2013년 2월
석사학위논문

C-shaped root canal configuration in maxillary molars

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상악 대구치에서 C형 근관에 관한 연구

2013년 2월 25일

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이 논문을 치의학 석사학위신청 논문으로 제출함

2012년 10월

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2012년　11월

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C형 근관은 하악 제 2대구치에서 가장 흔하게 나타나는 특이 형태이며 형태적 특성에 대한 보고와 유형에 대한 분류가 많이 보고되었다. 그러나 상악 대구치에 대해서는 이러한 보고가 거의 없으며 분류가 시행되지 않았다. 이 연구의 목적은 CBCT 스캔 자료를 조사하여 한국인의 상악 대구치에서 융합 치근과 C형 근관의 발현 빈도와 유형을 분석하는 것이다.

조선대학교 치과병원에 내원한 환자중, 2010년 2월부터 2012년 7월까지 교정치료를 목적으로 촬영한 총 911명(여성 518명, 남성 393명)의 환자의 CBCT (CB MercuRay, Hitachi, Tokyo, Japan) 영상을 조사하였다. 제 3대구치와 미성숙된 영구치를 제외하고 총 1786개의 상악 제 1대구치와 1767개의 상악 제 2대구치가 연구에 포함되었다.

CT 영상은 전용 이미지 프로그램 (PiViewstar, Rapidia MPR; Infinitt, Seoul, Korea)을 사용하여 세 가지 평면 (sagittal, coronal 및 axial)과 3차원 영상으로 재구성하여 평가하였다.

조사 결과, 융합 치근은 상악 제 1대구치의 3.3%, 상악 제 2대구치의 20.2%에서 발현되었고 C형 근관은 상악 제 1대구치의 0.9%, 상악 제 2대

구치의 2.8%에서 발현되었다.

비록 C형 근관이 하악 제 2대구치에서 가장 흔하게 나타나지만 상악 대구치에서도 또한 발현된다. 임상가들은 성공적인 근관치료를 위해서 이러한 해부학적 변이를 인지해야 한다.

Ⅰ. Introduction

The main objective of root canal treatment is thorough shaping and cleaning of all pulp spaces and its complete obturation with an inert filling material.[1] Untreated canal is one of the reason why root canal treatment fails.[2] A canal is often left untreated because the dentist did not perceive its presence. Therefore, clinicians must have thorough knowledge of root canal morphology including characteristic features and anatomic variations for successful root canal treatment.[1]

One of the most important anatomic variations is the C-shaped root canal configuration. In 1979, Cooke and Cox first described the clinical implications of C-shaped root canal configuration in molars.[3] It is difficult to diagnose and manage this variation, because of its unique feature with presence of fin or web connecting the individual root canals. This configuration may occur in mandibular first molar, mandibular first premolar, maxillary molars, but it is most frequently found in mandibular second molars.[4-8] Its anatomic feature and classification has been well documented in many literatures.[8-10] It is well-known that tooth anatomy varies according to racial origin.[11,12] The incidence of C-shaped root canals in mandibular second molars has also ethnic difference and it is more higher in Asians than in other racial groups.[13-18] Only limited number of studies reported C-shaped root canals in maxillary molars, and its classification has not been established.

The aim of this study was to investigate the incidence of fused roots and C-shaped root canals in maxillary molars and to classify the types by analyzing cone-beam computed tomography (CBCT) in a Korean population.

Ⅱ. Materials and methods

Digitized CBCT images from 911 subjects that had been obtained in Chosun University Dental Hospital, Gwangju, Korea, between February 2010 and July 2012 for orthodontic treatment were enrolled in the study. 393 men and 518 women were included in this study. Mean age of the patients was 21.9 years, ranging from 15 to 61 years. Fully erupted and completely root formed maxillary molars were included in this study. Third molars and immature teeth were excluded. A total of 3,553 maxillary molars (1,786 maxillary first molars and 1,767 maxillary second molars) were examined retrospectively.

The CBCT images were taken using CB Mercuray (Hitachi medical corp, Tokyo, Japan), and the scan settings were Φ15 ㎝ scan field of view, 0.3㎜ voxel size, 120 kVp, 15 ㎃, with a 10 second exposure time. Tomography sections in the axial, coronal, and sagittal planes were displayed by PiViewstar and Rapidia MPR software(Infinitt, Seoul, Korea). Contrast and brightness of images could be adjusted using the image processing tool of the software to ensure optimal visualization. The long axis of each tooth was determined and cross-sectional images at apical third were examined by rolling the tool bar from pulp chamber to the apex. The incidence and types of fused roots, C-shaped root canals were evaluated. The types of fusion was classified by sequence of each fused roots. C-shaped root canals were classified by each root canal which constitutes " C " shape.

