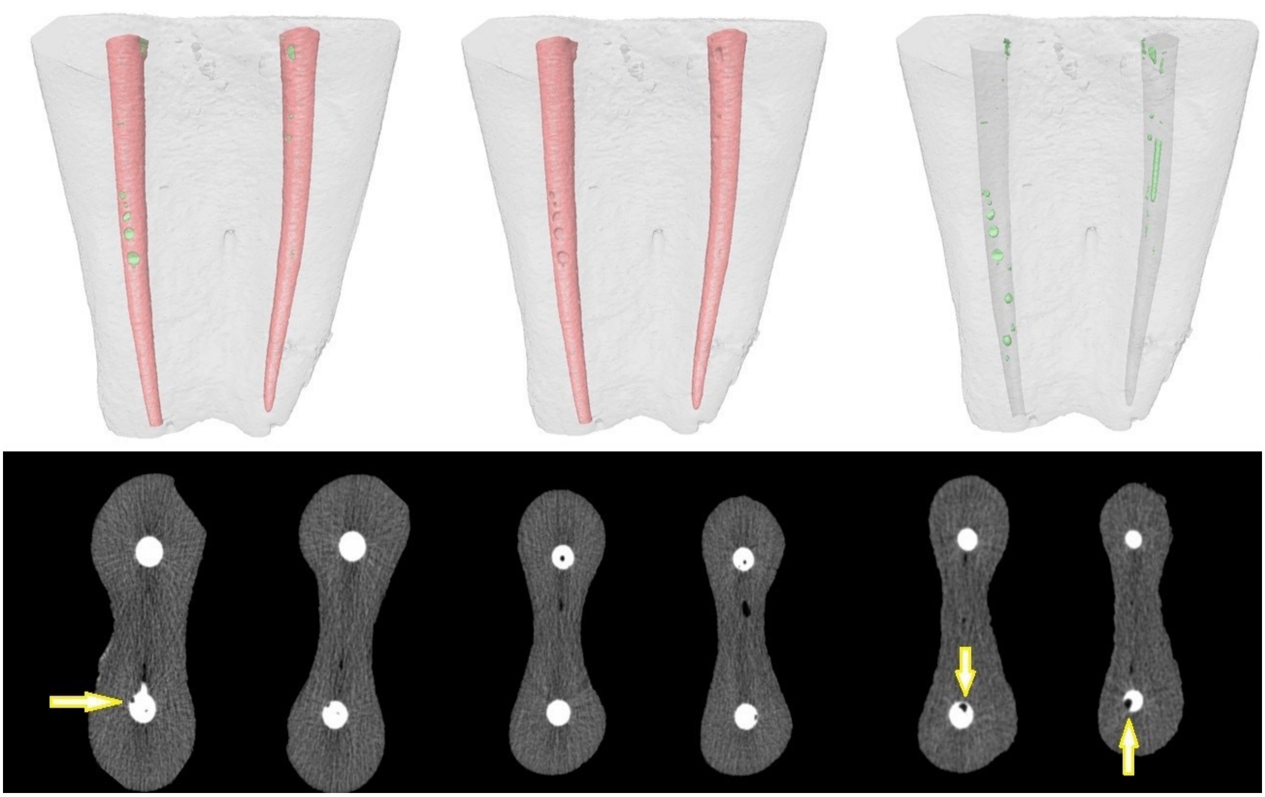

Figure 1. Examples of voids formed in the root canal filling shown along the root canal filling and axial section.

DISCUSSION

Voids between the root canal filling materials and the dentin wall may have a negative impact on the prognosis (17, 18). The purpose of the study was to evaluate the efficacy of the single-cone technique, which has recently gained popularity, in canals shaped with different kinematics. The success of canal filling is significantly influenced by the complexity of the canal anatomy (19). Because of their moderately complex anatomy and inclination, the mesial roots of mandibular molars were chosen for this study. Teeth ending in two separate foramens were preferred because the root canal formations in mandibular molars that end in the same foramen (Vertucci Type 1) may not provide accurate results in the evaluation of the root canal filling quality (5, 20). In this study, the single-cone system recommended by the manufacturers of NiTi instrument systems, especially for root canal fillings made with a bioceramic-based sealer, was compared with the traditional lateral compaction technique. Micro-CT, which allows for accurate three-dimensional examination and has been frequently used in similar studies (5, 13, 21, 22), was used as the evaluation method.

Regardless of the kinematics used, the single-cone technique was superior to the lateral compaction technique in the middle and coronal thirds due to fewer voids ($p<0.05$). However, in the apical third, there were no significant differences between the two filling methods ($p>0.05$). These results are supported by the findings of Moinzadeh *et al*. (15), Igleacias *et al*. (5), and Mancino *et al*. (23). Wu *et al*. (24) compared the single-cone and lateral compaction techniques and found that comparable result were obtained in the apical third. This is due to the canal's morphology, as it has a more rounded structure in the apical third. For the lateral compaction technique, more voids were observed in the middle and coronal thirds in this study. Hammad *et al*. (14), Zogheib *et al*. (25), and Keleş *et al*. (26) found similar results in their studies and indicated that the reason for void formation was the application of the spreader during the lateral compaction technique. In contrast, some studies found that the lateral compaction technique was superior to the single-cone technique (27-29). The imaging technique employed (29), the type of canal sealer (27), and the tooth type (28) could all be reasons for these different results.

Other than kinematics, the inconsistency in dimensions between the file and gutta-percha is one of the causes of void formation in root canal filling. The diameters of the gutta-percha were sometimes found to be greater than the file diameters in previous studies investigating the dimensional compatibility between compatible files and gutta-percha (7, 8, 30, 31). According to Bajaj *et al*. (30), Chesler *et al*. (31), and Mirmohammadi *et al*. (7), the WaveOne file and its own gutta-percha were more compatible regarding their dimensions than the other NiTi systems. Regarding the kinematics utilized, there were significantly fewer voids in the root canals formed by reciprocal movement compared to rotational movement ($p<0.05$). Previous studies (7, 30, 31) support the results of the current study. No previous studies have compared the compatibility of the file system and gutta-percha with the WOG or HEDM instrument systems.

The root canals were sealed with gutta-percha and bioceramic-based root canal sealer using either a single-cone or lateral compaction technique. Depending on the technique, different degrees of voids were found. None of the root canal filling techniques used in the study were able to completely fill the canals. Gordon *et al*. (12), Igleasias *et al*. (5), and Motamedi *et al*. (32) all had similar findings. Although it is stated that with thermomechanical compaction technique, the adaptation of the single cone used with bioseramic sealer is significantly better in middle thirds of the canals (33). In this study, the majority of voids were found in the apical third of the root canal space.

CONCLUSION

In terms of root canal filling techniques, the single-cone technique showed better results than the conventional lateral compaction technique regardless of the kinematics (reciprocal or rotational movement) in terms of void formation throughout the filling in the root canal. Using the single-cone technique with a bioceramic-based sealer (which is commonly used nowadays) according to the manufacturer's instructions can be effective to avoid void formation in the root canal filling.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

AUTHOR CONTRIBUTION STATEMENT

Conceptualization and design: F.H and A.Ö.
Literature review: A.Ö.
Methodology and validation: F.H. and A.K.
Investigation and data collection: A.Ö.
Data analysis and interpretation: A.K. and A.Ö.
Writing-original draft preparation: A.Ö. and G.K.B.
Writing-review & editing: F.H. and G.K.B.
Supervision: F.H.

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