IDR International Dental Research

Original Article

Quantitative analysis of the anatomy of mesial roots of mandibular first molars with Vertucci type I root canal configuration by means of micro-computed tomography

Ali Keleş [1], Cangül Keskin[1]

[1] Ondokuz Mayıs University, Faculty of Dentistry, Department of Endodontics, Samsun, Turkey

Abstract

Aim: This study aimed to evaluate the root canal morphology of Vertucci type I root canal configuration detected in mesial roots of mandibular first molar teeth using micro-computed tomography (Micro-CT).

Methodology: Micro-CT datasets of 269 specimens were evaluated for the detection of specimens with Vertucci type I root canal configuration for further analysis. Major and minor diameter, area, perimeter and roundness of root canal cross-sections at the beginning and midline of each root thirds were measured and recorded. The presence of apical delta, accessory canals, and deviation of major apical foramen from anatomical apex were investigated. Data was analyzed using descriptive analysis, ANOVA-Tukey, and Kruskal-Wallis H-Wilcoxon signed-rank tests.

Results: Vertucci type I canal configuration was present in the 4.46% of the specimens. The specimens often showed accessory root canals (50%) and apical deltas (41,6%). From the visual analysis of the 3D and 2D images, significant differences were detected among coronal, middle and apical thirds of the specimens regarding major and minor diameter, area, perimeter, and roundness ($p<0.05$).

Conclusion: Three- and two-dimensional analyses of mesial roots with Vertucci type I canal configuration indicated that this type of configuration presents large buccolingual diameters with long oval shape and has isthmus at coronal and middle thirds. At the apical third the root canals often terminate in an oval cross-sectional shape.

Keywords: Micro-computed tomography, root canal anatomy, Vertucci, mandibular first molar

Correspondence:

Dr. Cangül KESKİN
Ondokuz Mayıs University, Faculty of Dentistry, Department of Endodontics, Samsun, Turkey

E-mail:cangul.keskin@omu.edu.tr

Received: 25 October 2019
Accepted: 19 March 2020

Access Online

DOI:
10.5577/intdentres.2020.vol10.no1.4

How to cite this article: Keles A, Keskin C. Quantitative analysis of the anatomy of mesial roots of mandibular first molars with Vertucci type I root canal configuration by means of micro-computed tomography. Int Dent Res 2020;10(1):17-21. https://doi.org/10.5577/intdentres.2020.vol10.no1.4

Introduction

A variety of anatomical structures of root canals including the isthmi, fins, canal branching, and dividing at different levels are frequently encountered (1). The anatomy of mesial root canal system has been revealed by different visualization techniques ranging from radiographs taken from different angles to the use of micro-computed tomography (micro-CT) (2). Micro-CT

is an advantageous technique that accurately reveals the anatomical features of root canal configurations (2). This technology provides high-quality images and results in the discovery of new anatomical variations, irregularities, and classification systems (3, 4). Detailed knowledge of these variations is one of the most critical phases of endodontic treatment, which aims to establish disinfection of the whole root canal system (5, 6).

Vertucci type I root canal configuration describes a single root canal continuing from pulp chamber to apex (7). Vertucci type I configuration is commonly seen in the distal roots of mandibular first molar teeth, however, this type of configuration is much less frequent in the mesial roots (8). Incidence of Vertucci type I configuration in the mesial roots of mandibular first molars has been reported to range between 1% and 12% in by various studies that utilized different visualization techniques in different populations (6, 7, 9, 10). A recent CBCT study evaluated the root canal configurations of mesial roots of mandibular molar teeth in Turkish population and reported the frequency of Vertucci type I canals as 3% (11). The present study aimed to make a quantitative evaluation of the mesial root canals of mandibular first molar teeth with Vertucci type I canal configuration.

Materials and Methods

The experimental procedure was independently reviewed by the Malatya clinical researches ethics committee in accordance with the World Medical Association Declaration of Helsinki, with the approval number: 2013/145. The mesial roots of 269 mandibular first molars collected from patients who gave written consent for participation to the study, from Turkish population were scanned on the micro-CT system (SkyScan 1172; Bruker-microCT, Kontich, Belgium), which was operated with the parameters of 100 kV and 100 µA and produced slices with 2000 x 1330 pixel resolution and 10 µm pixel size using an 11 MP camera. The morphology of the specimens was visualized using Data Viewer and CTAn software (v.1.5, Bruker-microCT).

Micro-CT images of 12 specimens with Vertucci type I canal configuration were selected for further analysis. The location and number of accessory root canals were recorded. Accessory canals were defined according to American Association of Endodontists (AAE) Glossary of Endodontic Terms (12). Presence of apical delta according to the criteria set in previous studies was recorded (13, 14). The frequency of accessory root canals and apical deltas were analyzed using frequency analysis. The number of apical foramina was also recorded for each specimen. Deviation of major apical foramen (MAF) from the anatomical root apex were recorded by measuring the vertical distance between the levels of anatomical root apex and termination of root canal as described in a previous study (Fig. 1) (15).