Ⅲ. Results

Table 1 showed the types and numbers of fused roots in maxillary first and second molars. Root fusion were present in 402 (11.3%) maxillary molars of 3553 teeth examined in this study. 57 (3.2%) maxillary first molars and 345 (19.5%) maxillary second molars had fused root.

Table 1. Types and numbers of fused roots in maxillary first and second molars

Types of fused roots		Maxillary first molar (*n*=1786) (%)	Maxillary second molar (*n*=1767) (%)
Fusion of 2 roots	MB-P	6(0.3)	123 (7.0)
	DB-P	11(0.6)	5 (0.3)
	MB-DB	31(1.7)	41 (2.3)
Fusion of 3 roots	MB-DB-P	6(0.3)	1 (0.1)
	DB-MB-P		40 (2.3)
	MB-P-DB (V shape)	2(0.1)	13 (0.7)
	All root (Y or cone shape)		62 (3.5)
etc	B-P (teeth with 2 root)	1(0.1)	59 (3.3)
	MB-MP and DB-DP		1 (0.1)
	Total	**57(3.2)**	**345(19.5)**

" -" means fusion of roots (ie, "MB-P" means mesiobuccal root fused with palatal root)
B, buccal; MB, mesiobuccal; DB, distobuccal; P, palatal; MP, mesiopalatal; DP, distopalatal

Two or three roots were fused and 9 types of fusion were found in this study. Figure 1 showed the representative images of each types of fusion. The most common type was MB-DB in the first molars and MB-P in the second molars. The difference between

MB-DB-P and DB-MB-P type was sequence of fusion. The former made a C-shape which opened to mesial side, but the latter made a C-shape which opened to distal side. (Figure 1, D and E) Teeth that have palatal root fused with mesiobuccal and distobuccal roots were divided into 2 types. In MB-P-DB (V-shape) type, fusion was done in serial manner and it looked like the letter "V". In "All root" type, the cross-sectional image of coronal portion was looked like the letter "Y" or oval, and the cross-sectional image of apical portion was circular. (Figure 1, F and G)

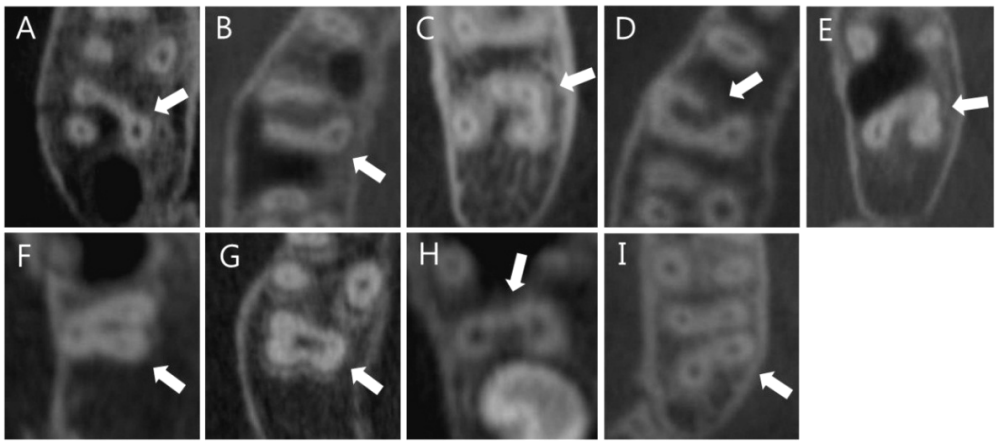

Figure 1. Types of fused roots in maxillary molars

The arrows indicate the fused roots of examined teeth, (A) MB-P, (B) DB-P, (C) MB-DB, (D)MB-DB-P, (E) DB-MB-P, (F) MB-P-DB, V shape (G) All root, Y or cone shape, (H) B-P, (I) MB-MP and DB-DP

Table 2 showed the types and numbers of C-shaped root canals in maxillary first and second molars. Unlike fused roots, the capital represented each root canal instead of root. C-shaped root canal configuration were present in 63 (1.8%) in maxillary molars

of 3553 teeth examined in this study. In first molars, there were 15 (0.8%) teeth with C-shaped root canal and all of them had C-shape result from fusion of mesiobuccal and distobuccal root canal. In second molars, 48 (2.7%) teeth had C-shaped root canal. Most common type was also MB-DB, followed by MB-P.

