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한국인의 상악 제 2대구치 치근단면 형태에 대한 연구

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ABSTRACT

Prevalence of Various Anatomic Variations in Cross-sectioned Apices of Maxillary Second Molars in Korean and Their Effect on Canal Cleanliness

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Purpose: This study evaluated the apical root canal system of maxillary second molars, in which conventional endodontic treatment had failed.

Materials and Methods: One hundred eighteen extracted endodontically failed maxillary second molars were examined to investigate the root canal morphology using clinical photographs. High-resolution cross-sectional images at the 3mm level from the root apices were taken to evaluate the anatomic variations and canal cleanliness. The incidence of anatomic variations and canals containing debris were evaluated statistically.

Results: One (0.85%) maxillary second molar had four separate roots, while 52 (44.07%) had three separate roots. The remaining 65 (55.08%) showed 6 different types of fusion in their roots. As the number of fused roots increased from none to three, the incidence of isthmuses in the cross-sectional images increased significantly from 43.40% to 76.92% in 2-root fusion and 88.46% in 3-root fusion. In addition, the occurrence of less-cleansed canals increased from 22.64% to 38.46% and 53.85%, respectively ($p<0.05$). Sixty four teeth (54.24%) had 3 canals while 38(32.2%) had additional canals; most of them were located in the MB roots (81.58%). Seventy six (64.41%) had isthmuses in the apical region and 58 out of 76 were located in MB roots.

Condlusions: Logistic analysis indicated that the less division of roots was associated significantly with the occurrence of insufficient cleaning during endodontic treatment (OR=1.765, $p<0.05$), while the presence of an additional canal showed no association.

Key words : Endodontics, Retreatment, Root canal anatomy, Maxillary second molar

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Ⅰ. Introduction

The aim of root canal treatment is to eliminate bacteria, infected dentin, and pulp tissue in the diseased root canal anatomy. The root canal treatment of diseased maxillary molars may be a challenge because of the accessibility and complexity of the canal anatomy, even though practitioners are now believed to have proper instruments and knowledge for successful non-surgical endodontic treatments. Often, they have trouble in thorough cleaning of the canals, particularly when they have to deal with the apical regions of canals with particular anatomic variations[1, 2].

As a result of the complexities and anomalies observed in the root canal system[3-5], intracanal debris and a smear layer may remain in the apical region and they sometimes contain bacteria[6], which can cause periapical diseases when they are not controlled properly. In addition, the presence of a smear layer may block the dentinal tubules of the canal walls, so that the infiltration of antimicrobial agents or sealers can be resisted[7, 8].

Maxillary second molar(MSM) is one of the most challenging teeth when performing root canal treatment because of its root canal complexity and the difficulties to access by location[4]. Therefore, understanding the wide variations in the root canal anatomy of a specific tooth and how those variations affect the cleanliness of the canals after chemo-mechanical preparation can help practitioners prepare for such an unpleasant confrontation during endodontic treatment.

Several studies have examined the root canal morphology of the maxillary molars using a radiographic evaluation of conventional periapical images and more recently, using computed tomographic imaging technology[9-11]. Although those methods are quite effective and practical to analyze root canal anatomy, they are not adequate to assess the canal cleanliness of endondontically treated teeth. Therefore, a visual examination of cross-sectioned apices in actual extracted MSMs that failed conventional endodontic treatment was made to determine the association between the specific anatomic features of the apical region and failed apical cleaning.

Ⅱ. Material and Methods

This study was approved by the institutional review board (IRB no. B-1509/314-102). One hundred eighteen MSMs extracted after conventional endodontic treatment and re-treatment had failed were examined. MSMs with perforations, cracks, fractured instruments or silverpoint fillings in the canals were excluded. Teeth with an unconventional treatment history, such as pulpotomy, were excluded as well. Clinical photographs of the extracted teeth were taken to evaluate the external root shape. The root apices were then sectioned at the 3mm level from each root-end with a high-speed hand piece using a diamond bur (FG 6856014, Mani, Tokyo, Japan). The cross-sectioned surface was examined using a dental microscope (OPMI®, Carl Zeiss, Oberkochen, Germany) at X25 magnification and digital image was taken (D90, Nikon, Tokyo, Japan). The examined specimens were classified according to the number of roots and the location where fusion had occurred.

