Evaluation of Filling Voids in Narrow Root Canals Prepared by TruNatomy System Using Two Different Obturation Techniques

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Directed by Professor Su-Jung Shin

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I. Introduction

The previously endodontically treated teeth are vulnerable to root fracture or crack. Root fractures and cracks are commonly untreatable and lead to extraction. Root canal taper is related to the fracture resistance of teeth. From these ideas, NiTi (nickel-titanium) files with reduced taper are developed. TruNatomy (Dentsply Maillefer, Ballaigues, Switzerland) is one of the newly developed NiTi file systems. However, narrowly shaped canals are not easy to obturate due to their inaccessibility and limitation when we use spreaders, heat pluggers and so forth. Therefore, clinicians expressed concern about the filling quality of

the narrowly enlarged root canals. Moreover, there have been no studies of proper filling methods in this situation.

With this background, this study aimed to compare the volume percentage of filling voids in root canals prepared with a newly introduced rotary system, TruNatomy (Dentsply Maillefer), and obturated by the modified continuous wave (CW) or single cone (SC) filling technique.

II Materials and method

Plastic artificial teeth with the shape of a maxillary molar having four canals (Dentalike, Dentsply Maillefer) were enlarged by using TruNatomy files and randomly allocated into either the CW or SC group. The volume percentage of filling voids at 1–6 mm from the apex was analyzed by using microcomputed tomography; mean values were compared by using independent two sample t tests ($p < 0.05$).

III. Result

The mean volume percentages of the filling voids were 2.81 ± 1.11% and 1.77 ± 0.82% in the CW and SC groups, respectively ($p < 0.05$). In the apical area (1–4 mm), volume percentages in the palatal were significantly different between the CW and SC groups; in the middle area (4–6 mm), volume percentages in the palatal and the second mesiobuccal canals were significantly different ($p < 0.05$). The SC group showed lower volume percentages of filling voids than the CW group.

IV. Conclusion

The canals prepared by the TruNatomy system can be obturated well by both the SC and CW techniques. The SC technique showed a lower number of voids, especially in the palatal canals.

Keywords: Obturation; voids; TruNatomy; Micro-CT

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I. INTRODUCTION

Crack or vertical root fracture of teeth often eventually lead to extraction. Root canal treated teeth are often vulnerable to vertical root fracture or crack because of the mechanically weak structure due to canal instrumentation and the force loaded during filling procedures [1,2]. The NiTi (nickel-titanium) files' tapers are related to the fracture resistance of the root canals and teeth [1,3,4]. From this background idea, clinicians became interested in the newly developed NiTi file systems. XP-endo Shaper (FKG Dentaire, La Chaux-de-Fonds, Switzerland), TruNatomy (Dentsply Maillefer, Ballaigues, Switzerland), EndoRoad (Maruchi; Wonju, Korea) NiTi files have less taper than commonly utilized NiTi file systems.

Utilizing the concept of minimally invasive endodontics, TruNatomy (Dentsply Maillefer) has been recently introduced as a new generation of rotary NiTi file system designed to preserve the maximum amount of peri-cervical dentine with a continuously tapering preparation [2,5]. The files are made of a new wire that has super-elastic properties; the manufacturer claims that this file system can follow the natural shape of the canal easily [5]. The apical tip sizes of TruNatomy files are similar to those of the other commonly used NiTi file systems. For example, the apical size of TruNatomy Prime Shaping file is 0.26, which is similar to that of ProTaper Gold F2 (Dentsply Maillefer) [6]. However, the TruNatomy files have a regressive taper and maintain a 0.8 mm maximum flute diameter. Although this new file system may have the advantage of less tooth preparation and preservation of tooth structure, it would be challenging for obturation in narrow canal spaces with less taper. For example, a less enlarged pericervical area will prohibit the heat plugger tip from reaching a location 3−5 mm from the working length if the continuous wave (CW) filling technique is used. To overcome this disadvantage, the manufacturer developed TruNatomy Conform Fit Gutta-Percha cones (Dentsply Maillefer). Based on the manufacturer's instructions, these gutta-percha (GP) cones can be condensed at 7 mm from the working length by the heat plugger. By altering the thermoplasticity of the GP, they overcame the potential filling difficulty. Although the manufacturer suggested the compensatory filling method to overcome a limitation in filling narrow canals, there have been no studies to evaluate the filling quality in root canals using the TruNatomy system and this modified CW technique.

Moreover, it was questioned whether a single cone (SC) filling method that has become popular recently could be utilized for narrow canals prepared by TruNatomy files. The canals prepared by the TruNatomy NiTi file system are narrower than those prepared by other systems. When using the SC method with a calcium silicate–based sealer, there is a concern whether the calcium silicate–based sealer can penetrate the narrow canal sufficiently, because most calcium silicate–based sealers demonstrated lower flowability than epoxy-resin-based sealers such as AH Plus (Dentsply DeTrey, Konstanz, Germany) [7–9].

To analyze the volume of the canal filling voids, micro-CT been used in the previous studies [10–14]. Other than micro-CT, many traditional methods including staining, bacterial penetration, SEM have been used. [13,15,16,17]. Micro-CT analysis is non-destructive and can reconstruct a 3-dimensional image. By analyzing the gray scales of the 3-dimensional reconstructed image, the volume of the canal filling void is able to be quantified.

To the knowledge that we have so far, there were previous studies that focused on the mechanical properties or canal shaping characteristics of the TruNatomy files [18–20];

moreover, none of these studies investigated the quality of obturation in root canals prepared by TruNatomy systems.

With this background, the purpose of this study was to measure the volume percentage of filling voids (%V) in canal fillings of artificial upper first molars prepared by using TruNatomy NiTi files and obturated by using TruNatomy Conform Fit Gutta-Percha cones by two different filling techniques and evaluated under micro-CT. The null hypothesis was there would be no significant difference in the percentage of filling voids between two obturation methods.

