Evaluation of Sealing Ability of Mineral Trioxide Aggregate (MTA) as a Canal Filling Material Using Micro-Computed Tomography

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Evaluation of Sealing Ability of Mineral Trioxide Aggregate (MTA) as a Canal Filling Material Using Micro-Computed Tomography

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감사의 글

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실험을 진행하는데 있어 어려움이 많았는데, 그때 마다 진행할 수 있도록 도움을 주신 서덕규 선생님, 홍승혜 선생님, 이채은 선생님께도 감사의 말씀을 전합니다.

즐겁고 힘든 일 함께 하며 늘 응원해주는 소중한 의국원들, 특히 항상 곁에서 힘이 되고 의지가 되어준 오민정 선생님께 고마운 마음을 전합니다.

마지막으로 가장 가까운 곳에서 격려해주고 아낌없는 사랑을 주는 가족에게 감사와 사랑을 전합니다.

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Abstract

Evaluation of Sealing Ability of Mineral Trioxide Aggregate (MTA) as a Canal Filling Material Using Micro-Computed Tomography

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1. Objectives

Mineral trioxide aggregate (MTA) has been widely used in perforation repair, retrofilling, pulp capping and apexification. Recently, MTA has also been used as an orthograde canal filling material. However, only small number of studies have investigated the sealing ability of MTA as an orthograde canal-filling material. Therefore, the aims of this study were as follows: (1) evaluate the sealing ability of MTA and gutta-percha (GP) in 5mm apical canals, (2) separately compare the sealing abilities of these

materials in mesial and distal canals and (3) investigate the differences in the sealing ability between mesial canal and distal canals.

2. Materials and Methods

Twenty-two extracted sound human mandibular molars were collected. The root lengths were adjusted to 12 mm after cutting the crowns of the teeth. The canals were instrumented with the ProFile® system (Dentsply Maillefer, Ballaigues, Switzerland) to a master apical size of #35/06 in a crown down manner. Next, the teeth without a canal filling (n = 2) were used as negative controls to determine the range of density for micro-computed tomography (micro-CT) analysis, and the other teeth were randomly assigned to two groups (n = 10) according to the obturation material. In the MTA group, the prepared canals were obturated with ProRoot® MTA (Dentsply Maillefer, Ballaigues, Switzerland) using a specialized MTA delivery gun, the Micro-Apical Placement (MAP) System (Dentsply, Tulsa Dental Specialties, Tulsa, OK), Obtura S-Kondensers (Obtura Spartan, Earth City, MO, USA), and absorbent paper points (Meta Dental Co., Cheongju, Korea). In the gutta-percha (GP) group, the prepared canals were obturated with gutta percha (Diadent, Seoul, Korea) and AH Plus® sealer (Dentsply DeTrey, Konstanz, Germany) using a continuous wave vertical compaction technique. All canal filling procedures were performed under a dental microscope (OPMI PICO; Carl Zeiss, Gottingen, Germany) at 10× magnification.

Micro-computed tomography (Skyscan 1076, SkyScan, Kontich, Belgium) was used to scan the teeth. Then, NRecon (NRecon v1.6.3.2; Skyscan) and CT-An (SkyScan) were used for the reconstruction and measurement of the volume of the filling materials (V_M) and the gap between the filling material and the tooth structure (V_G). The percentage volume of the gap (V_G%) was calculated as V_G / (V_M+V_G) * 100. Finally, CT-Vol (Skyscan) was used for the three-dimensional (3D) volumetric visualization.

The Mann–Whitney test was used to determine the statistical significance of the following differences: 1) the percentage volume of the gap (V_G%) of the MTA and GP groups, 2) the V_G% of the MTA and GP groups within the mesial canal groups, and 3) the V_G% of the MTA and GP groups within the distal canal groups. Additionally, a Wilcoxon signed rank tests were performed to analyze the differences between the following: 1) the V_G% of the mesial and distal canal groups, 2) the V_G% of the mesial and distal groups within the MTA groups, and 3) the V_G% of the mesial and distal canal groups within the GP groups.

3. Results

The MTA groups showed significantly higher V_G% than did the GP groups. The same results were observed within the mesial canal group. However, within the distal canal group, the MTA and GP groups exhibited no statistically significant difference. In contrast, the mesial canal groups showed significantly higher V_G% as compared to the distal canal group ($p = 0.001$). The same results were observed within the MTA and GP groups.

Three-dimensional images showed homogenously filled canals and compactly filled isthmuses in the GP groups. However, in the MTA groups, irregularly filled canals, unfilled isthmuses, and patterns of voids due to plugger condensation were observed.

4. Conclusions

Based on the results of this study, MTA exhibited significantly lower sealing ability as compared to gutta-percha when used as an orthograde filling material. Significantly lower sealing ability of MTA was seen in the mesial canal groups of human mandibular molars, which represent a complex canal type, but not in the distal canal groups, a simple canal type in this study. Two-dimensional (2D) and 3D images from micro-CT analysis revealed that most gaps were investigated in the isthmus area or under the root curvature as a plugger mark.