Table 2. Types and numbers of C-shaped root canals in maxillary first and second molars

Types of C-shaped root canal	Maxillary first molar (n=1786)(%)	Maxillary second molar (n=1767)(%)
MB-P		11 (0.6)
DB-P		2 (0.1)
MB-DB	15 (0.8)	29 (1.6)
DB-MB-P		3 (0.2)
MB-P-DB(V shape)		2 (0.1)
MP-DP (teeth with 4 root canals)		1 (0.1)
Total	**15 (0.8)**	**48 (2.7)**

"-"means fusion of root canals that make C-shape

MB, mesiobuccal; DB, distobuccal; P, palatal; MP, mesiopalatal; DP, distopalatal

Figure 2 showed the representative images of each type of C-shaped root canals. In MB-P type, C-shaped root canals were result from fusion of 2 roots (MB-P) or 3 roots (MB-P-DB), and fusion of root canals was partial or complete (Figure 2, A and B). In DB-P type, C-shaped root canals were result from fusion of 3 roots (DB-P-MB) and fusion of root canals was partial (Figure 2, C). In MB-DB type, C-shaped root canals were result from fusion of 2 roots (MB-DB) or 3 roots(MB-DB-P), and fusion of root canals was partial or complete (Figure 2, D and F). One tooth

with 4 root canals had C-shaped root canal result from fusion of mesiopalatal and distopalatal root canal. (Figure 2, H)

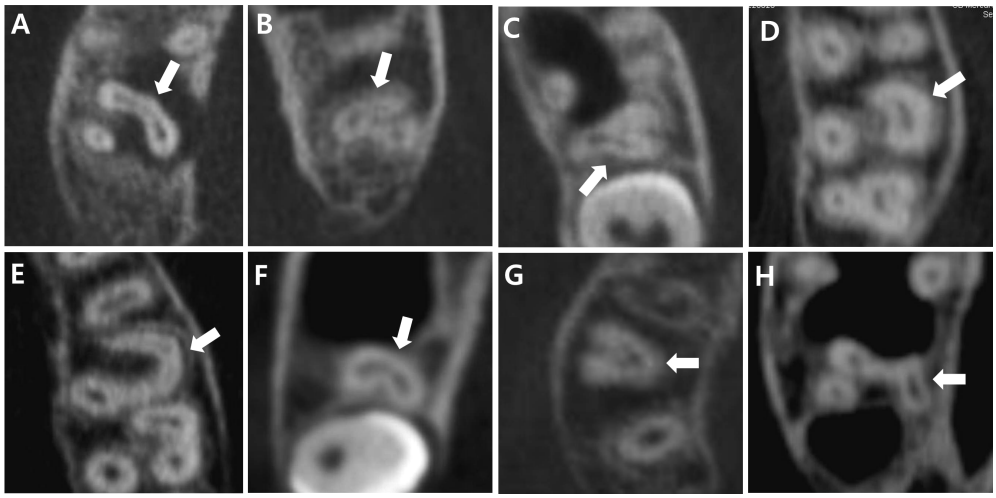

Figure 2. Types of C-shaped root canals in maxillary first and second molars

The arrows indicate the C-shaped root canals of examined teeth, (A,B) MB-P, (C) DB-P, (D,E) MB-DB, (F) DB-MB-P, (G) MB-P-DB, V shape (H) MP-DP

Ⅳ. Discussion

This retrospective study investigated the incidence and types of fused roots and C-shaped root canals in Korean maxillary molars using CBCT.

Regarding the incidence of fusion in the maxillary first molars, our result (3.2%) was similar to those of Chinese (2.7%).[19] Earlier studies in Burmese, Thai, Indian and Chinese population found no fused root in maxillary first and second molars.[20-23] Recent study in a Korean population reported 0.73% in the first molars.[24] But, studies in a Caucasian, Chinese and Irish population reported higher percentages of fusion in the first molars (7.7%, 6.2% and 11.0%).[25-27]

In the second molars, incidence of fusion (19.5%) was higher than first molars, which is in accordance with the findings of several studies that reported higher prevalence in the second molars.[24-28] Earlier studies in Caucasian, Chinese and Irish population reported higher percentages (52.9%, 40.1% and 43.0%).[25-27] Recent study in a Korean population reported lower prevalence (10.7%) than our result in the second molars.[24] These differences could be caused by ethnic background, sample size, age of the subjects, method of study and criteria for fused root. Our criteria for fused root were adopted from Ross, which classified teeth with fusion of on third or less of the roots as having fused root.[25] However, the study reported lower incidence used different criteria that regarded roots as fused if fusion occurred on the entire root surface.[24] It is difficult to classify root numbers and

shapes because there was no generally accepted guidelines.[21] In our study, for example, it was difficult to distinguish between mesiobuccal root fused with distobuccal root and one buccal root with 2 canals that joined at the apical part (Vertucci type II).[1] Clear definition and general classfication of fused roots are necessary for comparing the results from different studies and for further study.