If two roots of the examined MSMs were merged at the cross-sectioned level (3mm from the root apex), those teeth were considered to have fusion in their roots. Fusion that occurred in the middle third or coronal third of the roots leaving apices apart were not counted in this study. The number and location of the canals and isthmuses were observed carefully and independently by two trained investigators. Agreement was made by consensus when the reading was different between two. The presence of 1) necrotic tissue remaining in the canal system, 2) hard tissue debris, 3) visible smear layer or obvious discoloration around filled canals, and 4) uninstrumented canals (regardless of discoloration) were considered to have unclean canals in apices. The prevalence of detected anatomic variations in each type of root shape was calculated and compared using a Chi-square test. The association between the anomalies and the incidence of unclean canals was evaluated statistically using a Chi-square test and logistic regression analysis (SPSS version 17.0, SPSS Inc., Chicago, IL, USA).

Ⅲ. Results

Of the 118 examined MSMs, one (0.85%) MSM had four separate roots, 52 (44.07%) had three separate roots, while the remaining 65(55.08%) had 6 different types of fusion in their roots. Thirty nine (33.05%) MSMs had 2 fused roots with an isolated single; 20 (52.28%) had fused mesiobuccal and palatal roots; 18 (46.15%) had fused buccal roots; and only one (2.56%) had a distobuccal root fused with a palatal root. Twenty six (22.03%) single-rooted MSMs, 7 (26.92%) had the palatal roots connected to either the mesiobuccal or distobuccal side of the fused buccal roots and 5 (19.23%) had a palatal root fused with both separate buccal roots. The fusion of all 3 roots into a cone-shape was found in the remaining 14 (53.85) single-rooted MSMs (Table 1).

Seventy six (64.41%) MSMs had isthmuses in the apical portion and 58 out of 86 observed isthmuses were located in the MB roots, whereas 15 of them were in the palatal roots and 13 were in the DB roots(Figure 1). Less cleansed canals were observed in 33 (44.42%) out of the 76 MSMs with apical isthmuses, while only 7 (16.67%) out of 42 MSMs without apical isthmuses showed signs of contamination or debris. The prevalence of an unclean canal was significantly higher in the MSMs with apical isthmuses ($p<0.05$).

Sixty four (54.24%) MSMs had 3 canals with 13 (11.02%) having 2 canals, while only 3 (2.54%) of them had single merged canals at the apex. Thirty eight (32.2%) MSMs had additional canals and most of them (81.58%) were located in the MB roots. Additional canals were

Table 1. The prevalence of isthmus, additional canal and unclean canal found in cross-sectioned apices of various root shape types.

Type of Root Shape		No. of specimens (%, in total)	No. of specimens with unclean canal	No. of specimens having canal Isthmus	No. of specimens having additional canal
			(%, in MSMs with same type of root shape)		
Separate 4 Roots		1 (0.85)	0 (0)	0 (0)	0 (0)
Separate 3 Roots		52 (44.07)	11 (21.15)	23 (44.23%)	20 (38.46)
Fused 2 Roots + Isolated Single Root	MBR-DBR fusion	18	5	10	8
	MBR-PR fusion	20	10	20	4
	DBR-PR fusion	1	0	0	1
	Subtotal	39 (33.05)	15 (38.46)	30 (76.92)	13 (33.33)
Fused 3 Roots	MBR-DBR-PR or DBR-MBR-PR fusion*	7	4	6	3
	MBR-PR-DBR fusion**	5	2	4	1
	Conical shape fusion	14	8	13	1
	Subtotal	26 (22.03)	14 (53.85)	23 (88.46%)	5 (19.23)
Total		118 (100)	40 (33.90)	76 (64.41)	38 (32.20)

* MSMs having palatal roots fused with either mesiobuccal or distobuccal side of fused buccal roots

** MSMs having palatal roots fused with both separate buccal roots

Abbreviations: MSM, maxillary second molar; MBR, mesiobuccal root; DBR, distobuccal root; PR, palatal root

significantly more frequent in the teeth with 3 separate roots compared to the teeth with other root types ($p<0.05$). The incidence of specimens having unclean canals was 34.21% in the MSMs with additional canals and 33.75% in the MSMs without extra canals (Figure 2). No significant difference in canal cleanliness was observed between 2 groups ($p>0.05$).

