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A micro-computed tomographic (micro-CT) analysis of the root canal morphology of maxillary third molar teeth☆

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ABSTRACT

Introduction: The aim of this study was to analyze the root canal morphology of maxillary third molars (MTMs) using micro-computed tomography (micro-CT).
Materials and methods: Seventy-eight consecutively-extracted human MTMs were scanned using micro-CT (spatial resolution = 13.68 μm per pixel). Dedicated software (SkyScan®) was used to create virtual reconstructions and perform 3D-analysis. A range of anatomical features were assessed; externally (root number, length, fusion, curvature, apex), within the pulp chamber (distance between canal orifices, floor thickness) and within the root canal system (root canal number, classification, ramifications, isthmuses, apical constriction).
Results: The donor age ranged from 19 to 73 years (mean ± SD 32.3 ± 16.5 years). MTMs possessed one or three roots, which principally curved buccally/palatally (75.9%), had 1–4 root canals and typically no apical constriction (84.4%). The average external root length was 11.89 ± 1.53 mm, while root canal length was 10.18 ± 0.35 mm. The root canal diameter 1 mm from the apex was 0.37 ± 0.23 mm and negatively correlated with donor's age ($r = -0.76$; $p = 0.01$), while pulp chamber thickness positively correlated with age ($r = 0.58$; $p = 0.035$). Significantly, furcation canals, canal loops and root canal calcifications were sporadic findings.
Conclusions: In some cases the anatomy of MTMs may not be as complicated as previously documented, being similar to the reported anatomy of other maxillary molars. During root canal treatment of MTMs, the frequent deviation of the apical foramen from the radiographic apex should be considered, as should the absence of an apical constriction in the majority of cases. In addition, buccal/palatal root curvature, often undiagnosed radiographically, is the most common root curvature in MTMs.

1. Introduction

The predictability and prognosis of root canal treatment is dependent on the ability of the clinician to successfully locate and negotiate the root canal system prior to chemo-mechanical debridement and filling. Difficulties can arise during treatment as a result of morphological variations between teeth, age alterations to dental hard tissue and unusual root patterns. Many of these problems can be eliminated by improving the operator's knowledge of root canal anatomy, which is fundamental to successful endodontic treatment (Vertucci, 2005).

A plethora of *in vitro* and *in vivo* studies have been carried out on the subject of root canal anatomy using a range of investigative techniques to analyze morphology, including tooth demineralization (Alavi et al., 2002; De Deus and Horizonte, 1975; Pecora et al., 1992; Sert et al., 2011; Sidow et al., 2000), inspection of cross-sections (Green, 1973), scanning electron microscopy, classic (Pineda and Kuttler, 1972) and digital (Domark et al., 2013) radiographic techniques and cone beam computed tomography (CBCT) (Blattner et al., 2010; Domark et al., 2013). Most of these techniques,

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however, are limited as they only offer a 2-dimensional analysis of the root canal system and cannot be readily compared with other samples qualitatively or quantitatively. Recently non-invasive, 3-dimensional micro-computed tomographic (micro-CT) analysis has gained popularity for root canal anatomy analysis offering advantages over traditional techniques (Grande et al., 2012; Harris et al., 2013; Skrzat et al., 2013; Spagnuolo et al., 2012; Versiani et al., 2012) with several root canal configurations analyzed using this technique, including maxillary first and second molars (Ahmed and Abbott, 2012; Grande et al., 2012; Versiani et al., 2012), mandibular first molars (Domark et al., 2013; Grande et al., 2012), premolars (Grande et al., 2012), canines (Versiani et al., 2013) and incisors (Leoni et al., 2014).

Dental hard tissue development, crown and root morphology and position in the dental arch all vary widely in third molar teeth (Kandasamy and Rinchuse, 2009), which is reflected in previously published studies that highlight that maxillary third molars (MTMs) do not possess a specific root canal pattern and demonstrate wide variation in their root canal morphology (Sert et al., 2011; Sidow et al., 2000). As a result they are believed to be very challenging in terms of endodontic treatment and are often extracted in clinical practice (Sert et al., 2011). The loss of first and second molar teeth increases the strategic significance of MTMs (Sert et al., 2011), as does the prescription of oral and intra-venous bisphosphonate medication, which reinforces the need to retain teeth to avoid bisphosphonate-related osteonecrosis as a result of extraction (Moinzadeh et al., 2013).

To the best of our knowledge this is the first study to investigate the root canal anatomy of MTMs using micro-CT. Recent micro-CT studies of other teeth (Grande et al., 2012; Versiani et al., 2012) have supplemented clinical knowledge on the subject of root canal morphology, enabling improved case planning and predicting problems that may arise during root canal treatment. The aim of this study was to analyze the root canal morphology of maxillary third molars (MTMs) using micro-computed tomographic (micro-CT) analysis.