II. MATERIALS AND METHODS

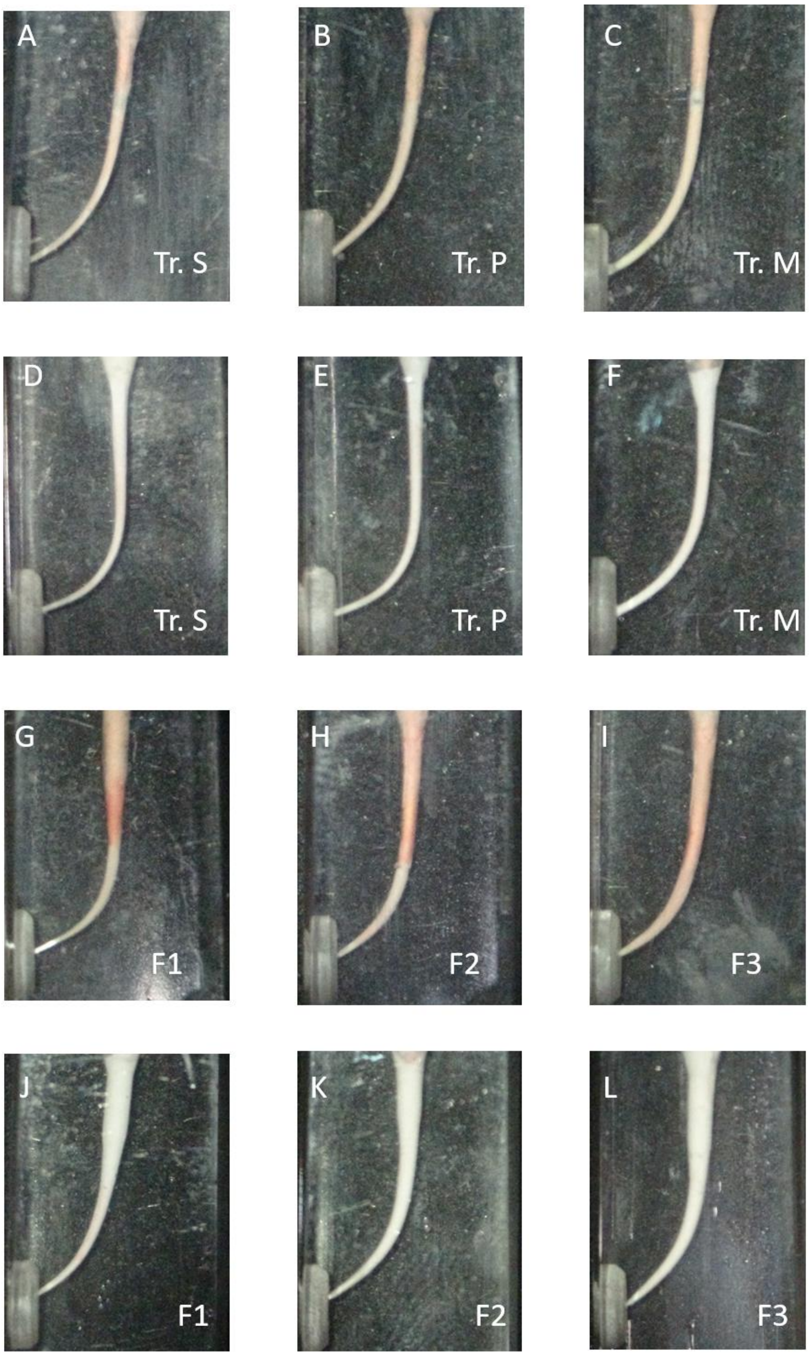
1. The pilot study: Observation of filling defect and sealer distribution by different canal preparation and filling techniques in a curved artificial canal

Twenty-four curved canal plastic models (Dentsply Maillefer, Ballaigues, Switzerland) were used for this pilot study. The canal length was 15.5 mm and each sample was prepared by TruNatomy NiTi files (Dentsply Maillefer) or ProTaper Gold (Dentsply Maillefer).

TruNatomy (Dentsply Maillefer) small (#20, 0.04 taper), prime (#26, 0.04 taper), or medium shaping files (#36, 0.03 taper) were used as final preparation files. For a canal prepared by ProTaper Gold (Dentsply Maillefer), the final size of canals was F1 (#20, 0.07 variable taper), F2 (#25, 0.08 variable taper), or F3 (#30, 0.09 variable taper).

The prepared models were filled with TruNatomy Conform Fit Gutta-Percha cones (Dentsply Maillefer) or ProTaper Gold Conform Fit Gutta-Percha points (Dentsply Sirona) matching size with the final shaping files. CW or SC filling technique was used to obturate the instrumented canals. In case of the models filled with TruNatomy Conform Fit Gutta-Percha cones (Dentsply Maillefer), the modified continuous wave filling technique (Gutta percha cone cutting at 7 mm level from the apical tip) was utilized rather than conventional continuous wave technique (Gutta percha cone cutting at 3–4 mm level from the apical tip).

CeraSeal (Meta Biomed) was used for the SC technique and AH Plus (Dentsply DeTrey) was used for CW technique. The filling defect and sealer distribution was examined by periapical radiographs and checked under a dental microscope. The results (Figure 1) showed that the sealers could penetrate well into the narrow canals and major filling defects were not noticeable. This pilot study seemed that there was not a big difference in filling quality between obturated canals. Thus, we established the null hypothesis: there would be no significant difference in the percentage of filling voids of canals prepared by TruNatomy NiTi files (Dentsply Maillefer) between two obturation methods.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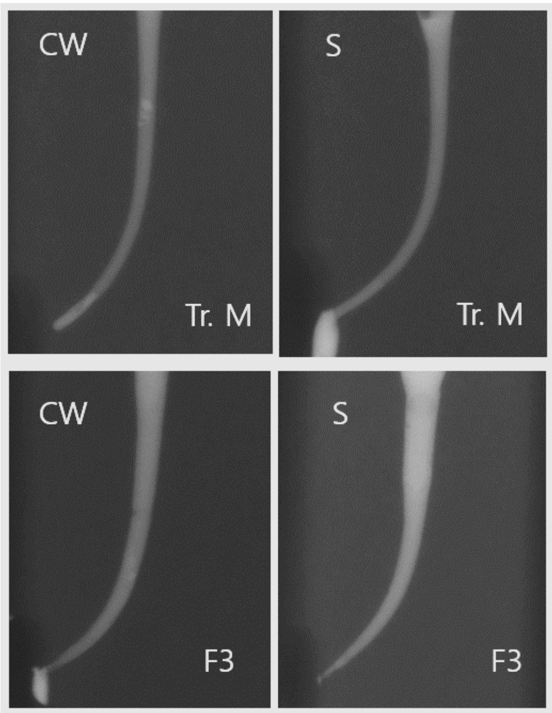


M

Figure 1. The microscopic and radiographic images of the obturated plastic canal models

(Dental operating microscope (OPMI Pico; Carl Zeiss, Jena, Germany), 12.5 × magnification)

(A, B, C) Modified continuous wave filling with AH plus (Dentsply DeTrey) and TruNatomy Conform Fit Gutta-Percha cone small (A), prime (B), and medium (C) (Dentsply Sirona)

(D, E, F) Single cone filling with CeraSeal (Meta Biomed) and TruNatomy Conform Fit Gutta-Percha cone small (D), prime (E), and medium (F)

(G, H, I) Continuous wave filling with AH plus and ProTaper Gold Conform Fit Gutta-Percha cone F1 (G), F2 (H), and F3 (I)

(J, K, L) Single cone filling with CeraSeal and ProTaper Gold Conform Fit Gutta-Percha cone F1 (J), F2 (K), F3(L)

(M) Periapical X-ray images of the obturated plastic canal models

2. Preparation of Plastic Tooth Samples

Twenty-three plastic artificial teeth (Dentalike, Dentsply Maillefer) with the shape of a human maxillary first molar were used. Each artificial tooth had four canals: mesiobuccal (MB), the second mesiobuccal (MB2), distobuccal (DB), and palatal (P). MB and MB2 canals were classified as Weine classification type III [21]. To determine each canal's working length (WL), a #10 sized K-file (Dentsply Maillefer) was placed in the canal, and the WL was determined until a point 0.5 mm from the apical tip.