Key words: canal filling, MTA, micro-CT

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I. INTRODUCTION

The material used for root canal obturation is one of the critical determinants of the success or failure of endodontic treatment. Gutta-percha and a sealer have been used as a root canal-filling material over the last century owing to advantages such as adequate obturation of the root canal space (Hammad et al., 2009), handling properties, and biocompatibility. However when gutta-percha canal fillings are tested *in vitro* in dye penetration, fluid filtration, or bacterial leakage models (Madison et al., 1988;

Chailertvanitkul et al., 1966; Jacobson et al., 2002; Fransen et al., 2008), these materials exhibit vulnerability. These results also suggest the weakness of gutta-percha in terms of coronal microleakage.

A number of new endodontic materials have been introduced with the goal of identifying the ideal material for root canal obturation,. For example, in 2004, a new obturation system was launched under the name Epiphany™, containing Resilon™ (Pentron Clinical Technologies, Wallingford, CT, USA) and a resin-based sealer (Shipper et al., 2004). Resilon™ is a thermoplastic synthetic polymer-based root canal-filling material. The performane and handling properties of Resilon™ are similar to those of gutta-percha, and Resilon™ can be heat-softened or dissolved with solvents such as chloroform for retreatment purposes (Azar M et al., 2011). In addition to its relatively convenient handling properties, this new resin-based filling material was found to increase the fracture resistance of the root (Monteiro et al., 2011). A few studies reported that the sealing ability of Resilon™ is similar to that of gutta-percha (Onay et al., 2006; Bodrumlu et al., 2007). However, Hirashi et al. reported that Resilon™ was venerable to enzymatic hydrolysis as compared to gutta-percha (Hirashi et al., 2007) .

Mineral trioxide aggregate (MTA) was introduced by Torabinejad and his group in the 1990s (Torabinejad et al., 1993). MTA was proven to have favorable physical, chemical, and biologic properties (Parirokh et al., 2010, Darvell et al., 2011; Torabinejad et al., 2010). MTA has been widely used for perforation repair (Pitt et al., 1995; Main et al., 2004), retrofilling, pulp capping and apexification (Maroto et al., 2003). Recently, MTA has also been evaluated as an orthograde canal-filling material (Bogen et al., 2009; Hayashi et al., 2004). Bogen and Kuttler suggested MTA as an alternative to gutta percha cones and demonstrated successful cases in which roots were obturated with MTA. Interestingly, in the same paper, these authors also presented micro-CT images of MTA filling with voids. Indeed, few studies have investigated the sealing ability of MTA as an orthograde canal filling material or the retreatability of MTA. Some studies reported that when MTA is used for orthograde root canal filling, its sealing ability is either inferior (Vizgirda et al., 2004) to or superior or similar (Vizgirda et al., 2004; Al-Hezaimi et al., 2005) to that of gutta-percha. One of the drawbacks of MTA is the difficulty in handling it. On mixing, MTA becomes a slurry paste that is difficult to handle and compact into the narrow and confined root canal spaces without creating voids. The sealing ability of any material might be negatively influenced by the presence of voids between its particles.

In the context of this background, we hypothesized that there would be no difference in the quality of canal filling that are created with gutta percha and sealer and those that are created with MTA. The aim of this study were as follows: (1) evaluate the sealing ability of MTA as a root canal filling material compared to that of gutta percha in 5 mm apical canals, (2) separately compare the sealing abilities of these materials in mesial and distal canals, and (3) investigate the differences in sealing abilities between mesial and distal canals.

II. MATERIALS AND METHODS

1. Preparation of Teeth Samples

This study utilized 22 freshly extracted human mandibular molars with fully formed apices. The inclusion criteria for the teeth were as follows: (1) two canals in the mesial root and a single canal in the distal root, (2) root curvature between 0° and 20°, (3) not undergone previous root canal treatment, and (4) no signs of cracks, perforation, internal resorption, external resorption, or root caries. To assess the internal resorption and curvature of the root canals, periapical radiographs were taken from both the buccolingual and mesiodistal directions. The degree of root curvature was calculated from the buccolingual radiographs using the method of Schneider (Schneider, 1971).

The crowns were cut with a high-speed bur under copious water spray such that equal lengths of 12 mm were achieved. After access preparation, the working length was determined using a size 10 or 15 K-files (Dentsply Maillefer, Ballaigues, Switzerland) that was introduced into the canal until it was seen at the apical foramen and then subtracting 0.5 mm from this length. All the canals were instrumented with a ProFile® NiTi system (Dentsply Maillefer) to a master apical size of #35/06 in a crown-down manner. Each canal was irrigated using 10 mL of a 2.5% sodium hypochlorite solution (NaOCl) and a 24-gauge needle between the instrumentations. When the instrumentation was completed, the canal was irrigated with 1 mL of 17% etylenediaminetetraacetic acid (EDTA) for 1 min. followed by 5 mL of 2.5% NaOCl. All the canals were dried with absorbent paper points (Meta Dental Co., Cheongju, Korea). Next, the teeth were randomly assigned to two groups (n=10) according to the obturation material. Teeth without canal fillings (n = 2) were used for negative controls in order to determine the density range for the micro-CT analysis.

