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Assessing various root canal filling methods in significantly curved canals using an in vitro investigation using micro-computed tomography- an invitro study.

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Abstract

Aim: To fill the severely curved root canals with different filling techniques and to compare these techniques using micro-computed tomography (micro-CT).
Materials and methods: Sixty extracted mandibular first molars (degree of root canal curvature >25) were selected. All samples were divided into four groups and filled with one of the following techniques: lateral condensation, single-cone, continuous-wave obturation, and core carrier. After they were scanned by micro-CT, the total area, filled area and void area of the root canal were calculated. The Mann–Whitney U and Kruskal–Wallis tests were used for statistical analysis ($p< 0.05$).
Results: It was shown that significantly more filling material was used in the lateral condensation and core carrier technique groups at 2 and 5 mm than in the single-cone and continuous-wave obturation technique groups ($p< 0.05$). It was observed no statistically significant difference at 8 mm ($p> 0.05$).
Conclusion: No technique could completely fill in root canal. Regarding the coronal part, all

techniques can be used for more effective filling as long as a good condensation is achieved. The use of a plugger with an optimal size according to the localisation of root canal curvature and the choice of a heat-resistant root canal sealer affects the success of the treatment in the thermoplastic techniques.

1. Introduction

The removal of pulpal tissue and necrotic materials, cleaning, biomechanic preparation, and complete canal filling are all necessary for endodontic therapy to be successful. The form of the root canal is also crucial for endodontic success. The root canal filling is affected by the degree of root canal curvature (Leung and Gulabivala, 1994; Neuhaus et al., 2016). The most popular method for characterizing the curvature was Schneider's 1971 study. Schneider (1971) distinguished three groups according to the degree of curvature: severe (25–70), moderate (10–20), and straight (5 or less). The root canal morphology can be precisely and non-invasively examined using micro-CT. The mineral concentration of anatomical structures is also measured by micro- CT, with a resolution of 5–30 lm and an accuracy of greater than 1% (Swain and Xue, 2009). The micro-CT and stereomicroscopic images of the accessory canals of the maxillary and mandibular roots showed a statistically significant correlation (Acar et al., 2015). Several root canal filling techniques are used during endodontic treatment, with lateral condensation as the most commonly used technique (De Moor and Martens, 1999; Cailleteau and Mullaney, 1997; Al-Dewani et al., 2000; Gilhooly et al., 2001). Although it is easy to control the working length during condensation, it can not fill irregularities in root canal as well as warm filling technique (Gilhooly et al., 2001; Wu and Wesselink, 2001). However, warm techniques have some disadvantages. The gutta-percha expands when heated, and during cooling it contracts. Therefore it may result in voids inside root canal filling (Schmalz and Ho¨ rsted- Bindslev, 2010; Peng et al., 2007).
The current study's objectives were to fill the curved root canals with lateral condensation, single-cone, continuous-wave obturation, and thermoplasticized gutta-percha core carrier, and to compare these methods by analyzing micro-CT images of the root canals' apical (2 mm), medial (5 mm), and coronal (8 mm) sections. The following were the null hypotheses that were examined:

1. In significantly curved canals, voids are present in all root canal filling procedures.
2. In curved canals, core carrier and continuous-wave obturation approaches work better than others.

Materials and methods

2.1. Calculation of root canal curvature

Sixty extracted mandibular first molars without resorption, crack, fracture or restoration on the root surface were selected. All tissue remnants and debris on the root surface were removed with ultrasonic tips, and all of the crowns were removed. Radiological images were obtained with the paralleling technique in the buccolingual and mesiodistal plane.

Radiographic images were transferred to the CorelDRAW X 8 (CorelDRAW Graphics Suite X 8-Corporate License, 2016, USA) program.The same program was used to determine the degree of curvature in accordance with Schneider's approach (Schneider, 1971). Included were sixty mandibular first molars with mesial root canal curvatures larger than 25.

2.2. Root canal preparation and obturation

A #10 K file (Mani, Japan) was used to measure the working length (WL) at a distance of 1 mm from the apical constriction. Using an X-Smart Plus Endomotor (Dentsply) and hand files (Mani, Japan), Protaper Next (Dentsply Maillefer) #X1–#X2 files were used to instrument the root canals.