MB canal length was 20.5 mm, MB2 canal length was 20.0 mm, DB canal was 19.5 mm and the P canal length was 22.0 mm, The initial apical file of MB and MB2 was #10 sized K-file file and that of DB was #15 sized K-file, and that of P was #20 sized K-file.

All the canals were prepared by using the TruNatomy NiTi System (Dentsply Maillefer). TruNatomy Orifice Modifier, TruNatomy Glider, and TruNatomy Shaping Files were utilized with a speed of 500 rpm and a torque limit of 1.5 N/cm, according to the manufacturer's instructions. The orifice modifier (#20, 0.08 taper) was used, and TruNatomy Glider (#17, 0.02 taper) was inserted into every canal up to the WL. For MB and DB canals, canal preparation was finished by using TruNatomy Prime Shaping file (#26). MB2 canal preparation was completed by using the TruNatomy Small Shaping file (#20), or P canal preparation was completed by using TruNatomy Medium Shaping File (#36).

After each filing procedure, the canals were irrigated by using distilled water and a TruNatomy irrigation needle (0.3 mm diameter) (Dentsply Maillefer). After completing canal instrumentation, the specimen was randomly assigned to one of the two groups based on the canal obturation technique. TruNatomy Conform Fit Gutta-Percha cones of matching size for each canal were placed into the canals and checked by radiography (Figure 2A). All canals were subsequently dried with fine-size paper points (DiaDent, Cheongju, Korea) before canal obturation.

3. Obturation of the Plastic Tooth Samples

The canal filling procedure was performed under a dental operating microscope.

- Modified continuous wave technique group (CW, n = 12): The GP cone tip was coated with a small amount of AH Plus (Dentsply DeTrey) sealer at the apical 3 to 4 mm part and inserted into the canal. The GP cone was cut at 7 mm from the apical tip, using a fine sized heat plugger (#30, 0.04 taper) (SybronEndo, Orange, CA, USA) and System B (SybronEndo), packed with BL S-Kondenser (#35) (B & L Biotech, Ansan, Korea) at the 7 mm level and backfilled by using SuperEndo Beta 2 (tip size #25) (B & L Biotech) at a temperature setting of 200 °C.

- Single-cone technique group (SC, n = 11): CeraSeal (Meta Biomed, Cheongju, Korea) was snugly inserted in the canal space by using the provided needle tip; the tip was gently moved towards the orifice from the point from which it was engaged in. A GP cone was moved upward and downward three times to ensure good penetration of the sealer, cut using a fine-sized heat plugger and System B (SybronEndo), and gently packed with BL S-Kondenser (B & L Biotech) at the orifice level.

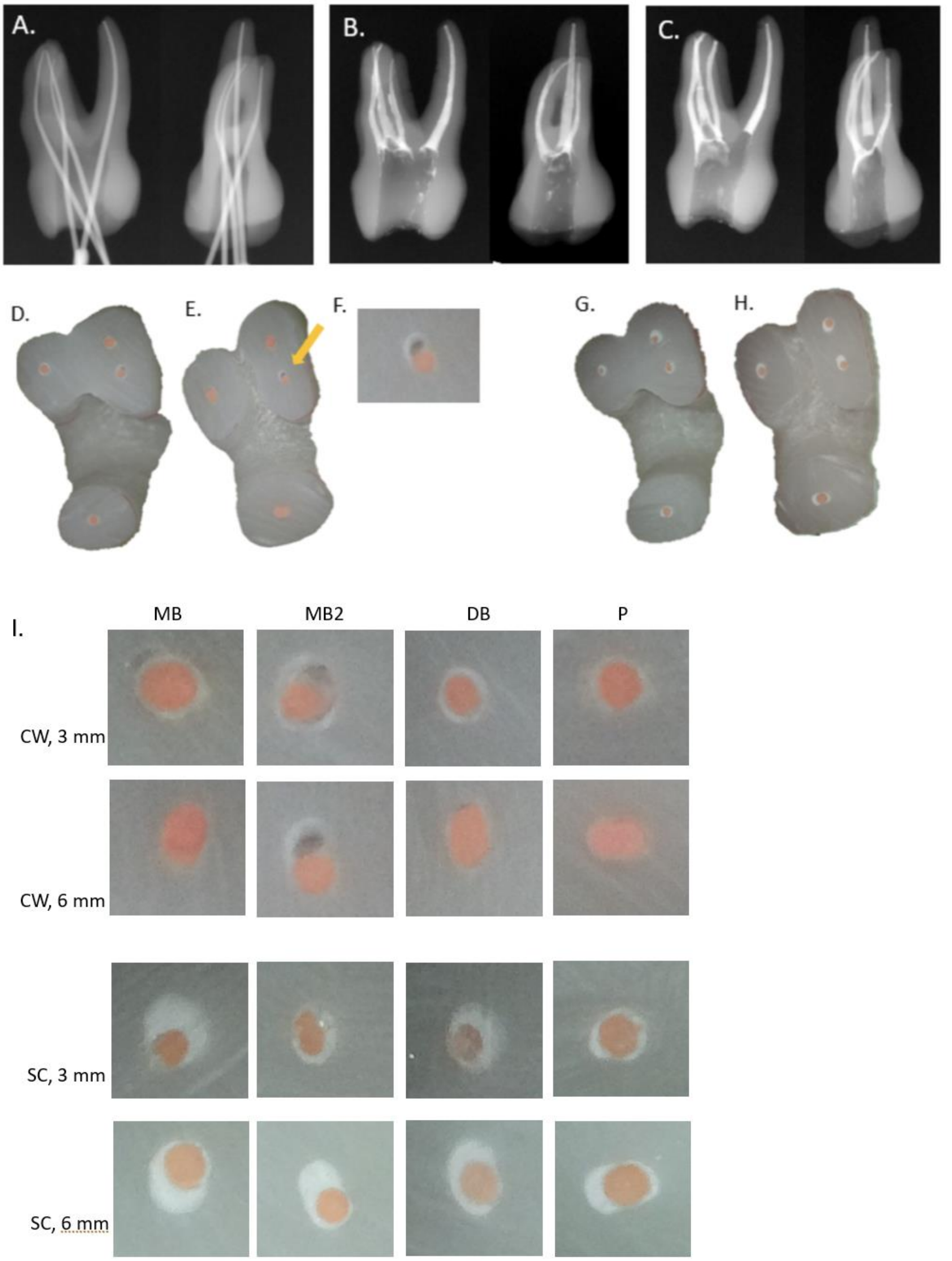

A.
B.
C.
D.
E.
F.
G.
H.
I.
MB
MB2
DB
P
CW, 3 mm
CW, 6 mm
SC, 3 mm
SC, 6 mm

Figure 2. Radiographic and microscopic images of representative specimens. (A) Master cone fitting; MB (mesiobuccal canal), TruNatomy Prime; MB2 (the second mesiobuccal canal), Trunatomy Small; DB (distobuccal canal), TruNatomy Prime; P canal (palatal canal), TruNatomy Medium. (B,C) Periapical X-ray of a sample in SC (single cone filling) (B) and CW (continuous wave filling) (C) groups. (D,E) Microscopic image of canal filling at 3 mm (D) and 6 mm (E) from the apical tip of CW group. The yellow arrow indicates the void of the canal filling. (F) Magnified image of the void of the canal filling at 6 mm from the apical tip (G,H) Microscopic image of canal filling at 3 mm (G) and 6 mm (H) from the apical tip of SC group (I) Microscopic image of CW and SC group of each canal at 3 mm and 6 mm from the apical tip

(Dental operating microscope (OPMI Pico; Carl Zeiss, Jena, Germany), 12.5 × magnification)

All of the samples were stored in a special condition described in the previous study [10] for 14 days until further investigation, using micro-CT, to provide appropriate moisture for setting the calcium silicate–based sealer; this is because the sealer requires water for the setting reaction and adaptation to the root canal wall [8]. All procedures were performed by two experienced operators (S. J. Shin and Y. J. Lee).

4. Micro-CT Imaging and Analysis

Three artificial teeth samples were randomly selected by utilizing online random number generator program (Calculator Soup). The canal shape of three randomly selected artificial teeth samples before canal preparation was compared by scanning them with a micro-CT scanner (SkyScan 1173, Bruker, Billerica, MA, USA) to confirm the consistency of root canal space in the model teeth. The setting for imaging views by using the micro-CT scanner was the same as used in the previous study by Kim et al. [10].

After completing of canal instrumentation, all samples were scanned under the same conditions as mentioned above. Then, root canal filling was performed depending on the experimental groups; the samples were stored for two weeks and scanned again. The overlapped images were used for further analysis. Reconstructed images were obtained from the scan by using NRecon software version 1.7.0.4 (Bruker microCT, Kontich, Belgium). The range of measurements was 1−6 mm from the root apex, and the CT-An software (version 1.17.7.2, SkyScan) was used to measure the volume of the root canal space, that of GP, and that of the sealer. The gray scale value of the void was between 0-69, the gray scale value of gutta percha was 70-218, and the gray scale value of the sealer was 219-255. The area 1−4 mm from the apex constituted the apical area, and the area 4−6 mm from the apex constituted the middle area.

The %V was calculated as follows:

The method of this calculation was based on the previous studies by Kim et al. [10] and

Jung et al. [22].

$$\%V = \{V_{canal} - (V_{sealer} + V_{GP})\}/V_{canal} \times 100 \qquad (1)$$

where V_{canal} is the volume of the canal and the V_{sealer} means the volume of the sealer, and the V_{GP} means the volume of the gutta-percha. They were classified by grayscale.

5. Statistical Analysis

Sample calculation was first performed based on the results from a preliminary study with a sample size of four in each group, using G*Power 3.1.9.6 (Universitat Kiel, Kiel, Germany) to detect significant differences (effect size: 1.27, alpha error: 0.05, power: 80%). The estimated sample size in each group was 11. To verify data normal distribution, Shapiro–Wilk and Kolmogorov–Smirnov tests were used. Independent two sample t tests were performed to compare the %V of the two different canal filling groups, using SAS version 9.4 (SAS Institute Inc., Cary, NC, USA). The p-values less than 0.05 were considered statistically significant.

After micro-CT scan, three representative samples from each group were selected for microscopic observation, and sectioned surfaces at the 3 and 6 mm levels were examined.

III. RESULTS

The pilot study is for testing the sealer and GP cones adaptability and filling quality. Figure 1 shows the microscopic image of the filled plastic canal models. All samples showed the well obturated canals; however, the sealer and gutta-percha portions were quite different between the single cone filling group and continuous wave filling groups. Furthermore, the instrumented canal diameter from middle 1/3 to coronal 1/3 was different between ProTaper Gold (Dentsply Maillefer) groups and TruNatomy (Dentsply Maillefer) groups because of the file design, shape, and taper. The result could infer that the latter can conserve more root canal dentin structure. Furthermore, the samples that the modified continuous wave technique were applied showed some gap at the level of GP cutting. Voids existed between the down-packed GP and back-filled one.

The randomly selected three artificial tooth specimens (Dentalike, Dentsply Maillefer) were scanned to evaluate the consistency of canal shape and length among specimens; it indicated that the three artificial teeth had similar canal structures (Figure 3).

The microscopic images (20 × magnification) of cross-sections at 3 and 6 mm from the apical tip revealed that both the SC and CW groups were well filled by the GP and sealer. The sealer portion of the SC group was greater than that of the CW group (Figure 2).

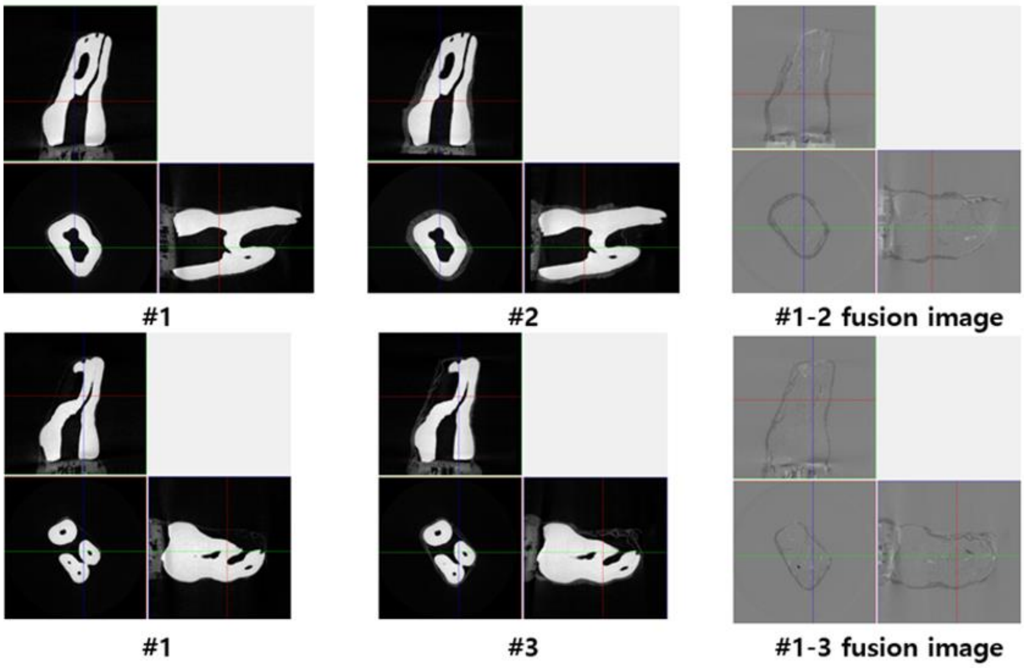


Figure 3. Micro-CT image of the randomly selected three artificial tooth specimens; Dentalike (Dentsply Maillefer) The fused image of artificial tooth specimens showed almost same canal structure, diameter, curvature, and length.

Canals of both the SC and CW groups were well filled with GP and the sealer as per micro-CT images. GP filled most of the canal space, and the sealer constituted the remaining space in the CW group compared with that in the SC group. In the area around 6 mm from the apical tip, the CW group showed more voids due to the gap between the surface of the cut master cone and the back-filled GP (Figure 4).

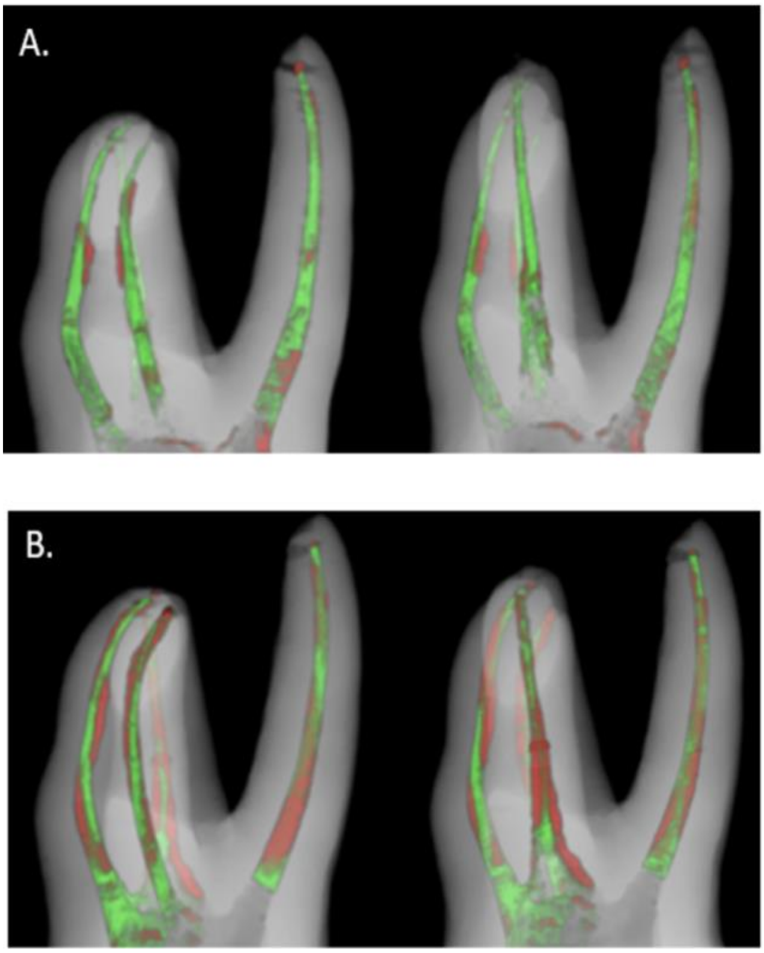
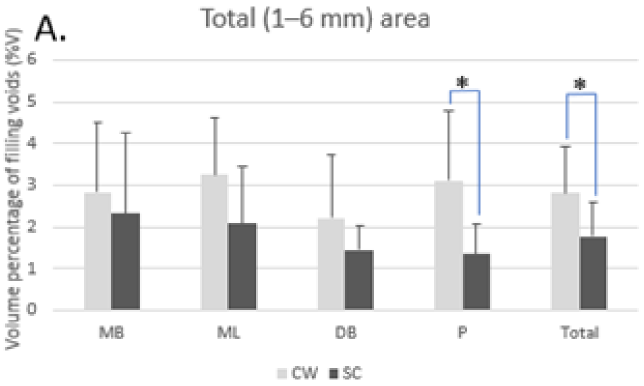
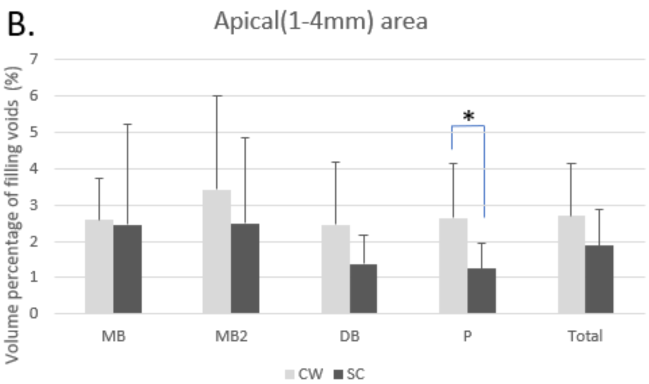


Figure 4. Three-dimensional reconstructed images of the obturated root canals. The green area indicates gutta percha and the red area displays sealer. The sample of the SC group showed more red space which means the sealer portion is more extensive than that of the CW group. On the other hand, gutta percha occupied most of the canal space of the CW group. (A) Reconstructed micro-CT scan image of CW group (B) Reconstructed micro-CT scan image of SC group CW, continuous wave filling; SC, single cone filling

The mean values of %V in the CW and SC groups were 2. 81 ± 1.11% and 1.77 ± 0.82%, respectively, and there was a significant difference ($p < 0.05$). Based on the root canals, %V total in the P canal demonstrated a significant difference between the two groups. In the apical area (1−4 mm), the $\%V_{apical}$ was significantly lower in the SC group in the P canal. In the middle area (4−6 mm), the $\%V_{middle}$ was significantly lower in the SC group in the MB2 and P canals (Figure 5).


A.
Total (1–6 mm) area
Volume percentage of filling voids (%V)
0
1
2
3
4
5
6
*
*
MB
ML
DB
P
Total
CW
SC


B.
Apical(1-4mm) area
Volume percentage of filling voids (%)
0
1
2
3
4
5
6
7
*
MB
MB2
DB
P
Total
CW
SC

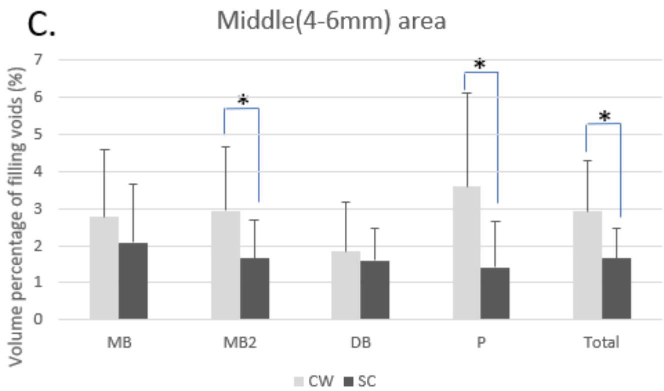

C.
Middle(4-6mm) area
Volume percentage of filling voids (%)
0
1
2
3
4
5
6
7
*
*
*
MB
MB2
DB
P
Total
CW
SC

Figure 5. Bar graph of the volume percentage of canal filling voids. An independent two-sample t-test was performed to compare the void volume percent of the two different canal filling groups. (A) In the total area (1–6 mm from the apical tip), there is a statistically significant difference of the percentage of voids (%V) between CW (continuous wave filling group) and SC (single cone filling group) in P canal (palatal canals) and total canals. SC group showed less void volume percentage. (B) In the apical area (1–4 mm from the apical tip), the percentage of voids (%V) is significantly lower in the SC group in the P canal. (C) In the middle area (4–6 mm from the apical tip), the percentage of voids (%V) is significantly lower in the SC group in the MB2 (the second mesiobuccal canal) and P canals. Asterisks (*) indicate statistical significance (p-value < 0.05).