As the number of fused roots increased from none (separate 3 or 4 roots) to two and three (MB-DM-P fusion), the incidence of isthmuses in the cross-sectional images gradually increased from 43.40% to 76.92% and 88.46% in the teeth with two fused and three fused roots, respectively; the MSMs containing unclean canals increased from 22.64% to 38.46% and 53.85%, respectively (Figure 3). The prevalence of unclean canals in the apices was significantly different among the three groups ($p<0.05$).

To assess the effects of less division in the roots on the occurrence of unclean canals after treatment, all teeth were classified into 3 categories according to the degree of fusion (0=Teeth having separate 3 or 4 roots, 1=Teeth having 2-root fusion, and 2=teeth having 3-root fusion). Considering the covariability with root fusion, the presence of an isthmus was not counted as a variable while an additional canal

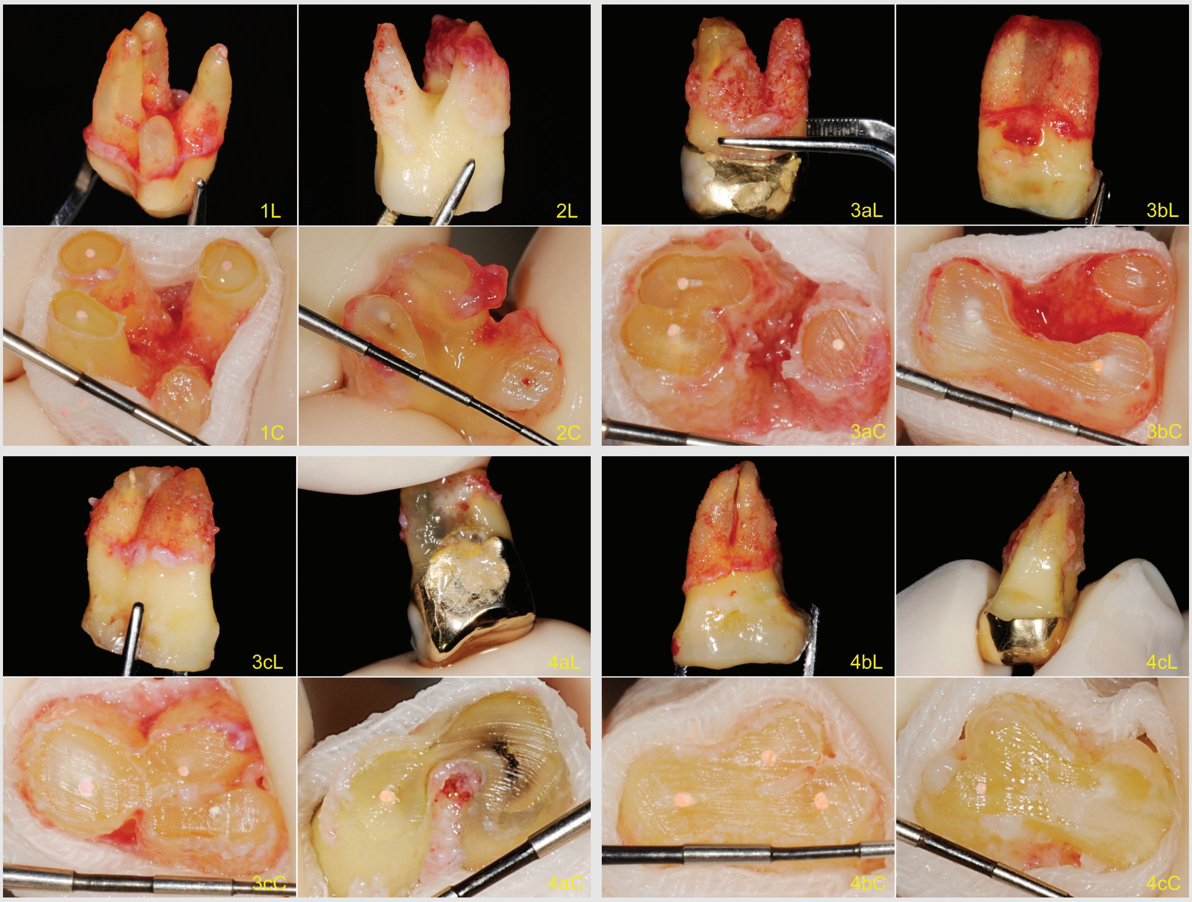

Fig. 1. Clinical Photographs of 8 Different Root Configurations in Examined Maxillary Second Molars (Numbers refer to Root Shape Types, L: longitudinal view, C: cross-sectional view). Type 1 - Separate 4 Roots, Type 2 - Separate 3 Roots, Type 3 - fused 2 Roots with isolated single root (3a: MBR-DBR Fusion, 3b: MBR-PR Fusion, 3c:DBR-PR Fusion), Type 4 - fused 3 Roots (4a: MBR-DBR-PR or DBR-MBR-PR Fusion, 4b: MBR-PR-DBR Fusion, 4c: Conical shape fusion) .

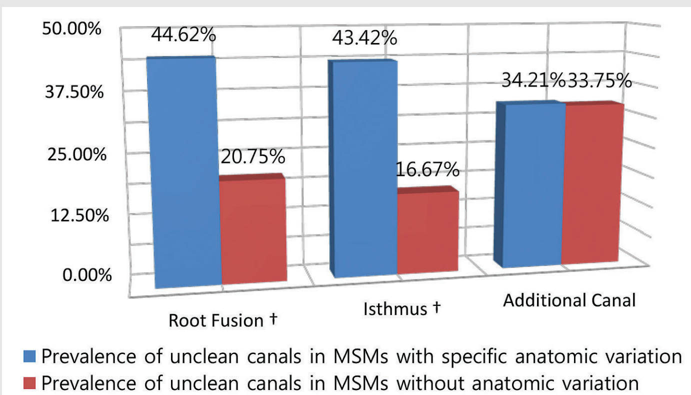

Fig. 2. Comparison of The Prevalence of Unclean Canals within MSMs having Different Anatomic Features in Apices
† = variation showing significantly higher prevalence of unclean canals (χ^2 test, $p<0.05$).

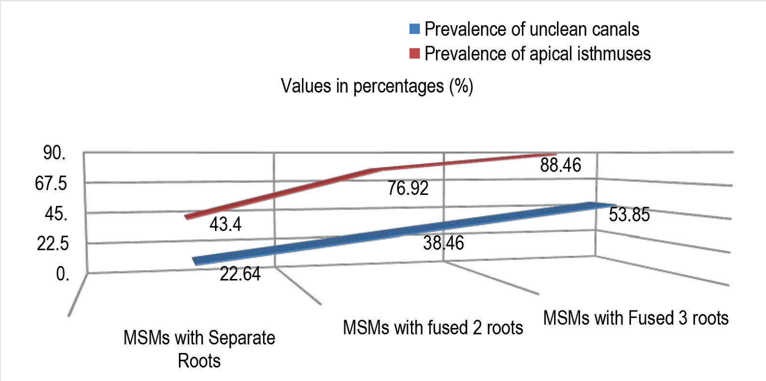

Fig. 3. Prevalence of MSMs with Unclean Canals and those with Isthmuses in Various Root Fusion Types (%)