In many studies, fused roots were classified into 5 groups.[26-28] But in this study, there were 9 types of fused roots because we separated fusion of all roots into 4 different types and presented two additional types. This classification provides more detailed information about morphology of maxillary molars. In our study, the most common type was mesiobuccal root fused with distobuccal root in the first molars. This result is consistent with previous reports.[19,26-28] In the second molars, fusion of mesiobuccal and palatal root was the most common type in this study. This result is consistent with previous study in a Chinese population, whereas other studies reported fusion of mesiobuccal and distobuccal root was most common.[26-28]

There were a few studies which reported C-shaped root canal configuration in maxillary molars. In 2002, De Moor reported estimated incidence of 0.091% in maxillary first molars by evaluating radiograph retrospectively.[29] In a study from Chinese using clearing method, Yang reported 4.9% in the maxillary second molars.[26] Our result was higher than the study of De moor in the first molars and lower than the study of Yang in the second molars. These differences also could be due to ethnic difference, sample size, method of study, and criteria for C-shaped

root canal. In the study of Yang, classification was done by connected orifice that resembles the latter "C".[26]

Several variations of C-shape root canals in maxillary molars were reported. Two earlier case reports described clinical cases of C-shape root canal result from fusion of distobuccal and palatal root canal.[7,30] In our study, C-shape result from fusion of distobuccal and palatal root canal was similar to those cases. De Moor also reported 4 cases of C-shaped root canal result from fusion of distobuccal and palatal root in maxillary first molar.[29] In our study, we cannot found any case same as those cases. Yilmaz reported a case that C-shape result from fusion of mesiobuccal and distobuccal root canals.[31] Two case reports using spiral CT or CBCT described C-shape result from merging of 2 palatal canals.[32,33] Recent study using CBCT reported a C-shaped maxillary first molar with three independent buccal root canals.[34] In our study, 6 types were found. Among these types, "MB-P-DB" has not reported earlier. And other 5 types are corresponded to those of previous reports. In agreement with previous reports, C-shape could result from partial fusion of root canals, not all root canals.[32-34]

The C-shaped root canal configuration in mandibular molars has typical root morphology and their classification has been well-documented and generally accepted.[8-10] But in maxillary molars with C-shaped root canal, there is no common root morphology like mandibular second molars. And the C-shaped root canals are caused by different types of root fusion. Therefore, clear description and classification of C-shaped root canal configuration in maxillary molars are necessary.

Evaluation of root canal morphology employed many methods either *in vivo* or *in vitro*. The laboratory methods include canal staining and tooth clearing,[1,4,14,15,20,21,26,27] sectioning,[8,18] *in vitro* radiography,[12,13] *in vitro* macroscopic examination,[28] micro-computed tomography.[10] The techniques used in clinical studies include intraoral radiography[11,25], reviews of patient records[29], examination during endodontic treatment,[16-18] CBCT.[19,22-24] The advantages of computed tomography(CT) are that it is noninvasive and allows 3D reconstruction and visualization of the external and internal anatomy.[35] CBCT allows higher resolution, short scan time and reduction in radiation exposure than traditional CT scans.[36] It can also provide personal data such as sex, age, and tooth position, so prevent the recruitment of inappropriate tooth samples in studies using extracted teeth, thus ensuring the accuracy of the research.[19] In our study, subjects were taken CBCT for orthodontic diagnosis and treatment, not for our study. So, additional cost, time and radiation exposure for this study were never exist. The large numbers of sample size can easily obtained respectively because of digital imaging system. Despite these advantages, at present, CBCT has low resolution than conventional radiographs.[36] Thus, more accurate methods, such as clearing technique or micro-computed tomography using extracted teeth is inevitable to obtain more detailed information of root canal anatomy. Further studies using these techniques are needed for thorough information about C-shaped root canal configuration in maxillary molars and successful root canal treatment of this specific anatomic variation

Ⅴ. Conclusion

This retrospective study of a Korean population showed the incidence and types of fused root and C-shaped root canals in maxillary molars. These anatomic variations are more frequent in the second molars than the first molars. Although C-shaped root canals are most frequently seen in the mandibular second molar, but they may also appear in maxillary molars. It is very important for a clinician to perceive this variation for successful root canal treatment.

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