INTRODUCTION

According to Swartz, Skidmore and Griffen, mandibular first molars have a significantly lower success rate compared with other teeth. Missed canals and the failure to remove all the microorganisms and pulp remnants from the root canal system are probably the main reasons for persistent infection around endodontically-treated molars. It is therefore important that clinicians have an awareness and good understanding of the variations in root canal morphology of the mandibular first molar.

Permanent mandibular first molars in Caucasian populations are generally two rooted teeth (one mesial and one distal root) with two mesial and one distal root canals. The two mesial root canals can end up in two distinct apical foramina or they can merge together at the root tip and end into one apical foramen.

Vertucci and William (1974) as well as Barker et al. (1974) reported the presence of independent middle mesial canals in the mesial root of lower first molars. According to a literature review by Baugh and Wallace (2004), the prevalence of a third mid-mesial root canal in mandibular first molars is between 1-15%. They also reported that the mid-mesial canal can be independent with a separate foramen, or this additional canal may have a separate canal orifice and then join apically with either the mesio-buccal or mesio-lingual canal.

In 1971, Skidmore and Bjorndal reported that 71.1% of distal roots of mandibular first molar teeth have only one canal, 28.9% can have two canals and in rare cases it can have three root canals. A review article (2010) revealed that the distal root of first mandibular molars had a Vertucci Type I configuration (single pulp canal is present from the crown to the apex) in 62.7% of cases followed by a Type II configuration (pulp canal separates in two near
the crown and joins at the apex to form one root canal) in 14.5% of cases (Figure 6) and a Type IV configuration (pulp canal separates into two distinct canals and extends till the root apex separately) in 12.4% of cases (Figure 7). Another variation can also be to find three root canals in the distal roots of mandibular first molars. The incidence of three root canals in the distal root of the mandibular first molar is between 0.2% and 3% (Figure 8). In addition to these case reports, there have been numerous studies that clearly indicated that the mandibular first molar could present with more than four root canals.

The number of roots for the mandibular first molar teeth may also vary. Carabelli (1844) was the first to report on mandibular first molars with supernumerary roots. The third root was located on the disto-lingual side and was called radix entomolaris (RE) (Figure 10). In very rare cases, the mandibular first molar can also present with an additional root at the mesio-buccal side and is called radix paramolaris.

PREVALENCE OF RE
The presence of RE in the mandibular first molar is associated with certain ethnic groups. In populations with Mongoloid traits (for example Chinese, Eskimo and American Indians) the frequency can range from 5-30%. However, in Eurasian and Indian populations it is less than 5% and in African populations less than 3%.

Radix entomolaris can be found on first, second and third mandibular molar teeth, occurring least frequently on second molars. Studies have also reported a bilateral occurrence with as frequency of 50-67%.

ETIOLOGY OF RE
According to Calberson et al. (2007) the etiology behind the formation is still unclear but it could be related to external factors during odontogenesis. Racial genetic factors can also influence profound expression of a particular gene that can result in the more pronounced phenotypic manifestation.

MORPHOLOGY OF RE
The coronal third of the disto-lingual root of RE can be fixed partially or completely to the distal root. Based on the curvature in a buccal-lingual orientation, the separate RE variants can be classified into three types according to De Moor et al. (2004). Type I refers to a straight root/root canal.

Type II refers to an initially curved entrance, which continues as a straight root/root canal. Type III refers to an initial curve in the coronal third of the root canal and a second curve beginning in the middle and continuing to the apical third.

RADI DiOGRAP HIC DIAGNOSIS OF RE
Walker and Quackenbush reported a 90% precision in the diagnosis of 3-rooted molars using only panoramic radiographs. However, due to the fact that the RE is found mainly in the same bucco-lingual plane of the disto-buccal root, it may cause superimposition on the preoperative periapical or panoramic image. This often results in inaccuracy to reveal this anatomic variation.

A major limitation of conventional radiographic images is to compress 3D anatomy into a 2D image or shadowgraph. In an attempt to overcome this drawback of conventional radiography in order to detect the presence of RE, it is helpful to take additional exposures changing the horizontal angulation of the main x-ray beam. Wang et al., demonstrated that 25-degree mesial radiographs were significantly better than 25-degree distal radiographs for RE visibility and determination of optimum diagnosis. According to Clark's rule (Also known as SLOB rule or Waltons projection), an object that moves in the same direction as the cone is located towards the lingual. Conversely, an object that moves in the opposite direction from the cone is located towards the buccal. Therefore, the RE image that moves distally is superimposed on the distobuccal root image that moves towards the mesial, when taking radiographs with small distal angulations.

According to Wang et al. (2011), radiographic images taken with eccentric beam angulations have the potential to improve diagnosis. However, they are inherently less distinct and they lose normal sharpness that is expected because anatomical structures could overlay roots and affect visibility and identification of roots and canals.

