

Quantitative Evaluation of Apical Delta Morphologies in Mesial Roots of Mandibular First Molar Teeth: A Micro-CT Study

Mandibular Birinci Molar Dişlerin Mezial Köklerindeki Apikal Delta Morfolojisinin Kantitatif İncelenmesi: Bir Mikro-BT Çalışması

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ABSTRACT Objective: The apical delta is the branching of the main root canal dividing into three or more ramifications near the root apex, while the main canal itself becoming indistinguishable. Aim of this study was to analyze apical delta morphologies of mesial root canals of mandibular first molar teeth quantitatively using micro-computed tomography (micro-CT). **Material and Methods:** Two hundred and sixty-nine mesial roots of mandibular first molar teeth were scanned by micro-CT. Following the initial scanning, 22 specimens showing apical delta ramifications were selected from reconstructed micro-CT images. The numbers and vertical extension of the apical ramifications were recorded. For each specimen, major diameter, minor diameter and roundness values at the most apical slices of the apical delta ramifications and at the slice where ramifications merged to form to main canal were calculated. Data were analyzed using descriptive statistics. **Results:** The incidence of apical delta was 13.01%. A total of 96 apical delta ramifications were quantitatively analyzed. The mean number of apical delta ramifications was 4.45 per specimen and the mean vertical extension was 0.95 mm. Majority of the apical delta ramifications exhibited noncircular cross sectional shape. **Conclusion:** The occurrence of apical delta is not uncommon in clinical practice. The shape, number and the height of the apical delta are variable. These complex morphological properties of apical delta might complicate three-dimensional shaping and obturation of root canal systems.

Keywords: Endodontics; x-ray microtomography

ÖZET Amaç: Apikal delta ana kök kanalının apeks yakınında 3 veya daha fazla dallanma göstererek aynı zamanda kendisinin radyografide izlenemez hale geldiği dallanmaları tanımlamaktadır. Bu çalışmanın amacı mikro-bilgisayarlı tomografi (mikro-BT) kullanarak mandibular birinci molar dişlerin mezial köklerinin apikal delta morfolojisinin kantitatif analizini yapmaktır. **Gereç ve Yöntemler:** 269 mandibular molar dişin mezial kökleri mikro-BT ile tarandı. İlk taramayı takiben elde edilen yeniden oluşturulmuş mikro-BT görüntülerinden apikal delta saptanan 22 diş seçildi. Apikal dallanmaların sayısı ve vertikal uzunlukları kaydedildi. Her örnekte apikal dallanmaların tespit edildiği en apikaldeki kesit ve dallanmaların ana kanalı oluşturmak üzere birleştiği kesitlerde majör çap, minör çap ve ovallik değerleri ayrı ayrı hesaplandı. Elde edilen veriler tanımlayıcı istatistiklerle analiz edildi. **Bulgular:** Apikal delta insidansı %13,01 olarak bulundu. Toplamda 96 adet apikal delta dallanması kantitatif olarak incelendi. Apikal delta dallanmalarının ortalama sayısı örnek başına 4,45 ve vertikal uzunluklarının ortalaması 0,95 mm olarak belirlendi. Örneklerin çoğunda apikal delta dallanmalarının sirküler olmayan bir kesit alanı gösterdikleri saptandı. **Sonuç:** Apikal deltanın klinik pratiğinde görülme sıklığı azımsanmayacak boyuttadır. Apikal delta dallanmalarının kantitatif analizleri bu varyasyonların sayı, şekil ve vertikal uzunlukları açısından çeşitlilik gösterdiğini ortaya koymuştur. Bu apikal delta dallanmalarının kompleks anatomisi kök kanal sisteminin üç boyutlu şekillendirilmesi ve doldurulmasını zorlaştırabilir.

Anahtar Kelimeler: Endodonti; x-ışınlı mikrotomografi

The complexity of the root canal system produces difficulties for fulfilling the goals of root canal treatment, which are cleaning and shaping of root canal system to an adequate geometry, especially in the

apical portion.^{1,2} One of these complexities is the presence of apical delta, which favors the free passage of blood vessels and nerves from the periapical compartment to the pulp tissue.³ The apical delta is described as a root canal dividing into three or more ramifications near the root apex, with the main canal becoming indistinguishable.^{4,5} The main root canal is divided more than three branches to form apical delta. These branches are at varying lengths and diameters moreover they leave the main canal with varying angles. Effective cleaning and irrigation of apical third is problematic even in root canals that end in a single foramen due to vapor lock effect or inability of root canal preparation instruments to adapt root canal anatomy.^{6,7} In the case of apical deltas, ramifications within the delta are difficult to clean, debride and obturate. Biofilm that colonized the apical delta and could not be eliminated after root canal disinfection might damage the long-term outcome of endodontic treatment.⁸

Mesial root canal configuration of mandibular molars has been addressed to show one of the most complex internal anatomies.⁹ Çalışkan et al. reported the prevalence of apical deltas in mesial roots of mandibular first molars as 8.47%.¹⁰ Micro-computed tomography (micro-CT) is reported as the most accurate method for revealing the actual anatomy and fine variations of the root canal system. The technology displays high-resolution images of root canal configuration without destroying specimens.^{11,12} Micro-CT also allowed researchers to make quantitative analysis to reveal the actual root canal anatomy and ramifications.¹³ The aim of the present study was to determine the frequency of apical deltas and quantitatively analyze the morphologic features of apical deltas in mesial roots of mandibular first molar teeth.