Group 1 consisted of lateral condensation technique (LC), Group 2 consisted of single-cone technique (SC), Group 3 consisted of continuous-wave obturation (CW) (Elements Free; SybronEndo, Orange, CA, USA), and Group 4 consisted of core carrier technique (GC) (GuttaCore; Dentsply Tulsa Dental Specialties,

Tulsa, OK, USA). Unlike in other groups, apical shaping was completed with #40 K and H hand files (Mani, Japan) in the LC. During canal preparation, 2.5% 2 mL NaOCl was used between instruments. As a final irrigation, 17% EDTA was used. Afterwards, all samples were filled using four different filling techniques with the AH Plus sealer were used (Dentsply DeTrey, Konstanz, Germany). Group 1: Lateral condensation technique: After a size 40/0.02 taper master cone (Meta Biomed, Korea) was covered with sealer, it was inserted into the root canal. The procedure was completed with a size finger 25 spreader and size 20/0.02 taper accessory gutta-percha cones.

Group 2: Single-cone technique: A size 25/0.06 taper guttapercha cone (Dentsply Maillefer) was used for the filling. The cone was covered with sealer, and the obturation was completed after the insertion of the cone into the root canal.

Group 3: Continuous-wave obturation technique: A size 25/0.06 taper gutta-percha cone (Dentsply Maillefer) was covered

with sealer and placed in the root canal. The gutta-percha cone was down-packed with the 0.06 taper Buchanan Hand Plugger of the Elements Free (SybronEndo, Orange, CA, USA) according to the manufacturer’s recommendation. After this step, the root canal was filled with gutta-percha heated at 200 degree celsius using the Backfill part. Gutta-percha was compacted with a stainless steel plugger with size 1–3 (Dentsply Maillefer).

Group 4: Core carrier technique: A size #25 GuttaCore obturator was selected and inserted into a Thermaprep 2 (Dentsply Maillefer) oven according to the manufacturer’s recommendation. Upon the oven’s signal, the obturator was removed from the oven and placed into the canal for 5 s. The part of the cartridge that stood out of the root canal was removed with the help of a tungsten carbide bur (Meisinger).

2.3. Imaging of the root canals

After the closure of the cavities with Cavit-G (3M Espe), sections were obtained at 2, 5 and 8 mm parts from the apex with the Micro-CT (SCANCO MEDICAL, lCT 50) to compare the success of these obturation techniques. The X-ray tube was operated at voxel size 20 lm, FOV/diameter 20.5 mm, 70 kVp, 114 lA and integration time 600 ms. The images were transferred to the analysis software ImageJ (ImageJ 1.42 m, NIH, USA). The filled area, void area and total area of the root canal were calculated in pixels by x600 magnification. In addition, 4 samples from each group were scanned in 3D (Fig. 1).

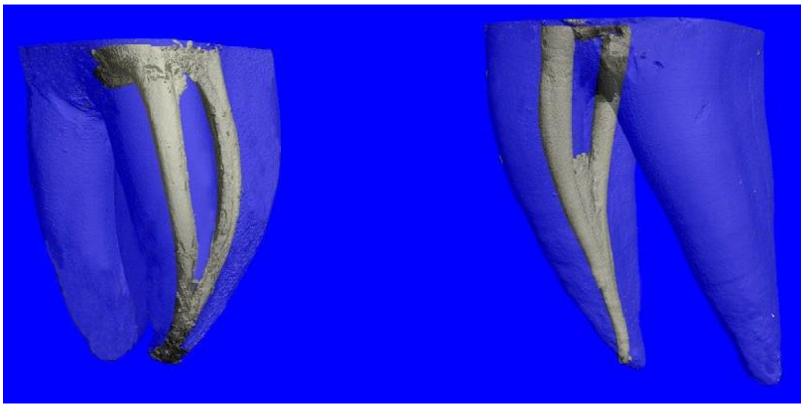

Fig. 1 The 3D images of different mesial root canals.

2.4. Statistical analysis

Percentage values were obtained with the proportion of the filled area to the total root canal area. All statistical analyses were conducted with SPSS v21.0 (Statistical Package for Social Sciences) for Windows software. The Kruskal–Wallis and Mann–Whitney U tests were used to determine the group that was causing the difference. P values less than 0.05 were considered statistically significant

3. Results

The filled area, void area and total area of the root canal were calculated for each sample (Fig. 2).