Measurements were performed in seven different levels of the roots. These levels were top of coronal, middle and apical thirds, middle of coronal, middle and apical thirds and the last slice of apical foramen (Fig. 2). Roundness, major and minor diameter, area and perimeter values of axial root canal cross-sections in each measurement points from major apical diameter to the most coronal slice were measured, recorded and compared.

Figure 1. The presence of apical delta was recorded and deviation of major apical foramen from the anatomical root apex was measured as the vertical distance between the levels of anatomical root apex and termination of root canal.

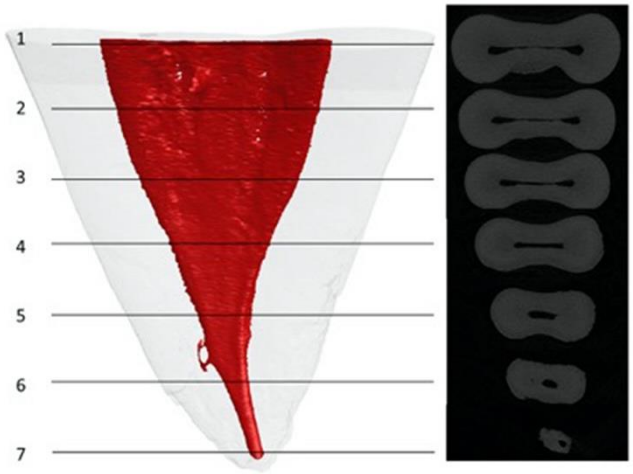

Figure 2. Representative 3D reconstruction of a specimen showing the segmentation of the root canal system: (1) top of coronal, (2) middle of coronal, (3) top of middle, (4) middle of middle, (5) top of apical, (6) middle of apical, (7) apical foramen.

Statistical Analysis

Shapiro-Wilk test, parametric tests were performed for the minor diameter data, whereas non-parametric tests were performed for major diameter, perimeter, roundness and area. Minor diameter changes were analyzed with ANOVA and Tukey tests. Kruskal-Wallis H and Wilcoxon signed-rank tests were used to analyze the differences of major diameter,

perimeter, area and roundness values among the selected levels (SPSS Inc, Chicago, IL, USA).

Results

In a total of 269 specimens 12 of them showed Vertucci type I root canal configuration, which corresponded the 4.46% of the specimens.

Accessory root canals were detected in 6 specimens (50%), which one of them showed 2 accessory root canals whereas the remaining 5 specimens showed a single accessory root canal. The numbers of the specimens showing accessory root canals were 2, 1 and 3 at the coronal, middle and apical third, respectively. One accessory canal was located at the distal aspect of the root, whereas the remaining was located at the mesial aspect of the roots.

Mean value for apical foramen deviation from anatomical apex was 0.48 ± 0.43 mm. The deviation of apical foramen ranged between 0.03 and 1.79 mm. Apical delta was detected in 5 specimens (41.6%) and the mean length of the apical delta ramifications was 1.35 ± 0.45 mm. The number of apical foramen ranged between 1 and 7, while the mean apical foramen number per specimen was 2.3 ± 1.9.

Major and minor diameter values showed a consistent decrease from coronal to middle and apical thirds (Table 1). The changes in the major and minor diameters were statistically significant among the thirds of root canals ($p<0.05$). The root canals showed an oval cross-sectional shape throughout. Roundness values showed a significant increase at the beginning of the apical third ($p<0.05$), however oval cross-sectional shape remained. Area and perimeter values exhibited decrease from coronal to apical with the lowest values were detected at the foramen apicale levels.

Table 1. Descriptive statistics for major diameter (mm), minor diameter (mm), roundness, area (mm^2) and perimeter (mm) of Vertucci type I root canals at selected levels

	Major diameter	Minor diameter	Roundness	Area	Perimeter
Top of the coronal third	3.82 ± 0.74^{a}	0.59 ± 0.11^{a}	0.10 ± 0.04^{a}	1.16 ± 0.43^{a}	12.01 ± 2.35^{a}
Middle of the coronal third	3.64 ± 0.76^{a}	$0.51 \pm 0.12^{a,b}$	0.10 ± 0.04^{a}	$0.98 \pm 0.43^{a,b}$	10.56 ± 1.73^{a}
Top of the middle third	2.88 ± 0.77^{b}	$0.48 \pm 0.10^{a,b,c}$	0.13 ± 0.06^{a}	$0.85 \pm 0.38^{a,b}$	$8,47 \pm 1.51^{b}$
Middle of the middle third	2.22 ± 0.53^{b}	$0.43 \pm 0.10^{b,c}$	$0.19 \pm 0.09^{a,b}$	$0.66 \pm 0.22^{b,c}$	$6,34 \pm 1.41^{c}$
Top of the apical third	1.44 ± 0.47^{c}	$0.43 \pm 0.09^{b,c}$	$0.31 \pm 0.14^{b,c}$	$0.43 \pm 0.15^{c,d}$	$4,10 \pm 1.13^{d}$
Middle of the apical third	$0.98 \pm 0.42^{c,d}$	$0.38 \pm 0.09^{c,d}$	0.40 ± 0.16^{c}	0.26 ± 0.11^{d}	$2,74 \pm 1.00^{d,e}$
Apical foramen level	0.45 ± 0.21^{d}	0.27 ± 0.10^{d}	0.56 ± 0.16^{d}	0.10 ± 0.08^{d}	$1,32 \pm 0,63^{e}$

* Different superscript letters in the same column indicate statistically significant difference ($p<0.05$).

Discussion

Mesial roots of mandibular first molars were reported to exhibit mostly Vertucci type VI and II configurations (8), which have been extensively studied using micro-CT regarding their anatomical features and treatment considerations (4, 16-18). Vertucci type I canal configuration is the most frequent configuration in the distal roots of the mandibular first molars, however it has been regarded as a less common configuration in the mesial roots.

The most important region has been considered as the apical part from therapeutical aspects (19). The deviations of major foramina from anatomical apices were reported to range between 0.2 and 3.0 mm depending on tooth type and patient age (7, 20). In the present study, the mean value for deviation of major apical foramen from anatomical apex was 0.48 ± 0.43 mm extending a maximum value of 1.79 mm, which was within the limits previously

reported in the literature. Root canal ramifications such as accessory canals and apical deltas are formed following an interruption of the epithelial root sheath development, giving rise to a canal containing fine blood supply and nerves (21). These ramifications, which are difficult to clean, disinfect and, obturate, are also clinically important because they might be necrotic and/or harbor bacterial biofilms (21). In the present study, 6 specimens (50%) exhibited accessory root canals whereas 5 specimens (41,6%) showed apical delta formation. The presence of these ramifications might further complicate the disinfection and, obturation in addition to presence of enlarged buccolingual dimensions of main root canal.

Root canal configuration has been reported to be influenced by age and ethnicity of the patient. In the present study examined specimens were collected from Turkish population. A previous CBCT study examined 966 mandibular first molars in Turkish population and reported the frequency of a single canal as 3% (11). In this study 12 specimens were analyzed with micro-CT to evaluate the frequency of Vertucci type I configuration among 269 specimens, which corresponded 4.46%. Micro-CT also enabled to make quantitative analyses of axial sections at each millimeter.

The buccolingual diameter of axial cross-sections at measurement points showed a constant increase from apical to coronal, whereas the cross-sectional shape changes from oval to long oval. The major diameter values showed significant decreases among the beginning of apical, middle and coronal thirds (Table 1). At the foramen apicale level, the major diameter ranged between 0.23 mm and 0.98 mm with the mean value of 0.45 ± 0.21 mm. Minor diameter values at this level ranged between 0.15 mm and 0.47 mm with the mean value of 0.27 ± 0.10 mm. Maximum values of buccolingual and mesiodistal diameters at the foramen apicale levels might present difficulties in the effective shaping and filling procedures. A root canal preparation instrument with ISO #40 apical size would be insufficient to clean such mesial root canal showing Vertucci type I canal configuration. On the other hand, any further enlargement could lead to complications such as strip perforation of thin mesial roots or root fracture. This incompatibility between instrumental design and anatomy might make difficult effective disinfection, cleaning, and three-dimensional filling of Vertucci type I canal systems.

A previous study showed a similar enlarged apical diameters for the mesial root canals showing Vertucci type II configuration (16). The similarity between the apical sizes of Vertucci type II and I could be attributed to the hypothesis of Hess, that claimed roots belonged to younger individuals show a single large canal, which differentiate due to the dentinal vertical partitions caused by secondary dentin accumulation with age (22). Peiris et al also reported mesial roots of mandibular first molars have mostly a single large canal until the first decade and root canal configurations were completely defined at third and fourth decades (23). However, the patient ages were unknown during specimen collection.

Conclusions

Vertucci type I canal configuration could occur in 4.46% of the mesial roots of mandibular first molars in the examined population and this type of configuration presents long oval cross-sectional shapes and long buccolingual diameters accompanied by the presence of an isthmus at the coronal and middle thirds, which might complicate biomechanical preparation and three-dimensional obturation of root canal systems.

Ethical Approval: Ethics committee approval was received for this study from Malatya Clinical Researches Ethics Committee in accordance the World Medical Association Declaration of Helsinki, with the approval number: 2013/145.

Peer-review: Externally peer-reviewed.

Author Contributions: Conception – A.K., C.K.; Design – A.K., C.K.; Supervision – A.K.; Materials – C.K.; Data Collection and/or Processing – A.K., C.K.; