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Root and root canal variations of the human maxillary and mandibular third molars in a Chinese population: A micro–computed tomographic study

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ABSTRACT

Objectives: To investigate the anatomical variations of the root and root canal configuration of the human third molars.
Designs: A total of 130 maxillary and 130 mandibular third molars were collected from a native Chinese population. All teeth were scanned by micro–computed tomography. After 3D reconstruction, the root and canal morphology of each tooth was examined both qualitatively and quantitatively.
Results: For maxillary molars, a single fused root (67 cases, 51.5%) and a single root canal system (64 cases, 49.2%) was most common root/canal form; the typical three-rooted molars were detected only in 33 cases (25.4%), and the secondary MB canals were detected only in 9 molars (6.9%). For mandibular molars, 62 teeth were single-rooted (47.7%) and 42 had a single root canal system (32.3%); 20 singled-rooted and 60 double-rooted molars exhibited independent mesial and distal root canal systems (61.5%), and the type 1-1 canal was the most common configuration for mesial (57 cases) and distal (81 cases) root canal systems. C-shaped canals were detected in 11 maxillary and 36 mandibular single-rooted molars. The mean root surface area, root and crown volume of mandibular third molars were significantly higher than the maxillary third molars ($P < 0.01$).
Conclusion: The root canal system of the third molars may exhibit several anatomic variations. Whereas in most of cases, the degree of the canal differentiation was at a low level, and the canal form was not complicate.

1. Introduction

The third molar is typically the last tooth to develop in the human dental arch. It generally erupts between the ages of 17 and 25 years old, and exhibits the greatest variation in size, shape, position, time of development and eruption (Scheid & Weiss, 2012; Sidow, West, Liewehr, & Loushine, 2000). The third molar has long been identified as a "trouble maker", and it can result in many problems such as impacted teeth, lower incisor crowding, atypical facial pain, caries, or pericoronitis (Ganss, Hochban, & Kielbassa, 1993; Irja, 2014; Nunn et al., 2013). Most of the times the dentist opts for extraction of third molars as a treatment modality.

Over the last few years we have seen improved dental materials and advanced technologies, which have greatly increased the success rate of root canal therapy, even for those complex root canal configurations. Today, third molars are retained and undertaking endodontic treatment more frequently. They might be selected for bridges abutments or as a donor tooth for replacement of a lost/non-restorable first or second molar (Mejàre, Wannfors, & Jansson, 2004; Tomar et al., 2013; Yu, Jia, Lv, & Qiu, 2017). Autotransplantation of a mature third molar conventionally requires thorough treatment of root canals within 3–4 weeks to avoid pulp and periapical inflammation (Andreasen & Pedersen, 1985; Schwartz & Andreasen, 1988).

Since the anatomy of third molars may be affected by the ethnic and geological factors (Scheid & Weiss, 2012; Scott & Turner, 1997), understanding the root canal system morphology of the third molar among different ethnic groups is of great clinical and anthropological significance. By using tooth clearing technique, Sidow et al.-(2000) carried out a comprehensive study on root canal systems of 150 maxillary and 150 mandibular third molars. However, they have not recorded the age, gender, and race of the subjects, which may be seen as important influence factors on the tooth anatomy. Moreover, accurate odontometric analysis was unavailable for clearing technique since the step of demineralization is destructive to the sample teeth.

In recent years, micro-computed tomography (micro-CT) has been applied to investigate tooth anatomy because of its micrometer

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resolution and nondestructive nature (Fan, Cheung, Fan, Gutmann, & Bian, 2004; Gu et al., 2010; Gu, Zhang, & Liao, 2013; Gu, Zhang, Liao, & Fei, 2013). Scholars can conveniently generate 3D tooth/canal models from 2D cross-sectional images, and analyse them both qualitatively and quantitatively. However, until now only very few studies have addressed the third molars with large sample sizes by using this technology. The objective of this study was to analyse the anatomic variations of root and root canal morphology of extracted third molars in a Chinese population by using micro-CT scanning.

2. Materials and methods

A total of 130 maxillary and 130 mandibular third molars were collected in the Department of Dentistry, The First People's Hospital of Wujiang Dist. under an agreement with the patients by signing an informed consent. All subjects were Chinese natives. The teeth were extracted because of tooth impaction, non-restorable caries, pulpal or periodontal disease, pericoronitis or orthodontic or prosthodontic reasons. The protocol for processing human tissue specimens was reviewed and approved by the Ethnics Committees of the First People's Hospital of Wujiang Dist., Suzhou (Permit No 2016003). The methods were operated in accordance with the Declaration of Helsinki (2008). The tooth type was accurately identified during the oral surgery procedure. Teeth with obliterated cementoenamel junctions (CEJ) due to caries or restorations were excluded from the study. The extracted teeth were immediately stored in 10% neutral formalin. They were subsequently washed under tap water and immersed in 5% sodium hypochlorite solution for 2 h to remove adherent soft tissue. Calculus and stains were removed using an ultrasonic scaler.