was included as another potential factor. Logistic analysis indicated that less division of the roots in MSMs was associated significantly with the occurrence of a less cleansed canal after treatment (OR=1.765, $p<0.05$), while the presence of an additional canal was not closely related ($p>0.05$).

Ⅳ. Discussion

In the present study, the prevalence of root fusion in the examined MSMs was remarkably high; 55.08% was the highest rate among the results from other similar studies of root fusion. Studies performed in Ireland (43%), China (40.1~42.5%), India (6.7%), and even in Korea (10.71%)[12-15] reported a lower prevalence of root fusion. This suggests that fused roots of MSMS could be considered to be one reason for a failing root canal treatment. The incidence of an additional canal, however, was in agreement with a previous study targeting the Korean population[15]. Another study reported that C-shaped canals, which are relatively common in fused roots and often contain isthmus-like structures, were found frequently in the mandibular second molars of the Korean population[16]. Ethnic factors might have affected the distribution of those anatomic variations, as mentioned in other articles but differences in study design, sample size, assessment criteria should also be considered when explaining the discrepancies among these studies. For a visual identification of intracanal debris and smear layers in the root apices, the actual extracted teeth were examined instead of using a CBCT scanned image or other indirect methods. Because most examined specimens had a history of intractable root canal diseases that resulted in their extraction, the incidence of a particular anatomic variation may have shown a biased statistic result. Therefore, the results from the present study may change after examining a larger number of randomly selected specimens in the future.