1) MTA group: Freshly mixed tooth colored ProRoot® MTA (Dentsply Tulsa Dental, Tulsa, OK, USA) was prepared according to the manufacturer's instructions and delivered into the canal using a specialized MTA delivery gun (dia. 0.90 mm), the Micro-Apical Placement (MAP) System® (Dentsply Tulsa Dental, Tulsa, OK, USA). Next, MTA was first incrementally packed in the root canals using Obtura S-Kondensers (Obtura Spartan, Earth City, MO, USA) and extra moisture was absorbed with paper points. In the apical area, a #40 tip size of the Obtura S-Kondenser and the apical portion of a coarse size paper point (dia. 0.37 mm) were used. In the middle area, #50 tip size of the Obtura S-Kondenser and the apical portion of a coarse-size paper point were used. In the coronal area, a #60 or larger tip size of the Obtura S-Kondenser tip size and the coronal portion of a fine-size paper point (dia.≒0.8 mm) were used.

2) GP group: The prepared root canals were filled with gutta-percha cones (Diadent, Seoul, Korea) and AH Plus® sealer (Dentsply Detrey, Konstanz, Germany) using a continuous wave vertical compaction technique with a System B® (Courtesy SybronEndo, Orange, CA, USA) and Super Endo beta 2 ® backfill system (B&L Biotech, Ansan, Korea).

All canal-filling procedures were performed under a dental microscope (OPMI PICO; Carl Zeiss, Gottingen, Germany) at 10× magnification. Obturated teeth were examined radiographically to confirm the canal filling state and none of the teeth exhibited an incomplete canal filling state. All the specimens were stored at 100% humidity and room temperature until the micro-CT scan. All specimens were prepared by one operator.

2. Micro-CT evaluation

A SkyScan 1172 high-resolution micro-CT scanner (SkyScan, Kontich, Belgium) was used to scan the teeth. The micro-CT scanner had a pixel size of 30 μm, an X-ray source voltage of 100 kV, a beam current of 100 μA, an Al filter 0.5 mm thick, rotation step of 0.4° per step, and an exposure time of 316 ms. Images obtained from the scan were reconstructed with the NRecon (Skyscan) software. CT-An (SkyScan) was used to measure the volume of the gap between the filling material and the tooth structure. The range of measurements was apical 5 mm from 1 mm coronal to the root apex. Within that range, a density between 86 and 255 was assigned to be the volume of the filling material (V_M) and a density between 0 and 25 was assigned to be the volume of the gap (V_G). Then the percentage volume of the gap was calculated as $V_G / (V_G+V_M) * 100$ (Fig. 1). To observe the overall filling state, three-dimensional (3D) images of the filling material were visualized by CT-Vol (SkyScan).

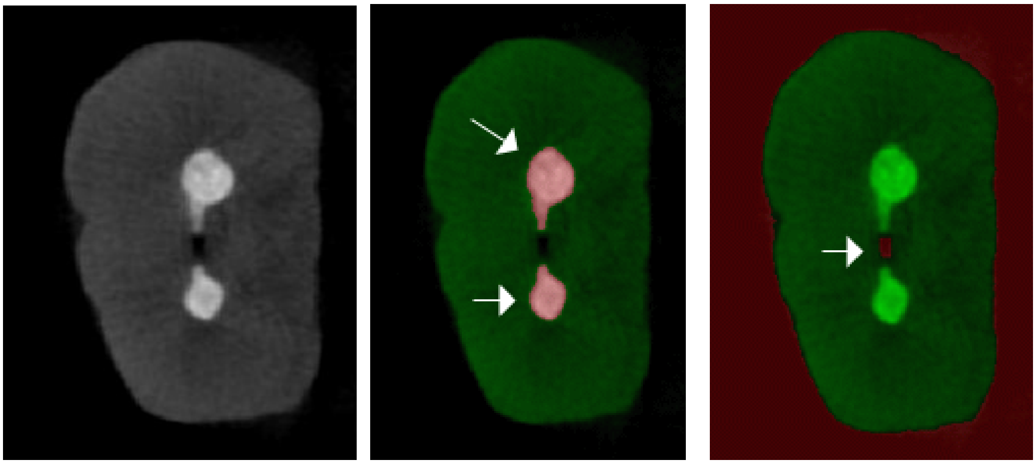

Figure 1. Procedure for the calculation of the percentage volume of gaps (V_G%) with CT-An. (a) Original micro-CT scan view. (b) Program setting for the capture of the density between 86 and 225 (marked by white arrow). The volume of this area was assigned to be the volume of the filling material (V_M). (c) Program setting for the capture of the density between 0 and 25 (marked by white arrow). The volume of this area was assigned to be the volume of the gap (V_G). The percentage volume of the gap (V_G%) is calculated as $V_G / (V_G+V_M) * 100$.

3. Statistical analysis

The Mann–Whitney test was used to determine the significances of the following differences: 1) the V_G% of the MTA and GP groups, 2) the V_G% of the MTA and GP groups within the mesial canal groups, and 3) the V_G% of the MTA and GP groups within the distal canal groups. Additionally, a Wilcoxon signed rank test were performed to analyze the differences between the following: 1) the V_G% of the mesial and distal canal groups, 2) the V_G% of the mesial and distal groups within the MTA groups, and 3) the V_G% of the mesial and distal canal groups within the GP groups.

The significance level was set at $p < 0.05$. The statistical analysis were performed using SPSS software version 20 (SPSS Inc., Chicago, IL, USA).

