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CBCT study of root and canal morphology of permanent mandibular incisors in a Chinese population

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Abstract

Objective. To evaluate root canal morphology of permanent mandibular incisor teeth in a Chinese population using cone-beam computed tomography (CBCT). ***Materials and methods.*** CBCT images of Chinese patients were collected and 1553 permanent mandibular incisors in the images were included. The following observations on the included teeth were to determine the number of roots, root morphology and canal configuration. The root canal configurations were classified. The effect of gender on the incidence of the second canal was investigated. ***Results.*** Of permanent mandibular incisors, 86.8% had a single root with single canal. Mandibular lateral incisors (17.5%) had a higher incidence of a second canal compared with mandibular central incisors (8.9%) ($p = 0.000$). A slightly higher percentage of incidence of a second canal was found in males (14.6%) than in females (11.9%) ($p = 0.129$). ***Conclusions.*** Permanent mandibular incisors with two canals had a relatively low incidence in this Chinese population. The incidence of a second canal did not differ between males and females. CBCT is a valuable aid during root canal treatment.

Key Words: *cone-beam computed tomography, morphology, permanent mandibular incisors, root canal*

Introduction

Accurate knowledge of the root and canal morphology is essential to confirm the highest possibility for success of endodontic treatment. However, variations in root and canal anatomy are very common, which needs to attract the attention of the practitioners. In fact, the lack of knowledge about variations in root canal anatomy has been regarded as one of the main reasons for endodontic failure.

Although human permanent mandibular incisors usually have relatively simple and uniform root canal morphology, the most common form of which was single root with single canal [1], ignorance of anatomical variations or additional canals may lead to endodontic failure.

In the past decade, there was very little literature which studied the root canal morphology of human permanent mandibular incisor teeth. Additionally, variations in the root canal morphology are thought to be racially and genetically determined [2,3]. Therefore, it is necessary to investigate variations in root canal anatomy and their characteristic features of mandibular incisor teeth in different racial groups. However, literature reviews found that studies on the root canal morphology of permanent mandibular incisors were conducted mainly in Europe, North America or Japan [1,4–7], while the information from a Chinese population was scarce.

Cone-beam computed tomography (CBCT) have been regarded as an excellent method for the three-dimension evaluation of root canal morphology [8,9]. A number of studies investigated the root canal systems *in vivo* or *in vitro* using CBCT, mainly focusing on maxillary molars [8,10] and mandibular molars [9,11]. Similarly, CBCT can also be used to determine the number and the morphology of the roots of the permanent mandibular incisors in patients.

The purpose of this study is to use CBCT technology to (1) investigate configuration and morphology of the canal system of the permanent mandibular central and lateral incisors; and (2) compare the incidence of a second canal in permanent mandibular incisors of males and females.

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Figure 1. Illustration showing the categorization of the five variants in permanent mandibular incisors according to the method by Vertucci [12].

Materials and methods

This study was conducted at the Affiliated Hospital of Stomatology, Chongqing Medical University and approved by the local ethics committee. The CBCT images of patients between April 2011 and May 2012 were collected and studied. These patients required CBCT examination for several dental aims and informed consent was obtained from each patient. The CBCT images were taken using a cone-beam computed tomography dental imaging system (iCAT, Hatfield, USA), operating at 120 Kv and 5 mA, with a scan time of 9–18 s. The scanning was carried out by skilled radiologists according to the manufacturer's instruction. Low dose radiation and high resolution were ensured. The age and gender of the patients and location of included teeth were also recorded.

A total of 1553 healthy, untreated, fully developed permanent mandibular incisors in the images were included in this study according to the including criteria. The including criteria was: (i) untreated permanent mandibular central or lateral incisors; (ii) no obvious dental caries or lesion; (iii) fully developed root and canal without resorption or calcification; (iv) no obvious loss of periodontal tissue; and (v) CBCT images of good quality within the permanent mandibular incisor region.

After collecting the CBCT images, the roots and canals of the teeth were observed in sagittal and horizontal sections by two separated investigators using an image-analysis software (eXamVision, New York USA). The contrast and brightness of the images were adjusted to ensure optimal visualization with this software. The following observations were recorded: (i) the number of roots and their morphology; (ii) the number of canals per root; (iii) canal configuration; and (iv) cross-sectional canal shape. The canal configuration classification was made according to the method by Vertucci [12] (Figure 1). The male and female incidence of a second canal was calculated and compared. If there was any dispute, another investigator would join in the discussion.