MATERIAL AND METHODS

After ethical approval by the university ethical committee (no: 13/145), extracted mandibular molars, which were extracted for the reasons nonrelated to the present study, were collected. Attached soft tissue and calculus were removed by periodontal cures. Any teeth showing fracture,

cracks, caries, previous root canal treatment or immature roots were excluded. Two hundred and sixty nine mandibular molars were included into the study. The crowns and distal roots were removed at the cemento-enamel junction (CEJ) level under water cooling using an Isomet 5000 low-speed saw (Buehler, IL, USA), and the mesial roots were collected in 10% formalin solution. The mesial roots of mandibular molars were mounted and scanned on a high-resolution micro-CT system (SkyScan 1172; Bruker-microCT, Kontich, Belgium), which was operated at 100 kV and 100 μ A. Slices presenting 2000 x 1330 pixel resolution with 10 μ m pixel size were obtained from each root using an 11 MP camera. Scanning was performed with 180° rotations around the vertical axis with a camera exposure time of 1400 msec and a rotation step of 0.4°. Data were reconstructed using NRecon software (v. 1.6.4, Bruker-microCT) with a beam-hardening correction of 45%, smoothing of 2, and an attenuation coefficient range of 0–0.06. Three-dimensional models of dentin and root canals were constructed using automatic segmentation thresholding and surface modeling in CTAn software. Dentin was color coded as transparent gray, and root canal configuration was visualized by color. CTAn and Data Viewer (v.1.5, Bruker-microCT) software were utilized to present the root canal configuration of each root. Micro-CT datasets of 22 roots showing apical delta were selected. The number of the apical delta and their ramifications were recorded. CTAn (v.1.5, Bruker-microCT) software was utilized to measure the distance between the most apical slice in which ramifications merged and apical foramen of each selected ramification as length of the apical ramification. The major diameter, minor diameter and roundness of each ramification at the apical foramen and the most apical slice of main canal in which ramifications merged were calculated using CTAn (v.1.5, Bruker-microCT). Quantitative measurement of each apical delta ramification was performed following the orientation of the vertical axis of the selected ramification with the vertical axis of the software template. The data was analyzed by descriptive statistics using SPSS 21.0 software (SPSS Inc, Chicago, IL, USA).

RESULTS

Overall percentage of apical delta was 13.01% (n= 22). Figure 1 presents the representative 2- and 3- dimensional images of apical delta ramifications and external appearances of apical foramina, respectively. 16 of the specimens (72.72%) showing apical delta could not be classified according to the classification system of Vertucci.¹⁴ From the remaining 6 specimens, 3 (13.6%) of them exhibited Vertucci type II, 2 (9.09%) of them exhibited Vertucci type III, 1 of them exhibited Vertucci type I and 1 of them exhibited Vertucci type VI root canal configurations.

A total of 96 apical delta ramifications in 22 specimens were quantitatively analyzed. Mean number of apical deltas was 4.45 ± 1.39 per specimen. The apical delta ramifications were mostly straight. Table 1 details the mean major diameter, minor diameter and roundness values of analyzed apical delta ramifications. The mean length, apical major and minor diameters of the ramifications were 0.95 ± 0.45 mm (ranging from 0.19 to 1.92) and 0.32 ± 0.15 and 0.22 ± 0.12 mm respectively.

DISCUSSION

Clearing technique is the most commonly used method to study apical deltas, however this technique is destructive to the specimen and does not provide quantitative data.¹³ Therefore, micro-CT was utilized in this study because it provided the exact and precise configuration and number of apical delta ramifications. Micro-CT is a non-destructive technology that allows three-dimensional reconstruction and quantitative analysis of internal root canal anatomy in such detail, which could not be obtained from clearing, sectioning or digital radiography techniques.¹⁵

In the present study, a large number (n=269) of mesial roots of mandibular first molar teeth were scanned, and 22 (13.01%) roots presenting apical deltas were detected. There are very few studies on

TABLE 1: Mean and standard deviation values of the major diameter (mm), minor diameter (mm) and roundness values of the main root canal cross section, which the ramifications merge at and each apical delta ramifications.