III. RESULTS

The results are shown in Fig. 2 and Tables 1 and 2. The MTA groups presented significantly higher V_G% than did the GP groups (p = 0.002, Fig. 2A). Comparison of the MTA and GP groups within the mesial canal groups revealed that the MTA groups showed significantly higher V_G% (p = 0.002, Fig. 2B). However, within the distal canal groups, the MTA and GP groups exhibited no statistically significant difference (p = 0.123, Fig. 2C).

When comparing V_G% of the mesial canal and distal canal groups, the mesial canal groups exhibited significantly higher V_G% than the distal canal groups (p = 0.001, Fig. 2D). The same pattern of results were observed within both the MTA and GP groups.

The 3D image of the filling material shows the overall filling state (Fig. 3). In the GP groups, the 3D image revealed a homogenous filling state and an almost perfectly obturated isthmus areas. In the MTA groups, an irregular filling state was observed on the 3D image, particularly in the isthmus and apical areas. On the sectional view, the unfilled space in isthmus area and the plugger mark under the curvature was evident.

Table 1. Median percentage volume of gaps (V_G%) in the MTA and GP groups

Group	Total	Mesial canal	Distal canal
MTA	4.7	7.91	0.66
GP	0.88	1.36	0.22
p	0.002*	0.002*	0.123

* *Statistically significant differences.*

Table 2. Median percentage volume of gaps (V_G%) in the mesial and distal canal groups

Group	V_G%
Mesial canal	3.36
Distal canal	0.36
p	0.001*

* *Statistically significant differences.*

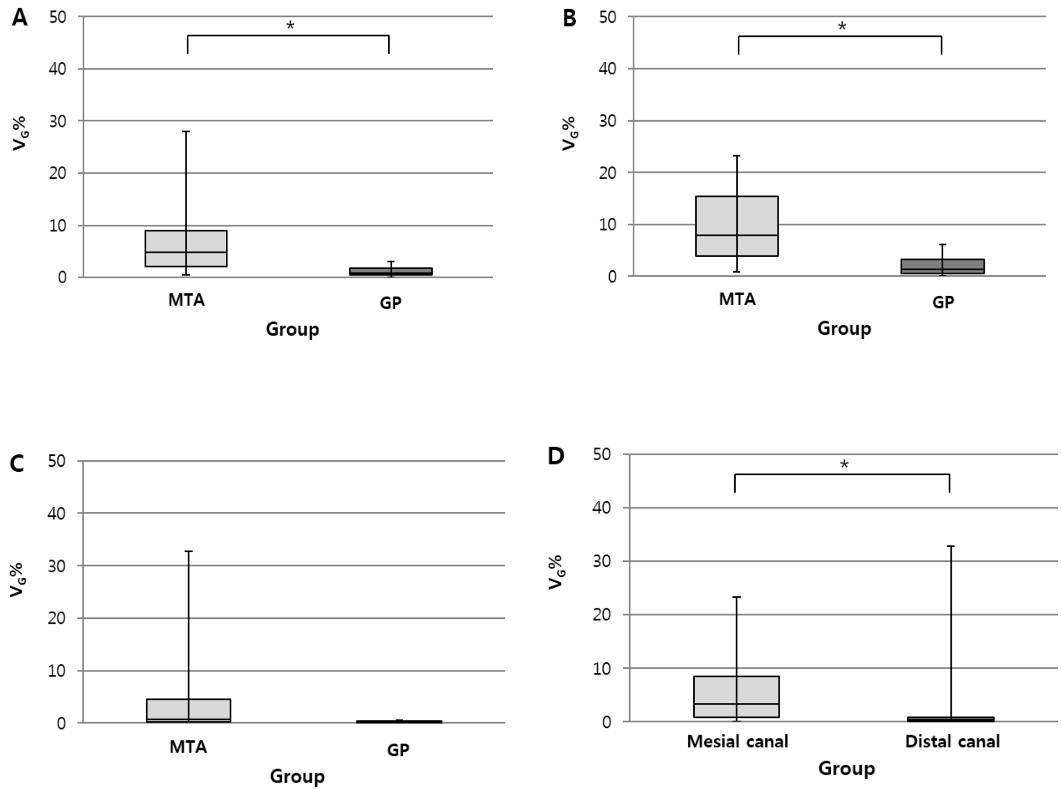

Figure 2. Box plots of the percentage volume of gaps (V_G%) of the MTA and GP groups (A) for collapsed across both types of canal, (B) for the mesial canal groups, and (C) for the distal canal groups. (D) Box plot of V_G% of the mesial canal and distal canal groups.

