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Use of CBCT to identify the morphology of maxillary permanent molar teeth in a Chinese subpopulation

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Abstract

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Aim To investigate variations in root canal configuration in the maxillary permanent molar teeth of a Chinese subpopulation using cone-beam computed tomography (CBCT).

Methodology A total of 269 patients with healthy, untreated, well-developed maxillary molars were enrolled, including those suffering facial trauma, and those who required a pre-operative assessment for implants. Radiographic examination by CBCT was conducted as part of their routine examination, diagnosis and treatment planning. Overall, 299 maxillary first and 210 maxillary second molar teeth were examined *in vivo* by CBCT. The number of roots, the number of canals per root, the canal configuration and the presence of additional mesiobuccal canals were recorded. Vertucci's classification for root-canal configurations was utilized.

Results All maxillary first molars had three separate roots; however, 52% of mesiobuccal (MB) roots had two canals with the remainder having one. All distobuccal and palatal roots had Vertucci Type I canal configurations. When the MB2 canal was present, 14, 69 and 16% of MB roots had Type II, IV and V canal configurations, respectively. The root canal system of the maxillary first molar teeth could be categorized into two variants: one with three separate roots with one canal in each of the distobuccal and palatal roots and two canals in the MB root, and the other with three separate roots with one canal in each root. Of 210 maxillary second molars, 10% had one root, 8% two roots and 81% three roots. Of the MB roots, 22% had two canals with the remainder having one. When the MB2 canal was present, 18%, 58%, 10% and 3% of MB roots had type II, IV, V and VI canal configurations, respectively. The root canal system of the maxillary second molar could be categorized into eight variants.

Conclusions Mesiobucccal roots of maxillary molar teeth had more variation in their canal system than the distobuccal or palatal roots. The root canal configuration of the maxillary second molars was more variable than that of the first molars. CBCT can enhance detection and mapping of the mesiobuccal root-canal system with the potential to improve the quality of root canal treatment.

Keywords: CBCT, maxillary molars, MB2, morphology, root canal system.

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Introduction

Successful root canal treatment demands that dentists have knowledge of root canal morphology. Root canal treatment of maxillary molar teeth has the highest clinical failure rates (Hartwell *et al.* 2007, Smadi &

Khraisat 2007), probably because these teeth have the most complex root and canal anatomy (Vertucci *et al.* 2006) with substantial variations in the mesiobuccal (MB) roots.

Wolcott *et al.* (2005) revealed there were significant differences in the incidence of a second mesiobuccal canal (MB2) between initial (primary) root canal treatments and secondary treatments (retreatments). This implies that failure to detect, debride or fill an MB2 canal is likely to be the main reason for the technical deficiencies in maxillary molars that in turn leads to a poor long-term prognosis as a result of residual intracanal infection (Weine *et al.* 1999, Vertucci 2005, Wolcott *et al.* 2005). Clearly, untreated canals or deficient root fillings result in proliferation of bacteria with a persistent periapical inflammatory response likely to occur.

A canal may be left untreated if its presence is not recognized by the dentist. Thus, all possible methods should be used to locate and detect the entire root canal system (Vertucci 2005). In laboratory studies various methods have been adopted to demonstrate canal anatomy, including canal staining and clearing techniques (Vertucci 1984, Imura *et al.* 1998, al Shalabi *et al.* 2000, Ng *et al.* 2001, Alavi *et al.* 2002, Yoshioka *et al.* 2005, Weng *et al.* 2009), transverse cross-sectioning (Kulild & Peters 1990, Schwarze *et al.* 2002), radiographic examination (Thompson *et al.* 1995, Fava & Dummer 1997, Weine *et al.* 1999, Omer *et al.* 2004), dentine troughing under magnification (Yoshioka *et al.* 2005), clinical operating microscope (Baldassari-Cruz *et al.* 2002), ultrasonics (Alaçam *et al.* 2008), scanning electron microscope (Gilles & Reader 1990, Schwarze *et al.* 2002) and micro-computed tomography (Plotino *et al.* 2006). But, in the clinic situation, use of an operating microscope (Sempira & Hartwell 2000) and conventional radiography (Omer *et al.* 2004) are the most common methods to evaluate tooth anatomy.