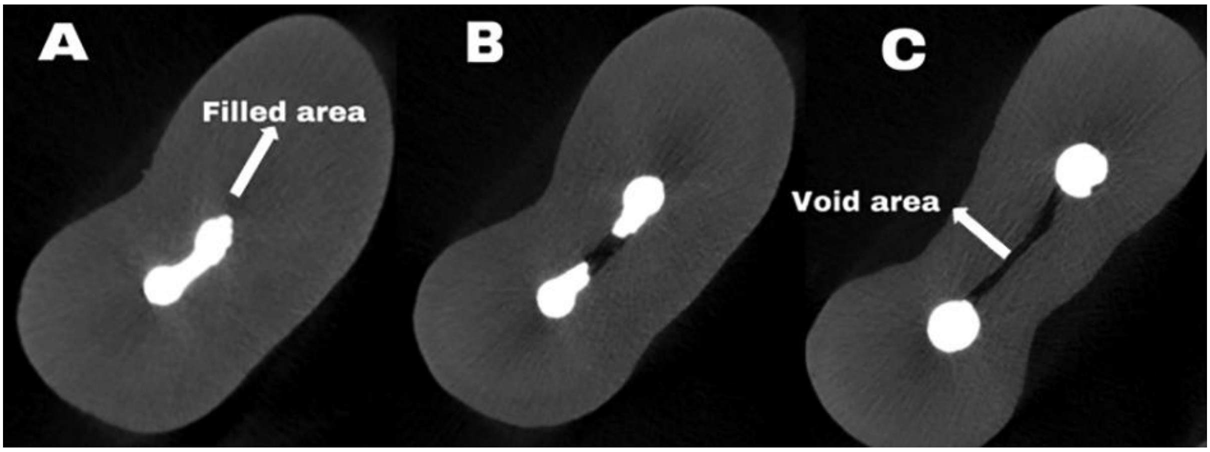

Fig. 2 The filled area, void area and total area of the same sample: A. 2 mm, B. 5 mm, C. 8 mm.

The percentage of filled area of the root canals was 88.51% in the LC at 2 mm and it was significantly higher than in the SC (78.44%) ($p < 0.05$). Regarding the filling rate of the root canals at 5 mm, the filling success in the LC (92.32%) was significantly higher than that in the SC (85.09%) and CW (85.35%) technique ($p = 0.037$). It was found no statistically significant difference among the groups in the filling success at 8 mm ($p = 0.207$). The minimum filling material was found in the SC group (Table 1).The intergroup comparison of each group revealed no statistically significant difference in most gutta-percha areas of the root canals at the 2, 5 and 8 mm in the LC ($p > 0.05$) and the percentage of filled area was more than 88.51% for all sections. There was no statistically significant difference in the obtained sections in most filling material in the root canals in the CW ($p > 0.05$). The most gutta-percha areas at 2 mm were significantly lower than other sections in the SC ($p < 0.05$). It was observed no statistically significant difference in the sections in the GC group with respect to most gutta-percha areas ($p > 0.05$).

4. Discussion

The extent of the root curvature affects the homogeneity and adaptation of the root canal fillings (Leung and Gulabivala, 1994; Neuhaus et al., 2016). The homogeneous filling of the curved root canals may be more difficult than that of the straight canals (Jafarzadeh and Abbott, 2007). Therefore, in this study, mandibular first molars with mesial root canal curvatures greater than 25 were preferred. The severely curved root canals were filled with the four different techniques and to examine the images of the 2, 5, and 8 mm of the roots using micro-CT in the present study. The results showed that, at 2 and 5 mm, LC was the most effective filling technique (Fig. 3). In a related investigation, Da Silva et al. (2002) used a digital radiography system to evaluate the lateral condensation approach with the thermoplasticized gutta-percha core carrier used in the curved canals. They noticed tiny gaps in a number of canals filled using the lateral condensation technique, but they did not discover any voids in the core carrier group. The thermoplasticized gutta-percha core carrier and lateral condensation approaches did not differ statistically significantly in terms of leakage when Abarca et al. (2001) used the dye penetration test to assess the mandibular first molars with curved mesial canals.