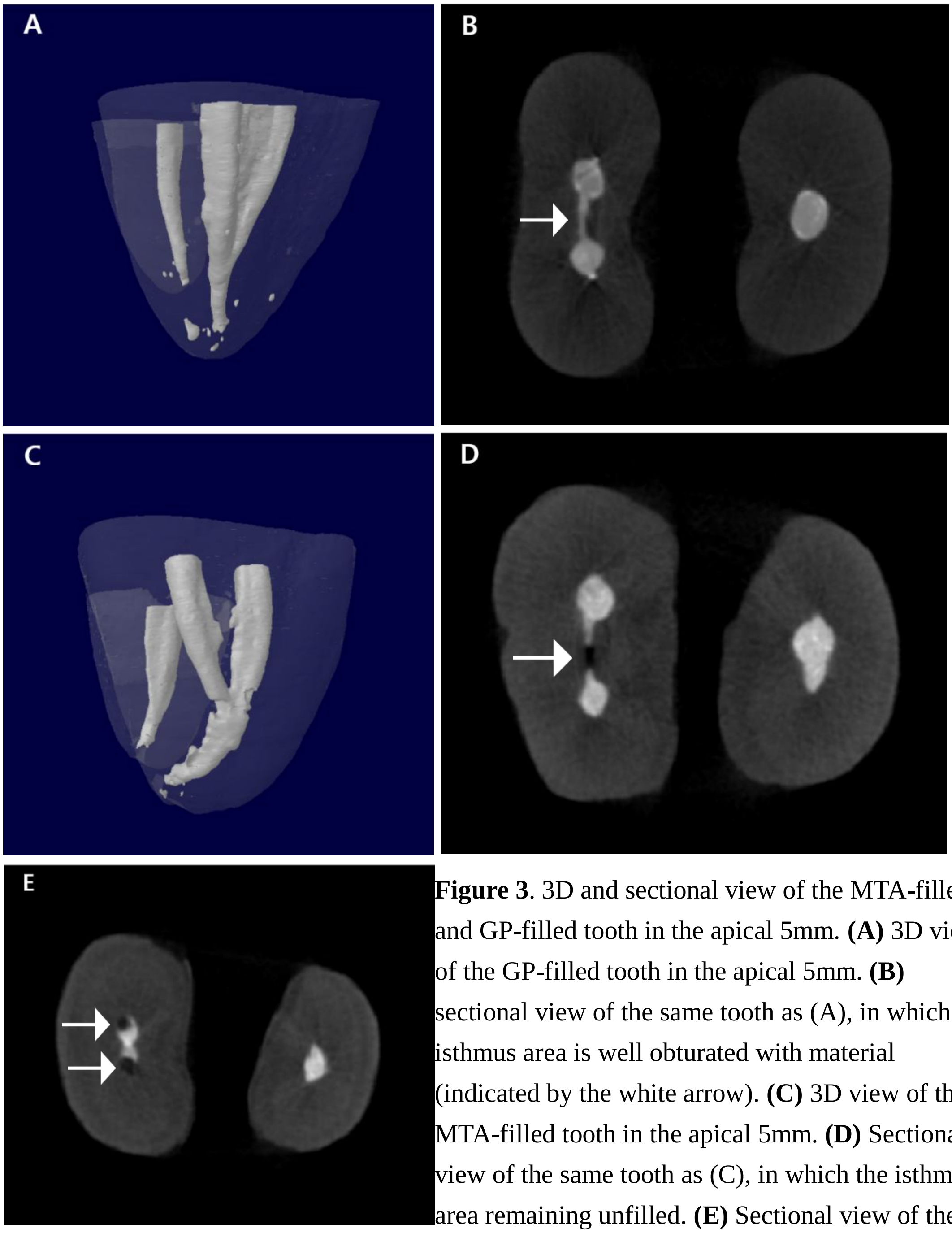

Figure 3. 3D and sectional view of the MTA-filled and GP-filled tooth in the apical 5mm. **(A)** 3D view of the GP-filled tooth in the apical 5mm. **(B)** sectional view of the same tooth as (A), in which the isthmus area is well obturated with material (indicated by the white arrow). **(C)** 3D view of the MTA-filled tooth in the apical 5mm. **(D)** Sectional view of the same tooth as (C), in which the isthmus area remaining unfilled. **(E)** Sectional view of the same tooth as (C), the white arrows indicate the voids in filling material suggesting a plugger mark.

IV. DISCUSSION

In the conditions of the present study, the seals produced by the traditional gutta-percha techniques was superior to those produced by MTA. The poor sealing produced by the MTA might have been caused by its poor handling characteristics. The first possible reason might due to the delivery and packing system used in MTA fillings. We used an MTA delivery gun, endodontic plugger, and a paper point to pack the MTA paste. These are not specialized instruments for MTA packing, but were rather highly available and frequently used instruments in our clinic. However, when packing with the endodontic plugger, it can be covered with the MTA slurry paste and create voids as a result of the packing motion. This mark was observed in some micro-CT views (Fig. 3E). To compensate for the weakness of the endodontic plugger, a paper point was utilized to pack the MTA paste while absorbing extra moisture, but this technique had problems similar to those of the endodontic plugger. Additionally it was difficult to control the packing pressure of MTA. Another cause of the low sealing ability might have been the absence of a sealer. When gutta-percha and sealer are used, the sealer can fill the gap between the GP and the canal, and other complex anatomy (i.e., isthmuses, accessory canals, fins, anastomoses, apical deltas, and other irregularities of the root canal space). For these reasons, orthograde filling with MTA might be technique-sensitive, which might explain the large interquartile range of the sealing abilities that were observed in our data for the MTA group. Our results imply a possible clinical situation in which internal voids and gaps are left between the filling material and the canal wall depending on the case.

Our results are consistent with those of Vizgirda et al. who reported that the apical seal produced by traditional gutta-percha techniques was superior to that produced by MTA. However, Al-Hezaimi claimed the opposite results, saying that orthograde filling of a root canal with MTA may be more resistant against human saliva leakage than vertically condensed gutta-percha and sealer. Differences in the methodologies for measuring sealing abilities might have contributed to these differences.