2. Materials and methods

2.1. Sample selection and preparation

Ethical approval (KBET/186/B/2014) for the study was granted by the Jagiellonian University Medical College Bioethical Committee, Krakow, Poland. Thereafter, seventy-eight consecutive human MTMs (44 left and 34 right side) were non-traumatically extracted after obtaining patients' consent. The patient's gender, ethnic origin, age and any relevant medical history was noted from the patient records. MTMs were excluded if the apex was not fully formed, the tooth was restored, previous root canal treatment had been completed or if root or crown caries were present. The teeth were stored for 24 h in a 5.25% sodium hypochlorite solution (Chloraxid 5.25%, CERKAMED, Stalowa Wola, Poland) to remove organic surface debris. After 24 h, the teeth were inspected and any calculus removed using an ultrasonic scaler, washed under running water, blotted dry and stored in saline in labeled individual plastic vials (Grande et al., 2012). Prior to scanning, the teeth were removed from the vials and blotted dry.

2.2. Micro-CT scanning

MTMs were scanned using a micro-CT scanner (SkyScan® 1172, Aartselaar, Belgium) at a spatial resolution of 13.68 μm per pixel. Shadow images were obtained using an X-ray energy source of 80 kV and a 0.5 mm Aluminum filter. The angular step between image acquisitions was 0.4° and each image was averaged after 5 frames. MTMs were mounted on a plasticine attachment to facilitate precise repositioning of the specimen along the z-axis with

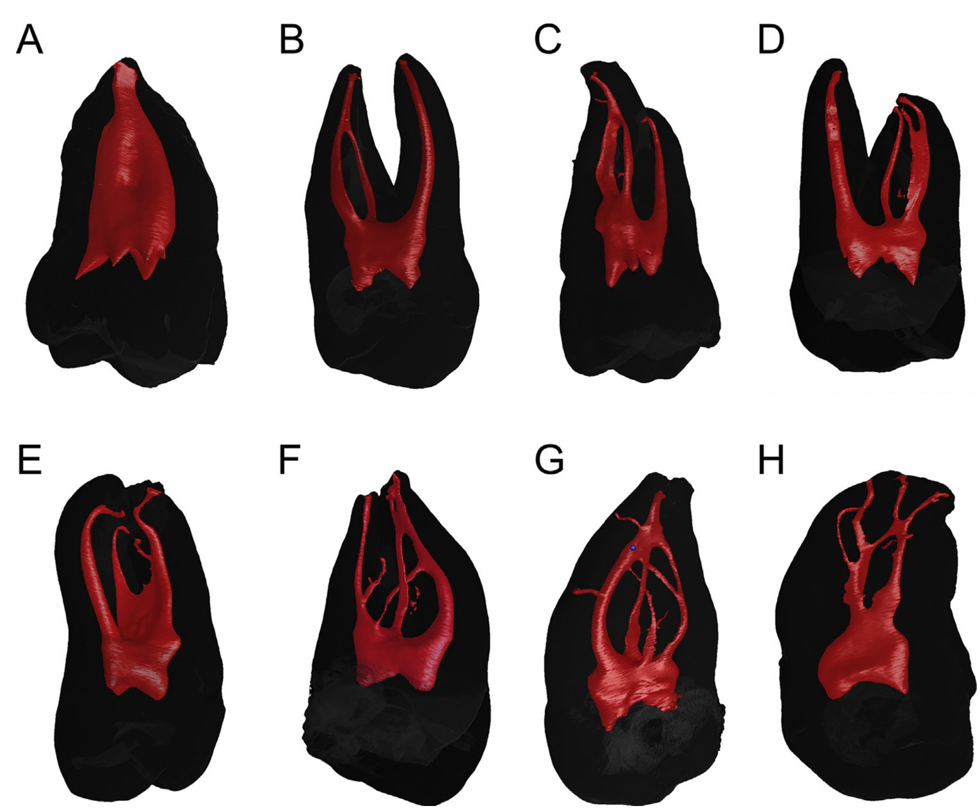

Fig. 1. Virtual reconstructions of the internal anatomy of selected maxillary third molars shown as transparent mesial views of various pulp chambers and root canals. (A–D) maxillary third molars with different numbers of apical foramina: (A) one; (B) two; (C) three; (D) four. (E–H) Anatomical findings in maxillary third molars: (E) C-shaped canal, furcation canal; (F) sheet connection isthmus; (G) isthmuses, lateral canals, and a calcification marked in blue; (H) isthmuses and canal loop.