First, in the present study, it was believed that the result was affected by the obtainment of the sections only at certain levels and the usage of severely curved canals instead of straight canals. Second, the experimenter had more experience in the LC technique than other filling techniques. Therefore, this could have made the LC technique was more successful. Some previous studies reported that the results of the single-cone technique were less successful than those of other filling techniques (McKissock et al., 2011; Obeidat and Abdallah, 2014). We noticed that the findings in the literature were in concordance with our own. As a result of the usage of the standard round-shaped gutta-percha cones, factors such as the lack of a full adaptation with the canal walls and filling failure of the isthmus and lateral canals contribute to the low success rate of this technique. The obturation technique applied with continuous heat enables the plugging of the voids in the lateral canals, sulci and intracanal pockets (DuLac et al., 1998). Furthermore, this technique provides better sealing against coronal microbial penetration than the lateral condensation technique (Jacobson and Baumgartner, 2002). McKissock et al. (2011) compared the continuous-wave obturation and single-cone techniques regarding leakage and found that the number of voids in the root canals was significantly higher in the single cone technique. In our study, the SC was the most unsuccessful technique among all groups. Moreover, the least mean percentages were found for gutta-percha in all sections in this

group.The current study did not find this outcome surprising. In the C1 root canal configuration at 2 mm, Gok et al. (2017) discovered more void areas using heated gutta percha obturation procedures than using cold filling techniques. It was comparable to the current study's findings. It is challenging to fill in the apical portion of the canal curvature, and we think that curved canals have an appealing structure similar to the C1 root canal layout. No statistically significant difference ($p > 0.05$) was found when we compared the filling rates in the sections taken from the root canals filled with the CW. We were somewhat startled to see that the CW group's highest filling material was 8 mm and its minimum was 5 mm. The position of the root curves on that level explains why there are more voids in the medial third. It was assumed that the gutta-percha should be cut at a more coronal level because the Buchanan heat plugger cannot be inserted into the apical part of the canal curvature, which we consider as the reason for the voids in the apical part of the root curvature. It affects the success of the root canal treatment and the plugger with an optimal size according to the canal diameter in the CW technique.It was observed no statistically significant difference in the sections in the GC ($p > 0.05$). The examination of the images taken from all three sections showed that the most successful filling was achieved in the coronal part and the least successful filling in the apical part. Our findings indicated that the Gutta- Core was the most successful technique after the lateral condensation technique. We believe that the most important advantages of this technique are that the gutta-percha

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cartridge can easily be moved until the apical part of the curved root canal and that the filling can be conducted with a single movement.