IV. DISCUSSION

Our study compared the volume percentage of filling voids in canals prepared by three different sizes of TruNatomy files, using different filling techniques. The results demonstrated that both filling techniques used in the study showed favorable results.

In this study, the artificial teeth mimicking a maxillary first molar were used instead of human extracted teeth; many previous studies that used human extracted teeth were performed by using premolars or anterior teeth owing to the difficulty in controlling for the specimen since human molars have variations in the number of canals, anatomy, and length [11–13,23–25]. However, we considered that premolars and anterior teeth would have wider canal space than TruNatomy files. Hence, we used the plastic model teeth; however, the experiments using human teeth would be more relatable to clinical situations.

To reproduce the oral environment, the samples were stored in a 37℃ constant temperature water bath and the apical tip was stuck onto a wet floral foam brick. This condition provided appropriate moisture for setting the calcium silicate-based sealer because it requires water content for its setting reaction and adaptation to the root canal wall [26].

There were previous studies that the root canal instrumentation taper influenced fracture resistance of roots [1−3]; however, Elkholy et al.'s finite element analysis showed that access cavity size affected the life span of teeth regardless of the canal taper [6].

We compared two filling techniques that can be used to obturate narrow canals: CW and SC. The CW method used in this study was the modified method recommended by the manufacturer. Although it is more precise to use the same sealer in both groups, different sealers were used for each group in the experiment setting. Since the CW method contains heat application, a calcium silicate–based sealer was not used for this CW group due to a possible adverse effect of heat. Previous studies have reported that heat could affect calcium silicate–based sealers' chemical and physical properties [27,28]. CeraSeal (Meta Biomed) used in the SC group is one of the calcium silicate–based sealers designed for SC filling; however, the effects of heat application on the physical and chemical properties of the sealer have not been reported. Based on these reasons, AH plus (Dentsply DeTrey) was used in the CW group and CeraSeal (Meta Biomed) was utilized in the SC group.

Continuous wave filling is not an easy to learn technique compared to single cone filling technique [29]. The canals that are instrumented with less tapered NiTi files make the procedure more difficult. Due to the narrow structure, the instrument cannot advance into the root canal. The heat plugger cut GP at 7mm level in the modified continuous wave technique to overcome this obstacle. In spite of this modification, there was the difficulty of instrument handling and voids existed at the cutting level. Practitioners should be experienced to apply modified continuous wave technique for less tapered canals.

The single cone filling technique fills the canal with one gutta-percha cone and fills the remaining canal space with sealer. The method is simple, fast, easy to apply. However, since the sealer occupies a large portion of the root canal volume, there were concerns about the volume stability and dissolution as time passed. Despite these concerns, the development of bioceramic based sealers and the use of matching size cone can overcome possible disadvantages. The mechanical properties of the sealer could have a strong influence on the volume percentage of filling voids in root canals. The high flowability of the sealer can enable the good penetration into the canal. CeraSeal (Meta Biomed) showed higher flowability than AH Plus (Dentsply DeTrey) [30]. In addition, the dimensional stability is effective on the canal filling quality after time. The dimensional stability of CeraSeal (Meta Biomed) did not show a statistically significant difference among other sealers including AH Plus (Dentsply DeTrey); however, it showed a big dimensional change after 30 days [30]. Thus, the considerations for these properties are necessary for future research.

Micro-CT and the volume of voids have been used to assess root canal filling quality [31-33]. It is a known fact that non-obturated areas may allow the persistence of bacteria at this site, resulting in treatment failure [11,34], and proper canal obturation can prevent the penetration of microorganisms and toxins [34]. The analysis area was divided into the apical (1−4 mm) and middle (4−6 mm) portions. One millimeter from the apical tip was not included if the master cone did not go beyond apical 1 mm, because the void percentage could be overestimated. Thus, the study design was in agreement with other previous studies [10,35]. We also did not include the coronal area above 7 mm, since there might be a possibility of creating voids during backfilling, using the modified continuous filling technique. The canal filling by continuous wave technique often shows the junction gap between the back-filled gutta-percha and down-packed one. [29,36].

Several previous studies analyzing the %V of root canal filling reported a range from 1.5% to 5.7%, and these values were consistent with our findings [10-14]. The %V was 3.61−5.72% in the SC and CW groups in artificial mandibular first molar teeth, as reported by Kim et al. [10]. By utilizing single-rooted teeth, void volumes of 1.57% and 1.61% were observed in the CW and SC groups, respectively, as demonstrated by Angerame et al. [14]. Our study demonstrated that, in the apical area, the SC group showed significantly lower %V in the P canal than in the CW group. In contrast, there was no significant difference with respect to the other canals. Based on these results, it is possible that the modified CW method used in this study might not result in proper adaptation of the thermoplasticized GP in P canals. However, the volume percentage of filling voids in the apical area in P canals were 2.64 ± 1.50% and 1.26 ± 0.69% in the CW and SC groups, respectively, and these values were comparable with those from the previous study by Kim et al. that used 3 mm down-packing [10]. In addition, the sectioned images and micro-CT scans demonstrated that the occupied portion of GP filling was greater in the CW group than in the SC group. These findings demonstrated that heat application of this modified method (GP cutting at 7 mm from the apical tip) efficiently delivers heat at the apical area in the CW group.

Another finding in our study was that, in the MB2 canal, it was challenging to apply the fine-sized heat plugger and condenser at the 7 mm level due to the width and curvature of the canal. The CW technique in the MB2 canal depends more on the operators' proficiency as compared to the SC technique. Therefore, Chybowski et al. claimed that the SC filling method could be beneficial in filling narrow canals in this respect [37].

V. CONCLUSION

The SC group showed less void volume percentage than CW group in P canals of the apical area (1 – 4 mm), and MB2 and P canals of the middle (4 – 6 mm) area. Although they showed significant differences in some area of some root canals, the volume percentage of canal filling voids was similar or less than those of the previous studies. These results implicated that both techniques could be used in obturating the root canals minimally prepared. In the future, further research would be necessary to confirm the quality of obturation in minimally prepared canals in a clinical situation.