	Apical delta	Main root canal
Major diameter (mm)	0.32 ± 0.15	1.33 ± 0.76
Minor diameter (mm)	0.22 ± 0.12	0.34 ± 0.16
Roundness	0.58 ± 0.14	0.24 ± 0.13

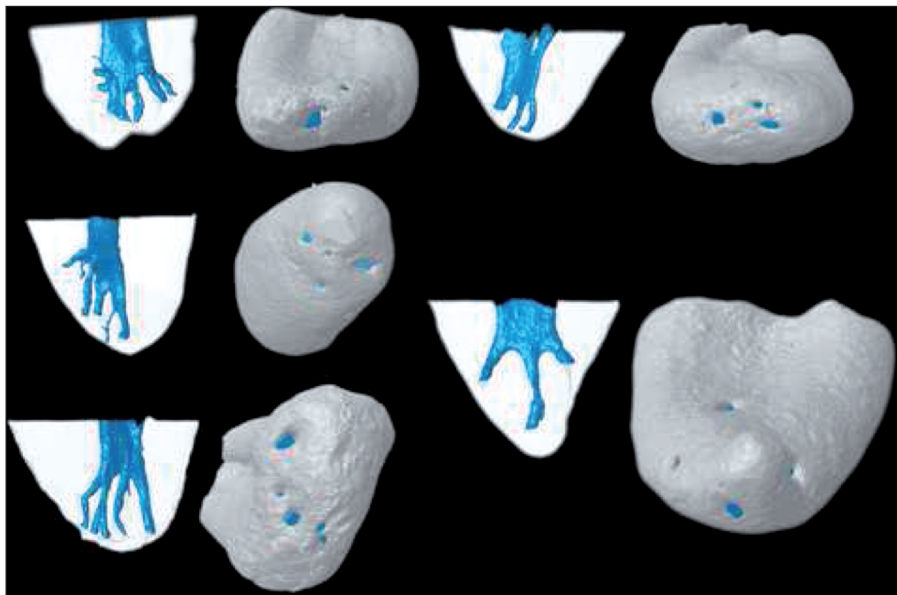


FIGURE 1: Representative 2- and 3- dimensional micro-CT images of apical delta morphologies.

the incidence of apical deltas using micro-CT. In a recent micro-CT study, Gao et al. evaluated the incidence of apical deltas according to the different tooth types and reported that mandibular molar teeth commonly present these ramifications.¹³ The results of the present study are in accordance with the report of Gao et al. despite the different study populations. The present study only evaluated the mesial roots of mandibular molar since these roots are considered to have the most complex internal anatomies. On the other hand Gao et al. reported significantly similar incidence rates between the mesial and distal roots of mandibular molars.¹³ In their study, Çalışkan et al. reported the prevalence of apical deltas in mesial roots of mandibular first molars as 8.47%.¹⁰ The increase in the prevalence rates might reflect the superiority of micro-CT techniques over the clearing method to detect fine anatomical variations. The mean number of apical delta ramifications per root was 4.45, which was similar to the results reported by Gao et al.¹³

The root canal configuration of most of the specimens presenting with apical deltas could not be classified according to the Vertucci classification (72.72%).¹⁴ The root canal configuration of the remaining specimens could be assigned to Vertucci type I, II, III and VI. Most specimens presented isthmuses, fins, branching, dividing, and rejoining of root canals at different levels. These ramifications and variations might constitute another factor that makes it much more difficult to reach, clean, disinfect and obturate the apical delta area apart from apical delta itself. It also can be concluded that complex root canals that tend to merge towards apical might present apical delta ramifications.

Vertical extension of the apical delta ramifications presents another difficulty for the preparation and obturation of root canal system. In the present study, the length of apical delta ramifications ranged between 0.19 and 1.92 with the mean value of 0.95 mm. Root canal filling quality is determined according to the homogeneity and vertical extension of filling. A homogenous root filling extending

to 0–2 mm short of the radiological apex is described as adequate.¹⁶ However in the case of a root showing apical delta ramifications which lengths are up to 2 mm, there are multiple root canal areas that may harbor biofilm structure and might not be instrumented or disinfected easily. All ramifications cannot be visualized in conventional periapical radiographs or cone-beam computed tomography due to insufficient resolutions. Therefore, the use of apex locators and 6–8–10 K files are recommended to explore the apical root canal anatomy. Prior to the procedure, clinicians must examine preoperative periapical radiographs with great care and suspect the possibility of apical deltas when the main canal becomes indiscernible at apical third abruptly. None of the apical delta ramifications extended beyond 3 mm in the present study, so it can be concluded that resection of apical 3 mm would eliminate the complete apical delta and related microbial load.

The mean apical major and minor diameters of apical delta ramifications were 0.32 and 0.22 mm, respectively. The apical delta ramifications were mostly straight and their cross sectional shape was variable. The majority of the specimens had non-circular cross sections; even some of them exhibited long oval cross sectional shapes (7.29%), with a ratio of the major diameter to the minor diameter greater than 2. The results of the present study indicate that morphologic features of apical delta ramifications might complicate the debridement of apical root canal system. Further studies are required to test the efficacy of disinfection and preparation techniques to debride apical delta ramifications.

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Conflict of Interest

Authors declared no conflict of interest.

Authorship Contributions

All authors contributed equally to this study.

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