The detection rate of MB2 canals in maxillary molars *in vivo* has been lower than that of laboratory-based reports (Imura *et al.* 1998). Several laboratory studies (Imura *et al.* 1998, Weine *et al.* 1999, Gorduysus *et al.* 2001) revealed that more than 70% of maxillary first permanent molars had MB2 canals. However, less than 40% of maxillary first molars had MB2 canals when treated *in vivo* (Weller & Hartwell 1989, Sempira & Hartwell 2000). Stropko (1999) reported that as the operator became more experienced and more specific instruments were used for micro-endodontics, more MB2 canals would be located in maxillary molars.

In the clinical situation, the operating microscope (Sempira & Hartwell 2000) and conventional radiography (Omer *et al.* 2004) are used at various stages of root canal treatment. However, it has been reported that use of a surgical microscope did not result in an increase in the number of second mesiobuccal canals located in maxillary molars, compared to when the access was modified and no microscope was used (Sempira & Hartwell 2000). Traditional periapical radiographs are essential for preoperative diagnosis (Reit *et al.* 2003); however, periapical radiography can only provide two-dimensional information. When roots of teeth overlap and anatomic structures are present, e.g. maxillary sinus, their interpretation is more difficult (Orstavik 1998, Patel *et al.* 2009a). Indeed, a previous study (Nattress & Martin 1991) concluded that radiographic images were not reliable for the detection of multiple canals.

In comparison, the recently developed limited cone-beam computed tomography (CBCT) designed for dental use, has a lower radiation dose and a higher resolution than traditional computed tomography scans (Arai *et al.* 2000, Patel 2009). It has proved useful in detecting periapical lesions (Low *et al.* 2008) and root canal morphology in the maxillary region (Tsiklakis *et al.* 2005, Nakata *et al.* 2006, Lofthag-Hansen *et al.* 2007, Patel & Horner 2009). CBCT, as a non-invasive tool, can provide three-dimensional images of dentoalveolar regions for disease diagnosis and morphological evaluation in endodontics (Cotton *et al.* 2007, Matherne *et al.* 2008). Matherne *et al.* (2008) used CBCT as the gold standard to compare the effectiveness of charge-coupled devices (CCD) and photo-stimulable phosphor (PSP) devices in identifying the number of root canals. They concluded that when compared with images obtained using CBCT, both CCD and PSP methods failed to identify at least 1 root canal system in approximately 4 of 10 teeth. This could lead to a less optimal healing outcome if a missed root canal was untreated.

The aim of this study was to use CBCT images taken for general dental diagnosis and treatment planning to determine the number of roots and canals of maxillary first and second molar teeth and to categorize the presence and morphology of MB2 canals.

Materials and methods

Patients

A total of 269 consecutive patients were enrolled in the study; they were referred to the West China Hospital of

Stomatology at Sichuan University, Chengdu, China, between May 2009 and February 2010, requiring radiographic examination by CBCT as part of their dental treatment. The images were taken as part of the routine examination, diagnosis and treatment planning of patients that included those suffering facial trauma or maxillary sinusitis, who required a pre-operative assessment for implants, or who needed orthodontic treatment because of an impacted tooth, etc. Distribution and percentage of the reasons why these CBCT images were taken were described in detail in Table 1. Informed consent was obtained from the patients and this study was approved by the Ethics Committee of the West China Hospital of Stomatology.

There were 140 women and 129 men with a mean age of 35 years (ranging from 17 to 60 years). A total of 509 teeth (299 maxillary first molars and 210 maxillary second molars) were analysed. They were selected for enrolment in this investigation based on the following criteria: (i) maxillary permanent molars without periapical lesions; (ii) the teeth involved had not been endodontically treated; (iii) no root canals with open apices, absorption or calcification; and (iv) the CBCT images were of good quality.