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References

1. Tian, SY.; Bai, W.; Jiang, WR.; Liang, YH. Fracture resistance of roots in mandibular premolars following root canal instrumentation of different sizes. *Chin J Dent Res.* **2019**, 22, 197-202.

2. Tang, W.; Wu, Y.; Smales, R.J. Identifying and reducing risks for potential fractures in endodontically treated teeth. *J. Endod.* **2010**, *36*, 609–617.

3. Sabeti, M.; Kazem, M.; Dianat, O.; Bahrololumi, N.; Beglou, A.; Rahimipour, K.; Dehnavi, F. Impact of access cavity design and root canal taper on fracture resistance of endodontically treated teeth: An ex vivo investigation. *J. Endod.* **2018**, 44, 1402-1406.

4. Kılıç, Y.; Karataşlıoğlu, E.; Kaval, ME. The effect of root canal preparation size and taper of middle mesial canals on fracture resistance of the mandibular molar teeth: An in vitro study. *J. Endod.* **2021**, 47, 1467-1471.

5. TruNatomy. Available online:

https://www.dentsplysirona.com/en/explore/endodontics/trunatomy.html (accessed on 4 February 2021).

6. Elkholy, M.M.; Nawar, N.N.; Ha, W.N.; Saber, S.M.; Kim, H.-C. Impact of canal taper and access cavity design on the lifespan of an endodontically treated mandibular molar: A finite element analysis. *J. Endod.* **2021**.

7. Mendes, A.T.; Da Silva, P.B.; Só, B.B.; Hashizume, L.N.; Vivan, R.R.; Da Rosa, R.A.; Duarte, M.A.H.; Só, M.V.R. Evaluation of physicochemical properties of new calcium silicate-based sealer. *Braz. Dent. J.* **2018**, *29*, 536–540.

8. Al-Haddad, A.Y.; Kutty, M.G.; Abu Kasim, N.H.; Ab Aziz, Z.A.C. The effect of moisture conditions on the constitution of two bioceramic-based root canal sealers. *J. Dent. Sci.* **2017**, *12*, 340–346.

9. Shakya, V.K.; Gupta, P.; Tikku, A.P.; Pathak, A.K.; Chandra, A.; Yadav, R.K.; Bharti, R.; Singh, R.K. An in vitro evaluation of antimicrobial efficacy and flow characteristics for AH Plus, MTA Fillapex, CRCS and Gutta Flow 2 Root Canal Sealer. *J. Clin. Diagn. Res.* **2016**, *10*, ZC104–ZC108.

10. Kim, S.; Kim, S.; Park, J.W.; Jung, I.Y.; Shin, S.J. Comparison of the percentage of voids in the canal filling of a calcium silicate-based sealer and gutta percha cones using two obturation techniques. *Materials* **2017**, *10*, 1170.

11. Somma, F.; Cretella, G.; Carotenuto, M.; Pecci, R.; Bedini, R.; De Biasi, M.; Angerame, D. Quality of thermoplasticized and single point root fillings assessed by micro-computed tomography. *Int. Endod. J.* **2011**, *44*, 362–369.

12. Celikten, B.; Uzuntas, C.F.; Orhan, A.I.; Orhan, K.; Tufenkci, P.; Kursun, S.; Demiralp, K. Özgür, Evaluation of root canal sealer filling quality using a single-cone technique in oval shaped canals: An In vitro Micro-CT study. *Scanning* **2016**, *38*, 133–140.

13. Huang, Y.; Orhan, K.; Celikten, B.; Orhan, A.I.; Tufenkci, P.; Sevimay, S. Evaluation of the sealing ability of different root canal sealers: A combined SEM and micro-CT study. *J. Appl. Oral Sci.* **2018**, *26*, e20160584.

14. Angerame, D.; De Biasi, M.; Pecci, R.; Bedini, R.; Tommasin, E.; Marigo, L.; Somma, F. Analysis of single point and continuous wave of condensation root filling techniques by micro-computed tomography. *Annali dell'Istituto Superiore di Sanità* **2012**, *48*.

15. Kim, SY.; Kim, KJ.; Yi, YA.; Seo, DG. Quantitative microleakage analysis of root canal

filling materials in single-rooted canals. *Scanning.* **2015**, *37*, 237-245.

16. Oliveira, AC.; Tanomaru, JM.; Faria-Junior, N.; Tanomaru-Filho, M. Bacterial leakage in root canals filled with conventional and MTA-based sealers. *Int. Endod. J.* **2011**, *44*, 370-375.

17. Vula, V.; Ajeti, N.; Kuçi, A.; Stavileci, M.; Vula, V. An In Vitro comparative evaluation of apical leakage using different root canal sealers. *Med. Sci. Monit. Basic Res*. **2020**, 25;26:e928175.

18. Peters, O.A.; Arias, A.; Choi, A. Mechanical properties of a novel nickel-titanium root canal instrument: Stationary and dynamic tests. *J. Endod.* **2020**, *46*, 994–1001.

19. Mustafa, R.; Al Omari, T.; Al-Nasrawi, S.; Al Fodeh, R.; Dkmak, A.; Haider, J. Evaluating in vitro performance of novel nickel-titanium rotary system (TruNatomy) based on debris extrusion and preparation time from severely curved canals. *J. Endod.* **2021**, *47*, 976–981.

20. Pérez Morales, M.L.N.; González Sánchez, J.A.; Olivieri, J.G.; Elmsmari, F.; Salmon, P.; Jaramillo, D.E.; Terol, F.D. Micro-computed tomographic assessment and comparative

study of the shaping ability of 6 nickel-titanium files: An in vitro study. *J. Endod.* **2021**, *47*, 812–819.

21. Weine, F.S.; Healey, H.J.; Gerstein, H.; Evanson, L. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. *Oral Surg. Oral Med. Oral Pathol.* **1969**, *28*, 419–425.

22. Jung, J.; Kim, S.; Kim, E.; Shin, S.-J. Volume of voids in retrograde filling: Comparison between calcium silicate cement alone and combined with a calcium silicate–based sealer. *J. Endod.* **2020**, *46*, 97–102.

23. Keleş, A.; Alcin, H.; Kamalak, A.; Versiani, M. Micro-CT evaluation of root filling quality in oval-shaped canals. *Int. Endod. J.* **2014**, *47*, 1177–1184.

24. Huang, Y.; Celikten, B.; Vasconcelos, K.D.F.; Nicolielo, L.F.P.; Lippiatt, N.; Buyuksungur, A.; Jacobs, R.; Orhan, K. Micro-CT and nano-CT analysis of filling quality of three different endodontic sealers. *Dentomaxillofacial Radiol.* **2017**, *46*, 20170223.

25. Celikten, B.; F Uzuntas, C.; I Orhan, A.; Tufenkci, P.; Misirli, M.; O Demiralp, K.; Orhan, K. Micro-CT assessment of the sealing ability of three root canal filling techniques. *J. Oral Sci.* **2015**, *57*, 361–366.