Results

The CBCT views of patients (190 male and 208 female) were studied in this study. The patients' ages were from 16–50 years (24.8 years on average). The majority of permanent mandibular incisors had Type I root canal morphology (86.8%). The five variants in permanent mandibular incisors are shown in Figure 2. The prevalence of the two canals system was as follow: central incisor 8.9% and lateral incisor 17.5% ($p = 0.000$) (Table I). From the horizontal view, four distinct canal types in the middle of roots were noted: (i) round, (ii) oval, (iii) long oval and (iv) ribbon, and the most prevalent type of the cross-section was oval (55.1%). According to the gender, 14.6% of teeth in males had a second canal, while it was 11.9% in females (Table II). No significant difference was found between males and females ($p = 0.129$). In most of the CBCT images, apical ramification, lateral branches and transverse anastomoses cannot be determined.

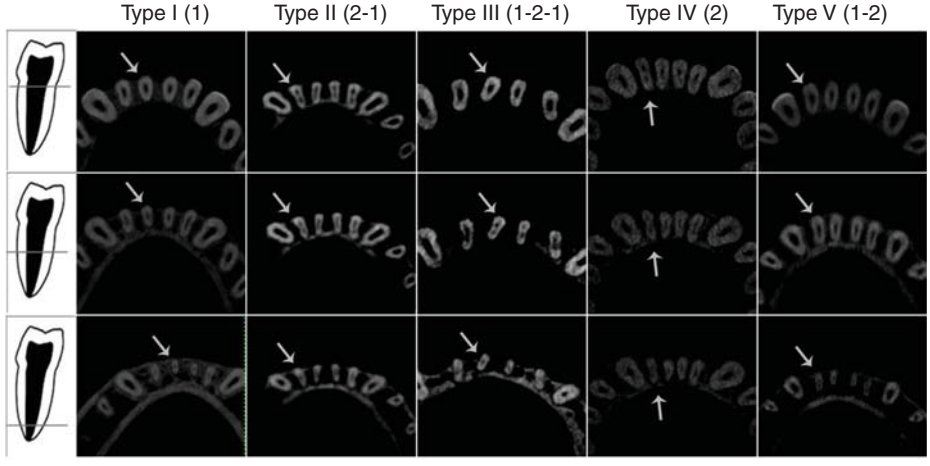

Figure 2. The CBCT images showing the five variants in permanent mandibular incisors.

Table I. Distributions and percentages of the five categories of variants in the root canal anatomy of mandibular incisors.

Teeth		Variant						Total
		Type I 1 canal	Type II 2-1 canals	Type III 1-2-1 canals	Type IV 2 canals	Type V 1–2 canals	Other	
Mandibular central incisor	Number	700	15	41	10	2	0	768
	Percentage	91.1	2.0	5.3	1.3	0.3	0	100
Mandibular lateral incisor	Number	648	31	82	22	2	0	785
	Percentage	82.5	3.9	10.4	2.8	0.3	0	100
Total	Number	1348	46	123	32	4	0	1553
	Percentage	86.8	3.0	7.9	2.1	0.3	0	100

Discussion

A main reason for failure in endodontic treatment of permanent mandibular incisors is considered as the inability to locate, debride and obturate a second canal. Kartal et al. [13] reported that the incidence of the presence of a second canal was 45%, whereas the incidence was 25.7% in Vertucci [14] and 20% in Green [15]. The lowest incidence of 11.5% was reported in Madeira et al. [5], followed by 12.4% in a study on a Japanese population [6] (Table III). These variations may be attributed to the differences in gender [16] and racial origin [17]. In the current study, only 13.2% of the mandibular incisors included had a second canal, which is relatively low compared with the previous studies. The low incidence may be due to the difference in race and gene. Another possible reason was because our study considered two canals connected by an obvious isthmus to be a single canal, which was classified to be two canals in a previous study [4]. According to gender, the incidence of a second canal in permanent mandibular incisors was relatively higher in males in this current study, which may provide a hint to the endodontists during root canal therapy. Age was reported to have an effect on the incidence of a second canal [18,19]. Fewer canals were found in the roots with increasing age because of calcification. It was found that there is a slow narrowing of root canals with age [20] and root canals may disappear with age. Now that the effect of age on variations is clear, age was not analysed as an influencing factor in this present study.