Radiographic techniques

The CBCT images were taken using a 3D Accuitomo scanner (Morita, Kyoto, Japan) operating at 80 kV and 5.0 mA, and the exposure time was 17 s. The voxel size was 0.125 mm and the slice thickness was 1.0 mm. Scans were made according to the manufacturer's recommended protocol. According to examination requirements the field of view 40 mm × 40 mm or 60 mm × 60 mm was selected. All the CBCT examinations were carried out by an appropriately licensed radiologist with the minimum exposure necessary for the adequate image quality. The lowest dose radiation and radiation field was guaranteed.

Table 1 Distribution and percentage of the reasons why CBCT images were taken

	Distribution	*Percentage*
Ectopic impacted teeth	92	34.2
Pre-operative assessment for implants	88	32.7
Maxillary sinusitis	22	8.2
Facial trauma	20	7.4
Odontogenic tumours	19	7.1
With symptoms after root canal treatment	18	6.7
Root longitudinal fracture	10	3.7
Total	269	100

Evaluation of the images

The CBCT images were analysed with inbuilt software (i-Dixel one volume viewer 1.5.0) using a Dell Precision T5400 workstation (Dell, Round Rock, TX, USA) and a 32-in. Dell LCD screen with a resolution of 1280 × 1024 pixels in a dark room. Contrast and brightness of images could be adjusted using the image processing tool of the software to ensure optimal visualization. A professional oral radiologist and an endodontist concurrently evaluated all the images to reach consensus in the interpretation of the radiographic findings.

The teeth included were radiographically examined by CBCT for (i) the number of roots and their morphology, (ii) the number of canals per root, (iii) the root canal configuration classified using Vertucci's classification (Fig. 1), and (iv) the variations of the morphology of the root canal systems. These were classified as follows (Fig. 2a, b):
Variant 1: Three separate roots, MB, distobuccal and palatal, with one canal in each root.
Variant 2: Three separate roots with one canal in each of the distobuccal and palatal roots and two canals in the MB root.
For the purpose of the study, the type of canal system in the MB root was classified using Vertucci's classification.
Variant 3: Two separate roots, a buccal and a palatal, with one canal in each root.
Variant 4: Two separate roots, a mesial and a distal, with one canal in each root.
Variant 5: One root with a single canal.
Variant 6: One root with two canals.
Variant 7: One root with three canals.
Variant 8: Three separate roots with one canal in the MB and palatal and two canals in the distobuccal.

The types of canal systems in Variants 3–8 were not further classified.

Results

The number of roots and their morphology

All 299 maxillary first molars had three separate roots. In the maxillary second molars, the number of roots was variable: of 210 teeth examined, 22 (10%) had a single root, 17 (9%) had two roots (of which four had a

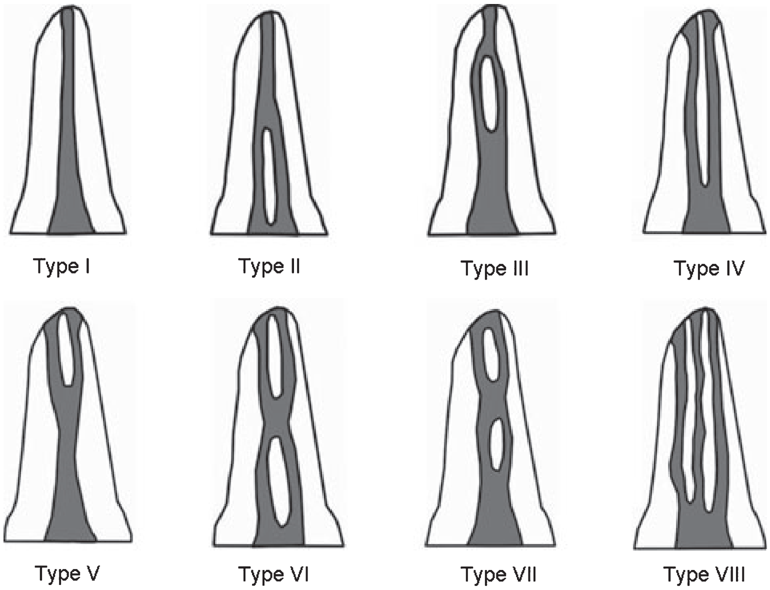

Figure 1 Vertucci's (Vertucci 1984) classification of the root canal system.

buccal and a palatal root and 13 had a mesial and a distal root) and 171 (82%) had three separate roots.