26. Al-Haddad, AY.; Kutty, MG.; Abu Kasim, NH.; Che Ab Aziz, ZA. The effect of moisture conditions on the constitution of two bioceramic-based root canal sealers. *J. Dent. Sci.* **2017**,*12*, 340-346.

27. Antunes, T.B.M.; Janini, A.C.P.; Pelepenko, L.E.; Abuna, G.F.; Paiva, E.M.; Sinhoreti, M.A.C.; Raimundo, I.M.; Gomes, B.P.F.A.; De-Jesus-Soares, A.; Marciano, M.A.; et al. Heating stability, physical and chemical analysis of calcium silicate-based endodontic sealers. *Int. Endod. J.* **2021**, 54,1175-1188.

28. Yamauchi, S.; Watanabe, S.; Okiji, T. Effects of heating on the physical properties of premixed calcium silicate-based root canal sealers. *J. Oral Sci.* **2021**, *63*, 65–69.

29. Mirfendereski M, Roth K, Fan B, Dubrowski A, Carnahan H, Azarpazhooh A, Basrani B, Torneck, CD.; Friedman, S. Technique acquisition in the use of two thermoplasticized root filling methods by inexperienced dental students: a microcomputed tomography

analysis. *J. Endod.* **2009**, *35*, 1512-1517.

30. Park, MG.; Kim, IR.; Kim, HJ.; Kwak, SW.; Kim, HC. Physicochemical properties and cytocompatibility of newly developed calcium silicate-based sealers. *Aust. Endod. J.* **2021**, *47,* 512-519.

31. Jung, M.; Lommel, D.; Klimek, J.; Jung, M.; Lommel, D.; Klimek, J. The imaging of root canal obturation using micro-CT. *Int. Endod. J.* **2005**, *38*, 617–626.

32. Wolf, M.; Küpper, K.; Reimann, S.; Bourauel, C.; Frentzen, M. 3D analyses of interface voids in root canals filled with different sealer materials in combination with warm gutta-percha technique. *Clin. Oral Investig.* **2014**, *18*, 155–161.

33. Hammad, M.; Qualtrough, A.; Silikas, N. Evaluation of root canal obturation: A three-dimensional in vitro study. *J. Endod.* **2009**, *35*, 541–544.

34. Saunders, W.P.; Saunders, E.M. Coronal leakage as a cause of failure in root-canal therapy: A review. *Dent. Traumatol.* **1994**, *10*, 105–108.

35. Zogheib, C.; Naaman, A.; Sigurdsson, A.; Médioni, E.; Bourbouze, G.; Arbab-Chirani, R. Comparative micro-computed tomographic evaluation of two carrier-based obturation systems. *Clin. Oral Investig.* **2012**, *17*, 1879–1883.

36. Silver, GK.; Love, RM.; Purton, DG. Comparison of two vertical condensation obturation techniques: Touch 'n Heat modified and System B. *Int. Endod. J.* **1999**, *32*, 287–295.

37. Chybowski, E.A.; Glickman, G.N.; Patel, Y.; Fleury, A.; Solomon, E.; He, J. Clinical outcome of non-surgical root canal treatment using a single-cone technique with Endosequence Bioceramic Sealer: A retrospective analysis. *J. Endod.* **2018**, *44*, 941–945.

국문 요약

트루나토미 시스템으로 형성된 좁은 근관에서 두가지 다른 충전 방법의 충전능력에 대한 평가

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I. 서론

근관 치료를 받은 치아들은 치근 파절 및 균열 등에 취약하다고 알려져 있다. 이러한 치근 파절 및 균열치는 종종 치료가 불가능하여 발치를 요하게 된다. 근관 확대 테이퍼(taper)가 치근의 파절 저항력과 관련이 있다는 연구는 많이 있으며, 이러한 배경으로 최근에는 테이퍼(taper)가 적은 파일들이 개발되었다. 새로 개발된 나이타이(NiTi) 파일 시스템 중 하나인 TruNatomy (Dentsply Maillefer, Ballaigues, Switzerland)는 파일의 테이퍼를 줄여 치경부에서의 근관 삭제를 최소화하였다. 그러나, 좁게 성형된

근관은 기구 조작 및 시야에 제한을 줄 수 있으며, 이로 인한 근관 충전의 어려움이 있을 수 있다.

이 연구의 목적은 새로 개발된 TruNatomy (Dentsply Maillefer) 나이타이(NiTi) 파일시스템을 이용하여 형성된 근관을 변형된 열가소성 충전방법(modified continuous wave, CW) 혹은 싱글 콘 충전 방법(single cone filling technique, SC)으로 충전하였을 때 발생하는 근관내에서 충전되지 않은 부분의 비율(부피 충전기공률)을 비교를 하기 위함이다. 귀무가설은 '두가지 충전방법에 따른 근관내에서 충전되지 않은 부분의 비율에는 차이가 없다.' 이다.

II. 재료 및 방법

상악 대구치 4 근관을 가진 Dentalike (Dentsply Maillefer)을 이용하였으며, 이 모형들을 TruNatomy 나이타이 파일을 이용하여 확대 및 성형하였다. 이후 무작위로 CW 혹은 SC 그룹으로 배정하였다. 부피 충전기공률을 근첨으로부터 1-6 mm 영역에 걸쳐 미세 전산화 단층촬영분석법(microcomputed tomography)을 이용하여 분석하였으며, 분석 영역인 1-6 mm 영역을 근첨 영역인 1-4 mm, 중간 영역 4-6 mm으로 구분하였다. 두 그루의 평균 값을 independent two sample t tests ($p < 0.05$)를 이용하여 비교 하였다.

III. 결과

CW군의 평균 부피 충전기공률은 2.81 ± 1.11% 였으며, SC군의 부피 충전 기공률은 1.77 ± 0.82% 였다 ($P<0.05$). 구개측 근관의 근첨 영역 (1-4 mm) 에서는 부피 충전기공률이 CW군에서 SC군보다 통계적으로 유의미하게 큰 값을 보였다. 구개측 근관과 제2 근심협측 근관의 중간 영역 (4-6 mm)에서도 부피 충전기공률이 CW군에서 SC군보다 통계적으로 유의미하게 큰 값을 보였다 ($p < 0.05$).

IV. 결론

구개측 근관 및 근심협측 제2 근관에서 SC 충전 방법이 더 적은 부피 충전기공률을 보이는 것을 확인할 수 있었다. 그러나, 두 방법으로 충전한 근관 모두 이전의 연구들과 유사하거나 낮은 근관 내 충전되지 않은 부분의 비율을 보여, 두 방법 모두 트루나토미 시스템을 이용하여 좁게 확대된 근관 충전에 적절한 방법임을 확인할 수 있었다.

핵심되는 말: 근관 충전, 빈 공간, 트루나토미, 미세 전산화 단층촬영분석법