In the present study, the mesial canal group demonstrated significantly lower sealing ability than the distal canal group regardless of the filling material. This result might be attributable to differences in the canal morphology of mesial and distal canals. Typically, mesial canals have more severe root curvature and have isthmuses that are difficult to fill. In this study, we included teeth with mesial canals of only Weine types II and III which contain isthmuses. Clinically, the results suggest that with any filling material, it might be more difficult to compact a mesial canal than a distal canal regardless of the filling material used.

Within the mesial canal groups, the GP groups showed higher sealing ability than did the MTA groups. We used a continuous wave vertical compaction technique for the GP groups. With this technique, thermoplasticized GP can flow into irregularities in the root canal space. GP may be advantageous for complex canal types for this reason. However, the MTA paste did not provide flowability comparable to that of the GP, therefore, the

MTA could not reach into small complex spaces such as an the isthmus. On the micro-CT view, most of the isthmus space was filled with material in the GP group, but fairly large areas in the isthmuses remained unfilled in the MTA group.

These results indicate that much more caution is required and that the possibility of the formation of gaps in small irregularities needs to be considered when performing orthograde fillings of complex canal types with MTA.

Within the distal canal groups, MTA and GP were not different in terms of sealing and the median V_G% were very low. However, these findings do not indicated that both MTA and GP provide high quality and stable seals. Within the MTA groups, the interquartile range was much larger than that of the GP groups, which indicates that MTA filling does not always guarantee a high sealing ability.

We only measured the apical 5mm because this measurement might be more clinically relevant in terms of root canal treatment success than measurements of the full canal length. In previous studies (El-Ma'aita et al., 2012), the apical canals have been found to be significantly worse than those of coronal canals regardless of filling materials. Thus, if we had analyzed the full canal lengths, the results might have indicate a high sealing ability, particularly for the MTA groups, and it might indicate no significant differences between the MTA and GP groups.

This study has some limitations. The distance and sizes of the isthmuses between the mesial canals could not be controlled when the specimen were randomized. Moreover, the small sample size, the MTA placement technique, and the operator's workmanship might have affected the results. A few studies have reported that the MTA placement technique (Oraie et al., 2012) and vehicle (Holland et al., 2007) may affect the sealing ability.

The micro-CT analysis used in the present study could provide clear an understanding of the location and volumetric measurements of gaps and internal voids because of its highly accurate and nondestructive characteristics of this technique (Jung et al., 2005; Zaslansky et al., 2011). Previous studies in this field have suffered the limitations of measuring and calculating the percentage of the surface areas of the filling materials and voids by the analysis of sectioned roots and the analyses based on digital imaging software. These techniques might be inaccurate because some filling material might be lost in the process, and because 2D techniques cannot be accurately applied to measure a 3D structure. The present study is one of the first to use micro-CT to measure the percentage of the surface and the volume of voids and gaps in root canals filled with MTA or GP.

V. CONCLUSION

Based on the results of the present study, the use of MTA as an orthograde filling material produced significantly poorer sealing abilities than did GP. Additionally, most of the voids were observed in the area of the isthmus or exhibited a plugger mark pattern. MTA exhibited significantly poorer sealing abilities in mesial canals in human mandibular molars, which are complex canal types; however, this difference was not observed in the simple-type distal canals in the present study. Thus, we recommend against the use of MTA for routine canal filling.

References

Al-Hezaimi K, Naghshbandi J, Oglesby A, Simon JH Rotstein I: Human saliva penetration of root canals obturated with two types of mineral trioxide aggregate cements. *J Endod* 31(6): 453-456, 2005

Azar M, Khojastehpour L, Iranpour N: A comparison of the effectiveness of chloroform in dissolving resilon and gutta-percha. *J Dent (Tehran)* 8(1):19-24, 2011

Bodrumlu E, Tunga U: The apical sealing ability of a new root canal filling material. *Am J Dent* 20(5): 295-298, 2007

Bogen G, Kuttler S: Mineral trioxide aggregate obturation: a review and case series. *J Endod*.35(6):777-90, 2009

Chailertvanitkul P, Saunders WP, MacKenzie D: The effect of the smear layer on the microbial coronal leakage of gutta-percha root fillings. *Int Endod J* 29(4): 242–8, 1966

Darvell BW, Wu RC: MTA, an hydraulic silicate cement: review update and setting reaction. *Dent Mater* 27(5): 207-22, 2011

El-Ma'aita, AM, Qualtrough AJ, Watts DC: A micro-computed tomography evaluation of mineral trioxide aggregate root canal fillings." *J Endod* 38(5): 670-672, 2012

Fransen JN, He J, Glickman GN, Rios A, Shulman JD, Honeyman A: Comparative assessment of ActiV GP/Glass ionomer sealer, Resilon/Epiphany, and gutta-percha/AH plus obturation: a bacterial leakage study. *J Endod* 34(6): 725–7, 2008

Hammad M, Qualtrough A, Silikas N: Evaluation of root canal obturation: a three-dimensional in vitro study. *J Endod* 35(4): 541-544, 2009