The number of canals per root

In maxillary first molars, all of the distal and palatal roots had one canal. Forty eight percent of MB roots had a single canal and the remainder had an MB2 canal.

In maxillary second molars, when three separate roots were present (in addition to one tooth with one canal in each of the MB and palatal roots, and two canals in the distobuccal root), all of the distal and palatal roots had a canal. For the MB roots, 78% had a single canal and the remainder had an MB2 canal. In the other maxillary second molars with one or two roots, 12 (32%) had one root with one canal, nine (24%) had one root with two canals, and one (3%) had one root with three canals. Seventeen maxillary second molars had two roots with one canal in each root (four with buccal and palatal roots, and 13 with mesial and distal roots).

The variations in the morphology of the root canal systems

Of the maxillary first molars, 48% were variant I and 52% variant II. The distribution and percentage of maxillary second molars in the eight categories of variants of root canal anatomy are described in Table 2.

Root canal configuration of MB root analysed by Vertucci's classification

The root canal configuration of the MB root of maxillary first molars when MB2 was present was 14% type II, 70% type IV and 16% type V.

The configuration of the MB root of the maxillary second molars was 18% type II, 58% type IV, 21% type V and 3% type VI.

Symmetry in the bilateral homonymous teeth

Of 45 patients who had both bilateral homonym teeth, 38 (84%) had perfect symmetry in the root and canal morphology of homonym teeth on the opposite side. When an MB2 canal was present in a maxillary molar, there was also very likely to be an MB2 in the opposite homonym molar of the same patient.

Discussion

This study used CBCT to evaluate the root and canal systems of 299 maxillary first molars and 210 maxillary second molars in 269 Chinese individuals. The results revealed that all of the maxillary first molars had three roots. The majority (52%) of the maxillary first molars had four canals, and 48% had three. These results are different from those of al Shalabi *et al.* (2000) who reported a higher percentage (78%) of maxillary first molars with four roots in an Irish population. The present results are more consistent