Each specimen was scanned along the tooth axis by using a micro-CT scanner (Skyscan 1174; Bruker-micro CT, Kontich, Belgium). All scans were performed with an aluminum filter (thickness = 1 mm) using 80 kV, 500 mA and a 180 ° rotation with a 43.3 μm voxel size. The data sets were transferred to the Mimics 17.01 (Materialise, Leuven, Belgium) software for 3D reconstruction and odontometric analysis. The internal and external tooth anatomy was reconstructed with a semiautomatic segmentation approach. A new tooth model was generated by using Boolean calculation of uniting the primary tooth model and the pulp cavity model, and any cavities in this tooth model were eliminated. The tooth models were then analyzed both qualitatively and quantitatively as follows:

(a) The number of roots, the root canal system configuration and the presence of accessory canals (including lateral canals and apical deltas) were recorded. The root canal configuration was classified according to Weine's classification (Weine, Kelly, & Lio, 1975). Within the purpose of this study, a root with a bifurcation within the apical ¼ level was regarded as a single root (Scott & Turner, 1997). The C-shaped canals were classified into 3 types: (a) type 1, complete C (the cross-sectional canal shape resembled an uninterrupted C; C1 configuration in Fan's classification [Fan et al., 2004]) throughout the length of root; (b) type 2, cross-sectional incomplete C (C2 [canal shape resembled a semicolon resulting from a discontinuation of the C outline] or C3 [formed by 2 or 3 separate canals with a discernible isthmus linking them] in Fan's classification) throughout the root length; and (c) type 3, C1, C2, and/or C3 configuration(s) are detected only in certain cross-sections (Fig. 1).

(b) The root and crown length and volume, and the root surface area (RSA) were measured. The specimens with crown or root defects were excluded from the quantitative studies. A total of 140 teeth (44 maxillary and 96 mandibular third molars) remained for odontometric analysis. Within the purposes of this study, the vertical distance, along the long axis of the tooth, between the cementoenamel junction (CEJ) plane and root anatomic apex was defined as the root length, and the vertical distance between the CEJ plane and the highest cusp tip was defined as the crown length. The CEJ plane was used as reference to divide the tooth into 2 portions. The volume and the RSA of each portion were measured by Mimics software as reported previously (Gu, Tang, Zhu, & Feng, 2016; Gu, Zhu, Tang, Zhang, & Feng, 2017)(Fig. 2).

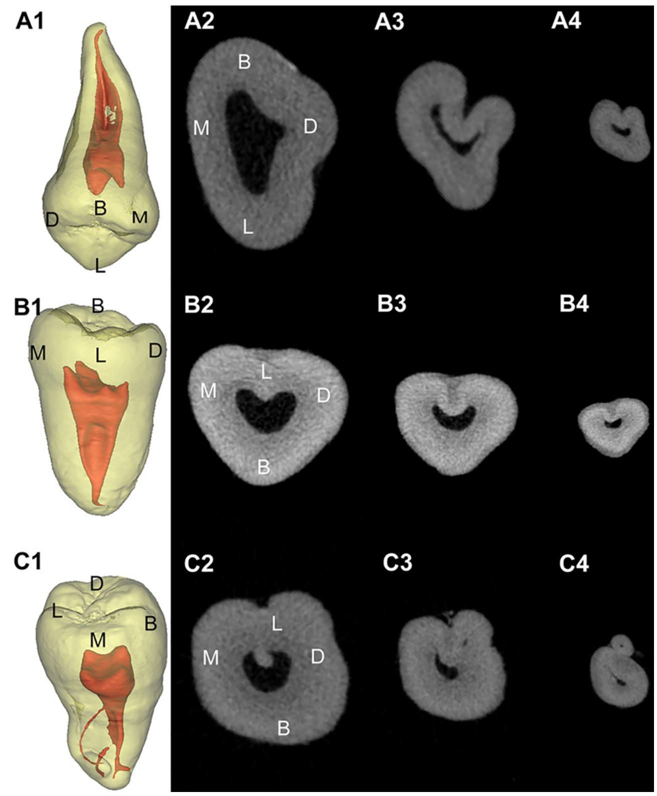

Fig. 1. Representative micro-CT images of C-shaped canals in the maxillary and mandibular third molars. (A) A C-shaped canal in a maxillary third molar; (B) a complete C throughout the root length (a mandibular third molar); (C) a mandibular third molar with a C + DL canal form (a mesial C-shaped canal combined with a distolingual canal).

Student's t test was used to compare the maxillary and mandibular teeth groups in relation to the length, volume and surface area. The level of statistical significance was set at 0.05 ($P < 0.05$).

3. Results

3.1. Information of the sample teeth and the root number

The information of the teeth sample (including age, gender, side, and root number) is summarized in Table 1. For the maxillary molars, the single-rooted form accounted for the largest proportion of 51.5% (67/130), followed by 25.4% (33/130) with the typical three-rooted form, and 19.2% (25/130) of the double-rooted form. Regarding the mandibular third molars, the single and the typical double-rooted form had a similar large proportion of 47.7% (62/130) and 46.2% (60/130) of cases, respectively.

3.2. Maxillary third molars

The root canal systems displayed more variations in the single-rooted maxillary molars (Table 2, Fig. 3A–H). They could contain a simplest Weine type I (1-1) canal (Fig. 3A), which accounted for the largest proportion of 42.6% (29/68); whereas in 3 specimens, the palatal (P) canal fused with mesiobucal (MB) or distobucal (DB) canal and formed 2 independent root canal systems (Fig. 3E and F) (these