Microcomputed tomographic evaluation of mandibular molars with single distal canals

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The aim of this study was to evaluate, using microcomputed tomography (μCT), the frequency of conjoined mesial canals in first and second mandibular molars with a single distal canal. Mandibular first (n = 114) and second molars (n = 114) with mature apices were randomly selected from a pool of extracted teeth. The specimens were decoronated to establish clinically the existence of a single distal canal. Teeth with C-shaped canals were discarded. Each tooth was scanned with a μCT system and evaluated in 3 dimensions. Of 228 examined teeth, 206 were included in the study. Of these, 129 (62.6%) displayed conjoined mesial canals with a single portal of exit, and 77 (37.4%) displayed 2 distinct mesial canals with 2 separate portals of exit. Of the teeth with conjoined mesial canals, 71 (55.0%) were second molars and 58 (45.0%) were first molars. Conjoined mesial canals exhibited a mean interorifice distance of less than 3.00 mm. These data regarding morphological patterns alert clinicians to the possible need to modify endodontic techniques in mandibular molars with single distal canals.

Received: December 11, 2013
Revised: June 20, 2014
Accepted: July 23, 2014

Key words: conjoined canals, microcomputed tomography, portal of exit

Failure of root canal therapy often results from an inadequate knowledge of the pulp canal anatomy, which leads to the possibility that root canal systems might be incompletely cleaned, shaped, and obturated.[1] The literature boasts an abundance of divergent data with regard to anatomical configurations of mandibular molars, many of which have cited frequencies determined early on by Hess.[2] A consequence of more recent research has been a dramatic modification in the total approach to access preparation and subsequent cleaning and shaping of the canal space.[3,4] However, dental anatomy and endodontic textbooks still vary considerably in their descriptions of the root canals of human teeth.[5-7] For example, although a dental anatomy textbook might describe the close relationship between the location of the apical foramen and the location of the anatomical root end, deviations from this norm occur at a fairly high rate, ranging from 34%-92%.[3]

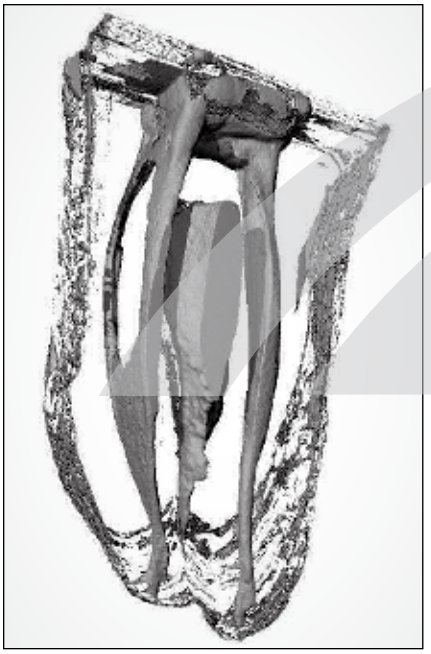

Fig. 1. Microcomputed tomographic image of a mandibular first molar with a single distal canal and conjoined mesial canals.

An investigation by Skidmore & Bjorndal attempted to determine the frequency with which the mesial and distal canals of mandibular molars join to form a common foramen before exiting the tooth.[4] The authors reported that 59.5% of mesial and 38.5% of distal canals remained separate along the entire length of the root, exiting the apex with separate foramina. They also found that 40.5% of mesial and 61.5% of distal canals joined into a common canal in the apical third and exited through a common foramen.[4]

There has never been an investigation, however, to evaluate mandibular molars that possess a single distal canal in order to determine the frequency with which the mesial canals join into 1 common canal that exits the apex through 1 common foramen (Fig. 1). In other words, no studies have evaluated the approximately 41% of mesial canals that join into a common canal and exit in a common foramen (as reported by Skidmore & Bjorndal) to determine how many have a single distal canal.[4] Investigators have reported the incidence of Vertucci type I canal anatomy (single canal with a single portal of exit) in the distal roots of mandibular first molars to be as high as 82%.[1,8] For mandibular second molars, the incidence can be as high as 96%.[8,9] It appears that mandibular first and second molars possess a single distal canal more often than not, and yet the literature does report the incidence of molars that have a single distal canal and conjoined mesial canals (Fig. 1).