Cone-Beam Computed Tomography (CBCT) provides dentistry with a practical tool for non-invasive and 3-dimensional (3D) reconstruction imaging for the use in endodontic applications and morphologic analyses. CBCT imaging allows for visualizing a new dimension, eliminate superimpositions, provide additional information for diagnosis and therefore enables a more predictable management of complex endodontic conditions compared with intraoral radiographs along with iatrogenic events that might occur in relation to canal curvature like instrument separation, perforation and ledge formation.
CLINICAL DIAGNOSIS OF RE

Clinical inspection of the tooth crown and analysis of the cervical morphology of the roots by means of periodontal probing can facilitate identification of an additional root. An extra cusp (tuberculum paramolare) or more prominent occlusal distal or distolinguinal lobe, in combination with a cervical prominence or convexity, can indicate the presence of an additional root.5

After access cavity preparation, the location of the canal orifice of the RE can also be problematic. The orifice is generally located disto- to mesio-lingually from the main canal or canals in the distal root. The orifice is often covered with overlying dentine or pulp roof remnants and must be removed before it is possible to locate the entrance of the canal. Extension of the access cavity to the disto-lingual side also ensures easy location.

A recent study by Souza-Flamini et al., (2014) used high resolution Micro-computed tomography (uCT) to examine the internal and external morphology of RE in mandibular third molars. The spatial configuration of the canal orifices on the pulp chamber floor was mostly in a trapezoidal shape and the radix canal orifice was usually covered by a dentinal projection.27

CASE REPORT

The patient, a 45 year old female presented with pain and discomfort on her mandibular left first molar, previously restored with a ceramo-metal crown. A pre-operative radiograph revealed evidence of extensive decay on the mesial margin as well as unusual root morphology (Figure 10a). The ceramo-metal crown was removed, caries excavated and a temporary crown placed. A CBCT, axial coronal slice confirmed the presence of two roots (mesial and distal)(Figure 10b). There was no clear evidence of canal orifices in the mesial root. Two canal orifices were visible in the distal root. Another axial slice in the midroot area, revealed the presence of distal root bifurcating into two separate roots. The additional root, branching off on the lingual aspect, confirmed the presence of radix entomolaris (RE)(Figure 10c).

The canals were negotiated with size 08 C+ and K-Files to patency and a length determination was done with an electronic apex locator (Pixie, Dentsply/Maillefer) and confirmed radiographically. Reproducible glide paths were prepared with hand files and the ProGlider instrument (Dentsply/ Maillefer) and the root canals prepared with ProTaper Next X1 and X2.

GuttaCore X2 verifiers (Dentsply/ Maillefer) were fitted into the prepared root canals and a periapical radiograph revealed that the verifier in the distal root canal travelled past working length (Figure 11a). A ProTaper Next X3 gutta-percha point was then fitted in the distal canal and a periapical radiograph confirmed a snug fit up to working length (Figure 11b). The mesio-buccal, mesio-lingual and radix entomolaris was obturated with size X2 GuttaCore obturators (Dentsply/Maillefer). The root canal system was obturated with the ProTaper Next X3 gutta-percha point using the continuous wave of condensation technique with the Calamus Dual Obturation Unit (Dentsply/Maillefer).

DISCUSSION

Radix entomolaris, first described by Carabelli, is an anatomical variant in the first permanent mandibular molar typically characterized by an additional third root located disto-lingually.14 RE occurs in first, second and third molars with the lowest prevalence in second mandibular molars.23,28,30 Although the presence of RE differs within associated ethnical groups, it should be regarded
as a normal anatomical variation within the Mongoloid population. Studies show no significant predilection for gender or side distribution with bilateral occurrence ranging between 50–67%. Another benefit of the system is the fact that the instrument is manufactured from M-wire and not traditional nickel titanium alloy. Research by Johnson et al (2008) demonstrated that the M-wire alloy could reduce cyclic fatigue by 400% compared with similar instruments manufactured from conventional nickel titanium alloys. The added metallurgical benefit contributes towards more flexible instruments, increased safety and protection against instrument fracture.

The authors used a Global G6 (Global, USA) six-step microscope fitted with LED illumination during the clinical procedures depicted in this article. The LED light source on this microscope delivers brighter and whiter illumination than that of metal halide and halogen light systems. The type of illumination makes the careful inspection of the pulp chamber floor to locate accessory canal orifices more predictable. Magnification and illumination can substantially improve the visualisation of root canal orifices. De Carvalho and Zuolo (2000) demonstrated in a study that the use of the DOM could increase the number of root canal orifices and determine the exact position and angulation of fractured canals.41 In general, limited field of view (FOV) machines are important diagnostic tools for locating and identifying root canals.41 The study also concluded that the combination of CBCT scanning with the dental operating microscope were errors such as improperly shaped canals.49

Protaper Next (Dentsply/Maillefer) was recently introduced to overcome these clinical challenges. GuttaCore consists of a carrier/core manufactured from a cross-linked, thermostet elastomer of gutta-percha coated in regular gutta-percha. The core is a polysoprene polymer cross-linked with peroxide for strength, designed to facilitate removal during retreatment and/or post space preparation by simply trephining through the core.

CONCLUSION

The successful outcome of root canal treatment depends to a large extent on access, cleaning and shaping and three dimensional obturation of the entire root canal system. CBCT technology as well as proper angulation when acquiring radiographic images proves helpful in locating canals in especially first mandibular molars with a high incidence of anatomical variations. A thorough understanding of the prevalence of RE, its anatomical variations as well as radiographic and clinical diagnosis will provide the clinician with a better understanding of its complexity in order to ensure successful treatment outcomes.
References