Holland R, Mazuqueli L, de Souza V, Murata SS, Dezan Junior E, Suzuki P: Influence of the type of vehicle and limit of obturation on apical and periapical tissue response in dogs' teeth after root canal filling with mineral trioxide aggregate. *J Endod* 33(6): 693-697, 2007

Hayashi M, Shimizu A, Ebisu S: MTA for obturation of mandibular central incisors with open apices: case report. *J Endod* 30(2): 120-122, 2004

Hiraishi N, Yau JY, Loushine RJ, Armstrong SR, Weller RN, King NM, Pashley DH, Tay FR: Susceptibility of a polycaprolactone-based root canal-filling material to degradation. III. Turbidimetric evaluation of enzymatic hydrolysis. *J Endod*. 33(8):952-6, 2007

Jacobson HL, Xia T, Baumgartner JC, Marshall JG, Beeler WJ: Microbial leakage evaluation of the continuous wave of condensation. *J Endod* 28(4): 269–71, 2002

Jung M, Lommel D, Klimek J: The imaging of root canal obturation using micro-CT. *Int Endod J* 38(9): 617-626, 2005

Madison S, Wilcox LR: An evaluation of coronal microleakage in endodontically treated teeth: part III—in vivo study *J Endod* 14(9): 455–8, 1988

Main C, Mirzayan N, Shabahang S, Torabinejad M: Repair of root perforations using mineral trioxide aggregate: a long-term study *J Endod* 30(2): 80-3, 2004

Maroto M, Barberı´a E, Planells P, Vera V: Treatment of a non-vital immature incisor with mineral trioxide aggregate (MTA). *Dent Traumatol*: 19(3):165–9, 2003

Monteiro J, de Ataide Ide N, Chalakkal P, Chandra PK: In vitro resistance to fracture of roots obturated with Resilon or gutta-percha. *J Endod* 37(6): 828-31, 2011

Onay EO, Ungor M, Orucoglu H: An in vitro evaluation of the apical sealing ability of a new resin-based root canal obturation system. *J Endod* 32(10): 976-978, 2006

Oraie E, Ghassemi AR, Eliasifar G, Sadeghi M, Shahravan A: Apical Sealing Ability of MTA in Different Liquid to Powder Ratios and Packing Methods. *Iran Endod J* **7**(1): 5-9, 2012

Parirokh M, Torabinejad M: Mineral trioxide aggregate: a comprehensive literature review-partⅠ: chemical, physical, and antibacterial properties. *J Endod* 36(1): 16-27, 2010

Pitt Ford TR, Torabinejad M, McKendry DJ, Hong CU, Kariyawasam SP: Use of mineral trioxide aggregate for repair of furcal perforations. *Oral Surg Oral Med Oral Pathol Oral Radiol Endod* 79(6):756–63, 1995

Raina R, Loushine RJ, Weller RN, Tay RF, Pashley DH: Evaluation of the quality of the apical seal in Resilon/Epiphany and Gutta-Percha/AH Plus-filled root canals by using a fluid filtration approach. *J Endod* 33(8): 944-947, 2007

Schneider SW: A comparison of canal preparations in straight and curved root canals. *Oral Surg Oral Med Oral Pathol* 32(2): 271-275, 1971

Shipper G, Orstavik D, Teixeira FB, Trope M: An evaluation of microbial leakage in roots filled with a thermoplastic synthetic polymer-based root canal filling material (Resilon) *J Endod* 30(5): 342-347, 2004

Torabinejad M, Watson TF, Pitt Ford TR: Sealing ability of a mineral trioxide aggregate when used as root end filling material. *J Endod* 19(12): 591-5, 1993

Torabinejad M, Chivian N: Clinical applications of mineral trioxide aggregate. *J Endod* 25(3): 197-205, 1971

Torabinejad M, Parirokh M: Mineral trioxide aggregate: a comprehensive literature review--part II: leakage and biocompatibility investigations. *J Endod* 36(2): 190-202, 1971

Vizgirda, PJ, Liewehr FR, Patton WR, McPherson JC, Buxton TB: A comparison of laterally condensed gutta-percha, thermoplasticized gutta-percha, and mineral trioxide aggregate as root canal filling materials. *J Endod* 30(2): 103-106, 2004).

Zaslansky P, Fratzl P, Rack A, Wu MK, Wesselink PF, Shemesh H: Identification of root filling interfaces by microscopy and tomography methods. *Int Endod J* 44(5): 395-401. 201

ABSTRACT (IN KOREAN)

Micro-Computed Tomography 를 이용한 Mineral Trioxide Aggregate (MTA)의 근관충전재로서의 밀폐도 평가

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I. 목적

MTA 는 천공의 수리, 역충전, 직접 치수복조술 및 치근단형성술 등에 다양하게 이용되어 왔으며 최근 근관충전재로서도 이용되고 있다. 그러나 MTA 가 통상적인 근관충전재로서 적절한 밀폐성을 가지는지에 관해서는 연구가 많지 않다. 따라서 이번 연구의 목적은 (1) 근관충전재로 MTA 를 이용하였을 때 밀폐도를 거타퍼챠와 비교하고 (2) 근심 근관과 원심

근관에서 각각 MTA 와 거타퍼챠의 근관밀폐도를 비교하고 (3) 부가적으로 근심 근관과 원심 근관의 근관 밀폐도를 비교하는 것이다.