Classic anatomical and morphological studies involving the canal space of human teeth have utilized sectioning (with coarse sandpaper disks) of specimens as well as clearing and/or dyeing the pulp space (with hematoxylin).[10,11] These techniques served a purpose by enhancing knowledge, enabling clinicians to modify their approach, and thereby improving root canal therapy as a whole; however, now a cleaner, less invasive, more detailed technique, microcomputed tomography (μCT), may be applied to examine root canal anatomy and morphology.[12-15] It is a relatively new field in the area of nondestructive, reproducible

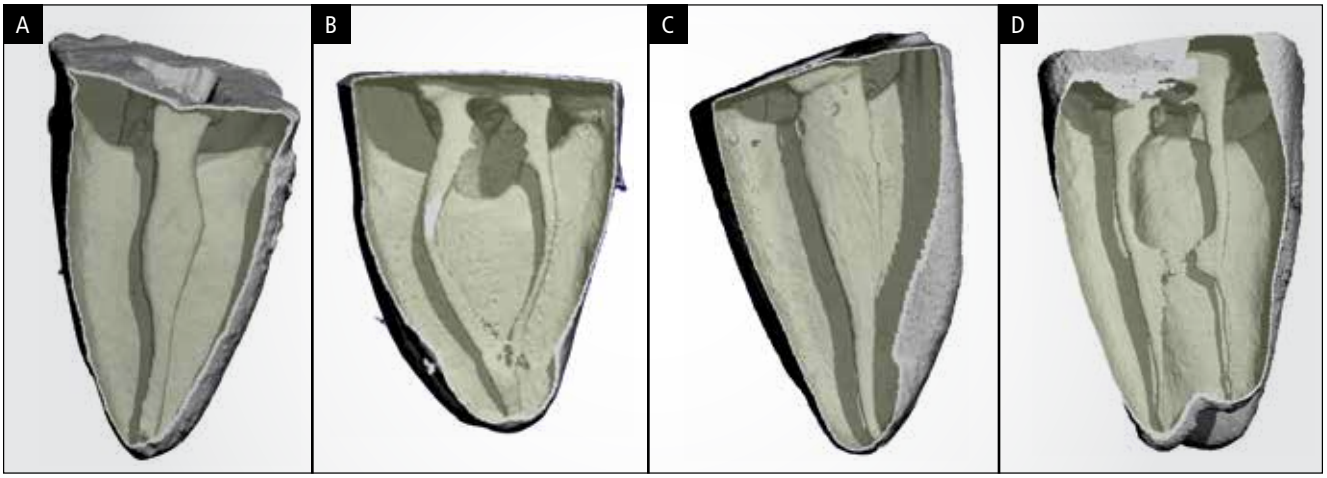

Fig. 2. A, B. Single distal canal with conjoining mesial canals. C, D. Single distal canal with separate mesial canals.

imaging and is based on the collection of 2-dimensional (2D) projections of X-rays through a specimen, which, in turn, are then used to reconstruct a 3-dimensional (3D) image.[16]

Although the root canal anatomy of mandibular molars has been described by many investigators, including the relatively low prevalence of C-shaped canals in mandibular second molars (less than 10%) as well as distolingual roots in mandibular molars, the present investigation was limited to 2-rooted mandibular first and second molars without C-shaped canals.[14,17] It is the opinion of the authors, based on intensive observation through years of clinical experience, that mandibular molars with 3 canals, or, more specifically, mandibular molars with single distal canals, may have a higher prevalence of conjoined mesial canals. Therefore, the aims of this study were to evaluate the frequency with which a single distal canal in mandibular first and second molars possessed mesial canals that were conjoined in 1 common portal of exit; record the interorifice distance for both conjoined and separate mesial canals; and determine the location at which the mesial canals joined.