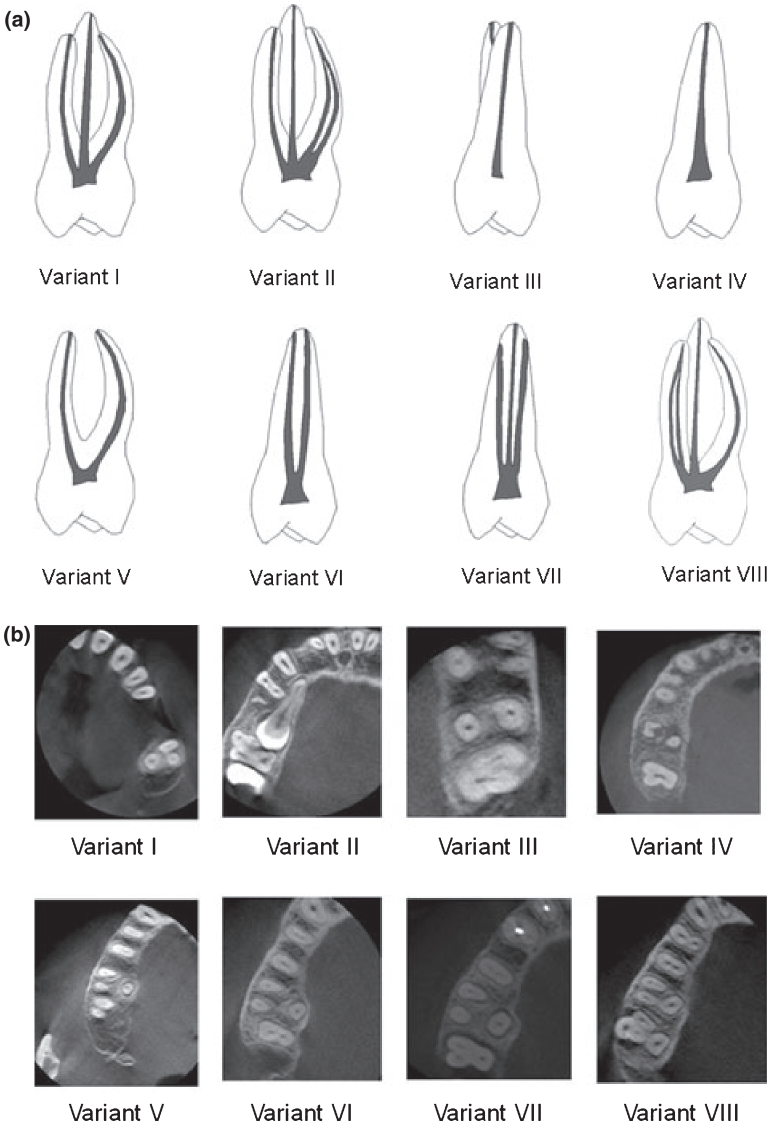

Figure 2 (a) Illustration showing the categorization of the eight variants in maxillary molars found in this study. (b) CBCT images showing the categorization of the eight variants in maxillary molars found in this study.

Table 2 Distribution and percentage of cases in the eight categories of variant of root canal anatomy of the maxillary second molars

	Variant								
	I	*II*	*III*	*IV*	*V*	*VI*	*VII*	*VIII*	*Total*
Number	133	37	13	4	12	9	1	1	210
Percentage	63.3	17.6	6.2	1.9	5.7	4.3	0.5	0.5	100

with those of Imura *et al.* (1998) who found a lower percentage (47%). All the fourth canals of the maxillary first molars were in the MB roots, which is consistent with the findings of Hartwell *et al.* (2007).

In maxillary second molars, 82% had three separate roots, 9% had two roots, and 10% had a single root. These results are consistent with a previous study (Peikoff *et al.* 1996) that reported three roots with three separate canals is the standard anatomical form in maxillary second molars.

In addition, two variants in the root canal anatomy of maxillary first molars and eight variants in maxillary second molars were identified. This indicates that maxillary second molars have a more complex root canal system. The most common anatomy of the maxillary first molar is that categorized as Variant II, with one canal in each of the DB and P roots and two canals in the MB root. The most common anatomy of

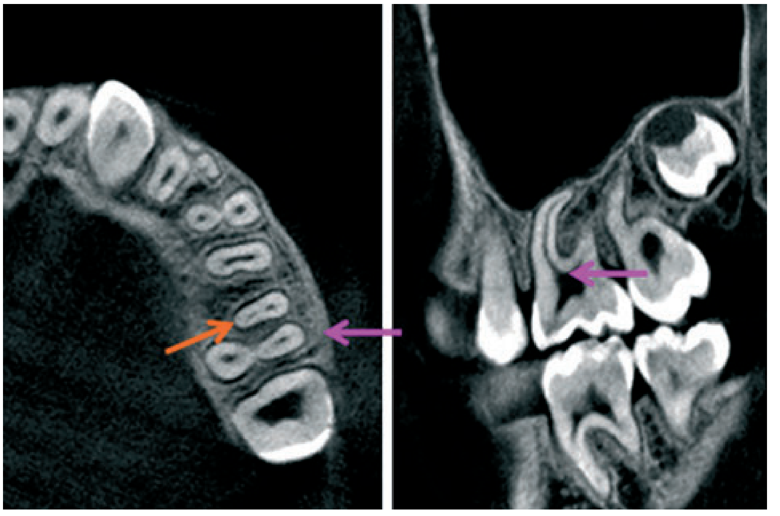

Figure 3 Cross-sectional CBCT image of maxillary first molar with a clearly distinguished second mesiobuccal canal. The *purple arrows* denote the maxillary first molar and the *orange arrow* denotes the second mesiobuccal canal.