II. 실험 방법 및 재료

22 개의 발치된 사람의 하악대구치를 수집한 후 치관을 제거하여 12mm 로 치아뿌리 길이를 맞추었다. ProFile® NiTi system (Dentsply Maillefer, Ballaigues, Switzerland)를 이용하여 crown-down tech. 으로 근관형성을 하였으며 최종 치근단 크기는 0.06 taper #35 로 하였다. 이후 2 개의 시편은 음성대조군으로 이용하여 microCT 분석에서 밀도측정에 이용하였고 나머지 시편은 충전재의 종류에 따라 두 가지 군(n = 10)으로 무작위로 배정하였다. MTA 군에서는 ProRoot® MTA (Dentsply Tulsa Dental, Tulsa, OK, USA)를 MTA gun 인 Micro-Apical Placement (MAP) System® (Dentsply, Tulsa Dental Specialties, Tulsa, OK) 와 endodontic plugger, paper point 를 이용하여 충전하였고 거타퍼챠 군에서는 거타퍼챠 (Diadent, Seoul,Korea)와 AH Plus® sealer (Dentsply DeTrey, Konstanz, Germany) 를 이용해 continuous wave vertical compaction technique 으로 충전하였다. 모든 근관충전 과정은 현미경 (OPMI PICO; Carl Zeiss, Gottingen, Germany) 10× 의 배율하에 진행하였다.

MicroCT (Skyscan 1076, SkyScan, Kontich, Belgium) 를 촬영하였고 NRecon (NRecon v1.6.3.2; Skyscan) 과 CT-An(SkyScan) 프로그램을 이용하여

상을 재건하고 충전재의 부피(V_M)와 충전재와 치아사이 공간의 부피(V_G)를 측정하였다. 이후 다음과 같은 수식을 통하여 공간의 부피 백분율(V_G%)을 구하였다 : $V_G/(V_M+V_G)*100$. 마지막으로 CT_Vol (Skyscan) 을 이용하여 삼차원적으로 각 재료로 충전된 이미지를 관찰하였다.

Mann-Whitney test 를 이용하여 다음에 대해 검정하였다. 1) 충전재와 치아사이 공간의 부피 백분율에 대한 MTA 그룹과 거타퍼챠 그룹의 차이 차이 2) 근심 근관에서 공간의 부피 백분율에 대한 MTA 그룹과 거타퍼챠 그룹의 차이 차이 3) 원심 근관에서 공간의 부피 백분율에 대한 MTA 그룹과 거타퍼챠 그룹의 차이. 부가적으로 Wilcoxon signed rank test 를 이용하여 다음에 대해 분석하였다. 1) 공간의 부피 백분율에 대한 근심 근관과 원심 근관 그룹의 차이 2) MTA 그룹에서 공간의 부피 백분율에 대한 근심 근관과 원심 근관 그룹의 차이 3) GP 그룹에서 공간의 부피 백분율에 대한 근심 근관과 원심 근관 그룹의 차이

III. 결과

MTA 그룹이 거타퍼챠 그룹에 비해 유의차 있게 높은 공간의 부피 백분율(V_G%)을 보였다. 근심 근관에서도 같은 결과를 보였으며 원심 근관에서는 MTA 그룹과 거타퍼챠 그룹 사이에 유의차가 없었다. 또한 근심 근관은 원심 근관에 비해 유의차 있게 높은 공간의 부피 백분율을 보였다. MTA 와 거타퍼챠 그룹에서도 각각 같은 결과를 보였다.

삼차원 영상에서 GP 그룹에서는 비교적 균질한 충전 상태와 거의 완전하게 밀폐된 isthmus 부위가 관찰되었다. 그러나 MTA 그룹에서는 불규칙한 충전 상태와 일부가 충전되지 않은 isthmus, plugger mark 로 보이는 공간이 관찰되었다.

IV. 결론

이 실험의 결과 내에서 MTA 는 통상적인 근관충전 재료로 사용될 경우 거타퍼챠보다 낮은 근관밀폐도를 보였다. 공간은 주로 isthmus 부위에서 나타나거나 근관 만곡의 하방에 plugger mark 의 형태로 나타났다. 복잡한 근관형태를 가지는 근심 근관에서 MTA 그룹은 거타퍼챠 그룹에 비해서 더 낮은 밀폐도를 보였으나 비교적 단순한 근관형태를 가지는 원심 근관에서는 두 그룹의 근관 밀폐도에 유의차가 없었다. 따라서 MTA 를 통상적인 근관충전재로 사용하는 것은 추천되지 않는다.

핵심 되는 말: 근관 충전, MTA, micro-CT

Raw Data

1. The percentage volume of gaps (V_G%) in the MTA groups

Sample	Mesial canal	Distal canal
1	3.14	0.89
2	4.18	0.09
3	15.86	9.08
4	11.36	1.23
5	23.29	32.77
6	0.82	0.29
7	6.70	0.04
8	9.13	3.09
9	5.53	0.17
10	15.21	0.43

2. The percentage volume of gaps (V_G%) in the GP groups

Sample	Mesial canal	Distal canal
1	1.90	0.59
2	3.22	0.52
3	2.24	0.06
4	0.01	0.05
5	6.07	0.13
6	3.49	0
7	0.41	0.10
8	0.62	0.44
9	0.81	0.40
10	0.80	0.31