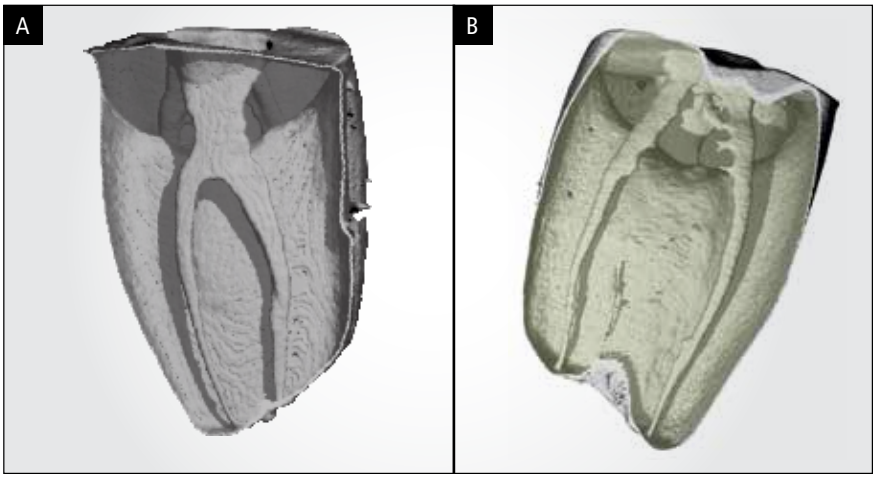

Fig. 3. A. Separate distal canals. B. Separate mesial canals.

Materials and methods

The authors (endodontists) randomly selected 114 mandibular first molars and 114 mandibular second molars with mature apices from a pool of extracted teeth; the identification of either first or second molar was confirmed by both a prosthodontist and restorative dentist.

The teeth were decoronated with a high-speed handpiece and fissure bur using copious amounts of water in order to establish clinically the existence of a single distal canal. The teeth were placed in a 6.15% solution of sodium hypochlorite and left in an ultrasonic cleaning unit (Coltene/Whaledent, Inc.) for 5 minutes to remove organic debris.

Six teeth were positioned on their mesial surfaces, secured with orthodontic wax on a 60-mm-diameter cell culture plate, and then placed in a 72-mm-diameter custom-designed specimen holder. A μCT system (μCT 100, SCANCO Medical AG) was used to scan the teeth over the length of the root. Scan settings were predefined at 18-μm voxel size, medium resolution, 90 kVp, 88-μA intensity, 0.5-mm aluminum filter, integration time of 500 milliseconds, and 30-μm slices. Each specimen was analyzed individually with the manufacturer's evaluation software, and scan times were approximately 3.5 hours per tube. Four plates, for a total of 24 teeth, were scanned at a time in the custom specimen holder.

Two examiners (AL, NM), blinded to the tooth type, evaluated each tooth in every possible 3D plane. Once scanned, each specimen was confirmed to have a single distal canal, or the tooth was