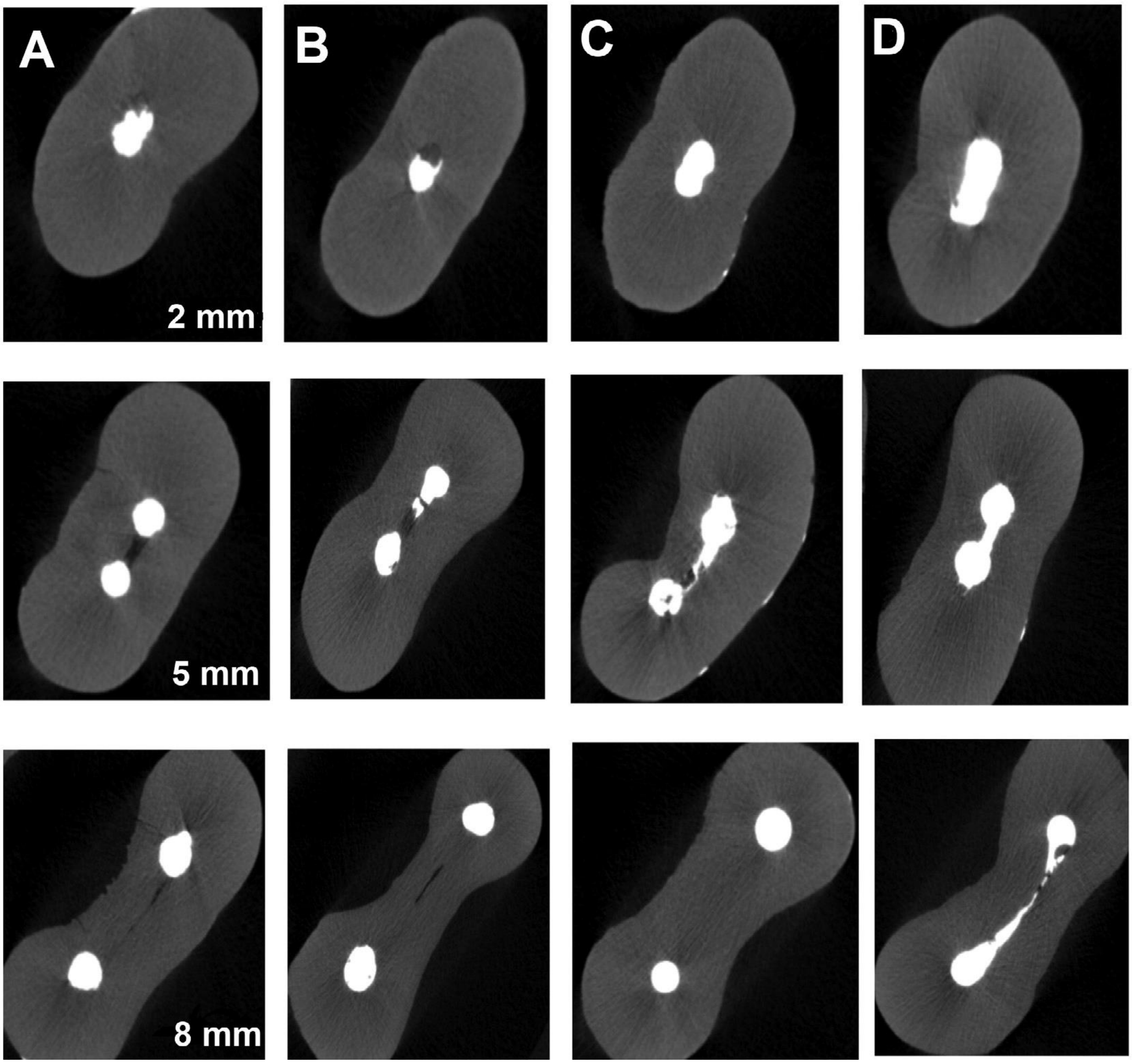

Fig. 3 The Micro-CT images of different root canal filling techniques (A, lateral condensation; B, single-cone; C, Elements Free; D, GuttaCore)

Compared with other filling techniques, it was found that the LC caused the development of dentinal defects (Shemesh et al., 2009, 2010). However, it was concluded that root filling procedures with GC, LC, and warm vertical compaction (WVC) techniques did not induce the development of new dentinal micro-cracks (De-Deus et al., 2017). In the present study, the development of dentinal micro-cracks after obturation was not evaluated.

The filling sealer considered the gold standard is AH Plus (Dentsply, DeTrey GmbH, Konstanz, Germany) (Silva et al., 2017). It is biocompatible (Leyhausen et al., 1999), having good physical properties that confer its long-term dimensional stability (Leonardo et al., 1999). Camilleri found that high temperature affected the chemical structure and setting time of AH Plus sealer. Therefore, it was not recommended for warm filling techniques (Camilleri, 2015). AH Plus sealer was used with different obturation techniques in the present study. One of the reasons why the CW was found to be less successful than LC technique might be due to changes in chemical structure of AH Plus sealer with high temperature. The choice of sealer according to the obturation technique should be considered.

There were several limitations in this study. First, the root canal curvature was not determined at which distance of the root canal. Although the degree of curvature was calculated,
localization of the root canal curvature was not considered. The curvature may have been at the middle part in some samples and at the apical part in others. It may have been caused the results to be different. Future researchers might perform about effect of localization of the root canal curvature on the success of the filling techniques. Second, it was used only one size plugger to ensure standardization in continuous-wave obturation technique. Different size pluggers might use according to localization of the root canal curvature. Third, all samples were scanned as 2D except four samples due to high cost and it was received only horizontally sectional images. 3D scanning could provide more detailed examination for this study.

Conclusion

The most effective methods at 2 and 5 mm, within the parameters of this investigation, were LC and GC, respectively. As long as a decent condensation is obtained, any approach can be utilized for filling the coronal section. For the root canal filling to be successful when using warm filling procedures, clinicians should select a plugger that is the ideal size based on the canal diameter and the location of the root canal curvature.

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