In clinical practice, the second canal of permanent mandibular incisors was often missed. Thorough knowledge of how and where to search for a possible second canal is essential with endodontic treatment on a permanent mandibular incisor. The practitioners should assume that the second canal exists and remove the shelf of dentin over the possible second canal and make a thorough search for a second canal. Direct access to the buccal canal is usually established after endodontic access, whereas the lingual canal is often missed because it is difficult to locate by the naked eye without fully removing the shelf of dentin. A dental operating microscope should be used to help locate the possible second root canal orifice.

Table II. Incidence of the presence of a second canal in mandibular incisors of male and female patients.

	Male (%)	Female (%)	*p*-value
Mandibular central incisor	10.4	7.4	0.147
Mandibular lateral incisor	18.8	16.3	0.356
Total	14.6	11.9	0.129

There was no significant difference between groups ($p > 0.05$).

The result of this study demonstrated that mandibular lateral incisors had a much higher incidence of the presence of two root canals compared with mandibular central incisors, which reflects the fact of this specific Chinese sub-population. This difference between the results of morphology studies may be due to variations in examination methods, classification system, sample size and ethnic background of teeth sources [7].

An ideal technique for root canal evaluation would be accurate, simple, non-destructive and feasible *in vivo*. The existing methods available are canal staining and clearing, digital radiographic techniques, Micro-CT techniques and CBCT. The staining and clearing technique has considerable value in the study of root canal anatomy *in vitro*, which gives the most detailed information of the pulp cavity in relation to the exterior of the tooth [6,12]. However, with advancement of dentistry, the sound extracted human teeth will be extracted only for severe periodontal disease or orthodontic purposes. Therefore, it is getting more difficult to collect sufficient numbers of sound permanent teeth for *in-vitro* studies with the canal clearing technique. Micro-CT is another important tool for the evaluation of the root canal morphology because of its high resolution and non-destructive nature, but it is not available in clinical practice owing to its high radiation. Only a two-dimensional view of the root canal system can be obtained by digital radiographic techniques, which leads to the loss of important information about root canal morphology.

Collecting a mass of sound teeth for *in-vitro* study becomes impractical now. Thus, we have to resort to

Table III. Percentages of root canal systems found in mandibular incisors in the previous studies.

References	No. of teeth	Teeth studied	Nature of study	Type					
				I	II	III	IV	V	other
Madeira et al. [5]	683	Mandibular central incisor	Staining and clearing	88.7	11.3				
	650	Mandibular lateral incisor		88.2	11.8				
Vertucci [1]	100	Mandibular central incisor	Staining and clearing	70	5	22	3	0	0
	100	Mandibular lateral incisor		75	5	18	2	0	0
Benjamin et al. [4]	364	Mandibular incisor	Radiography	58.6	40.1		1.3	0	0
Kartal et al. [13]	100	Mandibular incisor	Staining and clearing	55	16	20	4	3	2
Caliskan et al. [25]	100	Mandibular central incisor	Staining and clearing	68.63	13.73	13.7 3	0	1.96	1.96
	100	Mandibular lateral incisor		68.63	13.73	15.69	0	1.96	0
Miyashita et al. [6]	1085	Mandibular incisor	Staining and clearing	87.6	9.3		1.4	1.7	0
Sert et al. [7]	200	Mandibular central incisor	Staining and clearing	32.5	27.5	27	10	0.5	2.5
	201	Mandibular lateral incisor		36.8	26.9	26.4	9.5	0	0.5
Al-Qudah et al. [3]	450	Mandibular incisor	Staining and clearing	73.8	10.9	6.7	5.1	3.6	0

an *in-vivo* study by means of radiography. Clinically, CBCT is a good option and can be applied for measuring the root canals, identifying root canals and anatomical variation, evaluating root fractures and resorption and planning treatment [21,22]. Compared with the conventional CT scanner, its major advantages are considerable reduction in radiation exposure [23] and higher quality image rendering for assessment of dental hard tissues [24]. With CBCT, root morphology can be visualized in three dimensions, as can the number of root canals and their pathway [20]. In the present study, the number and morphology of root canals and the shape of cross-section can be easily determined using CBCT images. CBCT should be recommended to analyse root canal morphology before endodontic treatment and evaluate the quality of root canal filling after root canal therapy in cases with suspected complex canal morphology. For simple cases, CBCT examination is unnecessary and should not be recommended because of its higher radiation.

Under the conditions of this study, a second root canal occurred less frequently (13.2%) in the mandibular incisor teeth in this Chinese population. The incidence of a second canal did not differ between males and females. CBCT is a useful tool in assessing the morphology of the root canal in clinics.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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