the maxillary second molar with three roots, categorized as Variant I, has three separate canals. Although other authors (Chen & Karabucak 2006, Yilmaz *et al.* 2006, Kim *et al.* 2008) have observed that additional variations occur, these single tooth variants were of little concern, were mainly reported in case reports, and were not found in the present study. Figure 2a,b demonstrates the eight variant categories in the anatomy of maxillary first and second molars and present further description of these variations.

The complexity in the root canal morphology of maxillary molars mostly relates to the presence of the MB2 canal. The anatomy of the MB root has been the main focus of many studies (al Shalabi *et al.* 2000, Ng *et al.* 2001, Plotino *et al.* 2006, Smadi & Khraisat 2007, Imura *et al.* 2008, Weng *et al.* 2009). *Ex vivo* studies on the incidence of MB2 canals (al Shalabi *et al.* 2000, Ng *et al.* 2001, Plotino *et al.* 2006, Smadi & Khraisat 2007, Imura *et al.* 2008) revealed a high rate of detection of MB2 canals, but a wide prevalence ranging from 50% to more than 80% of teeth: this may partly be attributable to ethnic differences.

In the present study, MB2 canals were present in 52% maxillary first molars and 18% maxillary second molars. This is higher than that found in another study (Weng *et al.* 2009) in the same Chinese population that reported 18% MB2 canals in the maxillary first molar and 14% MB2 canals in the maxillary second molar in subjects of Han ethnicity. Clearly, the present study demonstrates that CBCT is an effective and powerful technique for detection of MB2 canals.

When an MB2 canal was present, the most common canal configuration was type IV, which is consistent with previous reports in a Thai subpopulation (Alavi *et al.* 2002).

It was also interesting to note that in many cases where the bilateral homonym teeth of the same patient were present, in 84% of cases the anatomy revealed bilateral symmetry. This is consistent with a previous study (Peikoff *et al.* 1996) that investigated the variants in root and canal morphology of maxillary molars using traditional radiographs. The CBCT can provide axial, transverse and tangent slices (Huang *et al.* 2010) and provides comprehensive information about the root canal from different directions that could not be detected using conventional radiographs or clinical techniques (as shown in Fig. 3).

Micro-computed tomography (Plotino *et al.* 2006) and the staining and clearing technique (Imura *et al.* 1998, al Shalabi *et al.* 2000) can detect most MB2 canals in maxillary molars, but these studies have all been conducted on extracted human teeth. A higher rate of detection of MB2 canals in Chinese maxillary molars was found in the present study using CBCT than in the previous study (Weng *et al.* 2009) using a modified staining technique. Huang *et al.* (2010) reported that a higher incidence of three-rooted and four-canalled mandibular first molars in Taiwanese individuals was found using CBCT compared with previous studies using periapical radiographs for the evaluation. These results indicate that CBCT is an effective tool in the endodontic treatment of maxillary molars, because failure to detect an MB2 canal is one of the major factors that contribute to the high failure rate of root canal treatment (Wolcott *et al.* 2005, Hartwell *et al.* 2007). Patel *et al.* (2009b) pointed out that CBCT as a non-invasive technique had other benefits in the diagnosis of endodontic diseases because it could detect periapical lesions at the earliest stages with high accuracy and could increase the chance of the treatment success over conventional radiographic examination.

Conclusions

The MB roots of maxillary molars in a Chinese population tended to have more variations in the canal system than the distobuccal or palatal roots. The root and canal configuration of maxillary second molars is more variable than that of the maxillary first molars. CBCT demonstrates potential in endodontic diagnosis and treatment management.

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