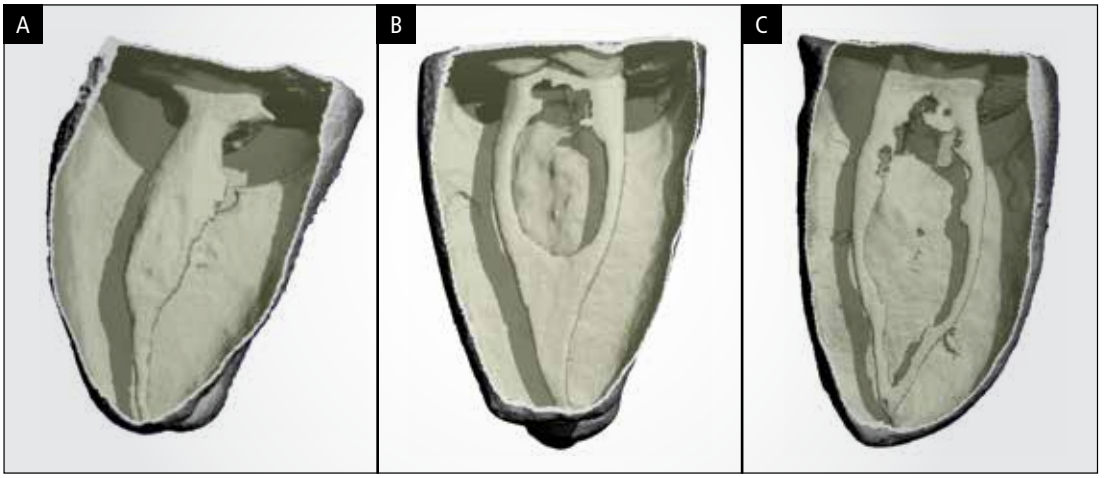

Fig. 4. Conjoined mesial canals. A. Coronal. B. Middle. C. Apical.

Table. Locations and mean interorifice distances of conjoined mesial canals in 206 mandibular molars.

Morphological feature	First molar (n = 58)	Second molar (n = 71)	Combined (n = 129)
Number of conjoined canals by location (%)			
Coronal third	6 (10.3)	16 (22.5)	22 (17.1)
Middle third	13 (22.4)	22 (31.0)	35 (27.1)
Apical third	39 (67.2)	33 (46.5)	72 (55.8)
Mean interorifice distance (mm)			
Conjoined canals	2.34	2.37	2.35
Separate canals	3.07	2.93	3.00

immediately discarded. From the sample pool of 228 examined teeth, 22 teeth were excluded because of calcifications, 2 separate distal canals, or C-shaped anatomy as revealed by the µCT analysis (detailed in the Results section). This process resulted in a final sample of 206 teeth.

Results

Of the 206 teeth with single distal canals that were included in the study, 129 (62.6%) displayed conjoined mesial canals with a single portal of exit, while 77 (37.4%) displayed Vertucci type IV mesial root anatomy, that is, 2 distinct canals with 2 separate portals of exit (Fig. 2).[1] Further examination of the 129 teeth with conjoined mesial canals revealed that 71 (55.0%) were second molars and 58 (45.0%) were first molars. After µCT evaluation, 22 teeth were excluded: 5 teeth possessed a canal space that was calcified and/or undetectable, 16 teeth possessed 2 distal canals with separate portals of exit (Fig. 3), and 1 second molar possessed a C-shaped root canal anatomy.

The location at which mesial canals joined was determined (Table). In first molars, 67.2% joined in the apical third, 22.4% joined in the middle third, and 10.3% joined in the coronal third of the mesial root. In second molars, 46.5% joined in the apical third, 31.0% joined in the middle third, and 22.5% joined in the coronal third of the mesial root (Fig. 4). There were 9 accessory mesial canals in first molars and 6 accessory mesial canals in second molars, a combined incidence of 7.3%.

The interorifice distance between mesial canals was also calculated. In first molars, conjoined mesial canals had a mean interorifice distance of 2.34 mm, while separate mesial canals had a mean interorifice distance of 3.07 mm. In second molars, the mean interorifice distance was 2.37 mm in conjoined mesial canals and 2.93 mm in separate mesial canals.

Discussion

It is well known that a detailed understanding of the complexity of root canal systems is important for clinicians to ensure successful root canal therapy.[5,18] This imperative, however, has challenged the profession since well before classic anatomical details were described by Hess with vulcanized rubber specimens in the 1920s.[2] Because conventional sectioning, clearing, and/or dye techniques are cumbersome, and clinical radiographs show only 2D projections, the use of imaging techniques that show root canal systems in 3D seems the logical choice for study of anatomy. Cone beam computed tomograms are superior to periapical radiographs not only for assessment of canal morphology but also for the detection of missed canals.[6,19]