The clinical significance of this study can be found in the remarkably high incidence of unclean canals in the specimens with fused roots which indicates that the incidence of both an isthmus and unclean canals increase gradually according to the degree of fusion in roots. A similar finding was cited in another study performed in China in that root canals of MSMs with 3-root fusion were more inclined to merge as a result of merging between the MB and DB canals or among the MB, DB, and P canals in the middle and apical third[12]. These findings commonly point out that the apical canal system becomes increasingly complicated as more roots are fused together. Combined with the findings from previous investigations showing the limitations of mechanical preparation in the apical canal system[3-5, 11, 17, 18], the results from the present study clearly show that the fusion that occurred in roots contributes to the reduced efficacy of conventional canal cleaning procedure by increasing the complexity of the canal configuration.

The presence of an isthmus in the canal system and its effects on endodontic treatment have already been examined in many different studies using a sectioning method[19-21]. On the other hand, only a few studies examined the incidence of an isthmus and additional canal in relation to the canal cleanliness. In the present study, more than 40% of MSMs with an isthmus had unclean canals while only 16.67% of normal specimens had intracanal debris. This shows how difficult complete removal of the intracanal contents from the canal isthmus in an actual clinical situation is, as already noted in numerous reports[3-5, 11, 17]. Not only do the isthmuses act as a physical barrier that blocks the access of the instrument and chemicals, they often hide from conventional periapical radiographic images[9, 22]. In accordance with other related studies, all three kinds of anatomic variations (root fusion, isthmus, and additional canal) were far more frequent in the MB roots[23, 24]. The continuous deposition of dentin in mesiodistal and buccolingual directions was reported to cause wide variations of the canal system found in the MB roots of maxillary molars[25, 26].

Numerous in-vitro studies evaluating the efficacy of various canal preparation methods used scanning electron microscopy (SEM) to detect uninstrumented canal walls and the remnants of debris[27-29]. In this study, some of specimens examined were replanted following retrograde filling so that advanced imaging techniques were not counted due to the limited extraoral time of temporarily extracted specimens. Although finding intracanal debris in high resolution photographs was not difficult for the examiners, SEM imaging or histologic analysis of a sectioned surface would have improved the accuracy of assessment.

One limitation of this study was that the treatment protocols and instruments applied previously to the specimens were not strictly standardized. Previous studies already reported the relative effectiveness of various canal instrumentation techniques using different evaluation methods. Unfortunately, the canal preparation procedure, which is closely related to the canal cleanliness, could not be identical, because the extracted MSMs had undergone prior root canal treatments in various clinics by practitioners with different periods of experience in endodontics. Nevertheless, the obviously higher incidence of intracanal debris observed in teeth with a specific type of anomaly has strong significance, because it shows how challenging the complete debridement of a specific anatomic structure is, regardless of the practitioner's proficiency or instruments efficiency.

Remaining tissue remnants and microorganisms in the less cleansed apical region are considered one of main causes of treatment failure[30]. According to the results from this study, clinicians should treat diseased MSMs of Korean patients with great caution in every step to avoid potential risks inherent in the specific anatomic variation. Advanced imaging technologies, such as CBCT scanning, will provide more detailed information of the apical canal system to them. On the other hand, cross-sectioning is better in detecting the root canal anatomy than CBCT[31]. Using an endodontic microscope may also help them to detect and clean the abnormal canal structures in apices[20].

Ⅴ. Conclusions

The presence of fused roots and isthmuses in the apical region are frequent and may contribute to the failure of complete cleaning and disinfection of the apical canal system. Practitioners always should take into account their presence in MSMs and be prepared with proper knowledge and tools to avoid insufficient cleaning.

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