In the present study, the authors sought to corroborate a simple observation made through a combined 50 years of clinical practice—mandibular first and second molars that possess single distal canals have a higher frequency of conjoined mesial canals. Therefore, the authors initially intended only to report the incidence of conjoined mesial canals in mandibular

molars with single distal canals. Once these findings were calculated, however, additional observations warranting further investigation were recorded: the presence of C-shaped canals, the presence of accessory mesial canals, the interorifice distance of mesial canals, the location of conjoined mesial canals, and the incidence of conjoined mesial canals with 2 distal canals with 2 separate portals of exit (Vertucci type IV).[1]

These additional findings provided interesting results as well. Sixteen teeth not fulfilling the inclusion criteria were clinically thought to possess a single distal canal following decoronation, but 3D imaging revealed otherwise. Each of these 16 teeth in fact possessed 2 Vertucci type IV distal canals.[1] Moreover, each of these specimens possessed 2 Vertucci type IV mesial canals as well (Fig. 3).[1] Thus, if a mandibular molar possessed 2 separate distal canals with 2 portals of exit, it also possessed 2 separate mesial canals with 2 portals of exit, for a combined incidence of 100.0%. Accessory mesial or middle mesial canals, encountered with a combined incidence of 7.3%, were found more often in mandibular first molars; previous studies agree with these findings as well.[7]

Measurement of the mesial canals of mandibular molars revealed that the interorifice distance was, on average, approximately 1.00 mm closer when mesial canals were joined than when they were separate (2.34 mm when joined vs 3.07 mm when separate for first molars and 2.37 mm when joined vs 2.93 mm when separate for second molars). When the locations of conjoined mesial canals in first and second molars were assessed, the combined incidence of conjoined canals was greatest (55.8%) in the apical third of the root and lesser in the middle third (27.1%) of the root (Fig. 4).

Thus, when clinicians access a mandibular molar with a single distal canal, they can expect to encounter 2 conjoined mesial canals approximately 62.6% of the time, more frequently (55.0%) in second molars. If the additional observations of the study are extrapolated, then if the tooth also possesses mesial canals that measure 2.00-2.50 mm apart, there is a greater chance that (1) the canals will join and (2) the canals will join in the apical third of the root. Clinically, it is also important to recognize that the mesial canals in mandibular first molars are more often closer together than those in mandibular second molars. In addition, mesial canals that are located greater than 3.00 mm apart are significantly more likely to remain separate throughout their length.

The results of the present study imply that clinicians who encounter such teeth should redirect their approach to access and subsequent treatment of these mesial canals. These findings may influence the technique used to establish a glide path and obtain a working length as well as the approach taken to shaping and cleaning the mesial canals. The existence of a guide to probable mesial root canal anatomy based on the existence of a single distal canal allows clinicians to avoid the potential misadventures that conjoined canals offer. Nevertheless, the findings of the present study are not definitive; clinicians must not assume that every mandibular molar with a single distal canal will have conjoined mesial canals but rather must be aware that there is a higher probability of their presence. Similarly, a mandibular first molar with 2 completely separate mesial canals and an apparent single distal canal may warrant further investigation to seek a potential second distal canal (which has a reported incidence of 28.9%).[4]

Conclusion

In a study of mandibular first and second molars with single distal canals, 62.6% exhibited conjoined mesial canals. Of the conjoined canals, 55.0% were found in second molars and 45.0% were found in first molars. Mesial orifices separated by less than 3.00 mm were increasingly likely to be joined. These data regarding the morphological patterns in mandibular molars with single distal canals should encourage clinicians to modify their assessment and treatment techniques in these situations and thereby enhance the chances for successful endodontic treatment.

Acknowledgments

The authors wish to thank the University of Michigan Graduate Program in Endodontics as well as Michelle Lynch, Christine L. Lamia, RDH, Kari A. Gregerson, and Xianli Tang, DDS. The use of the SCANCO μCT 100 and MicroCT Core was funded in part by National Institutes of Health/National Center for Research Resources grant No. S10RR026475-01.

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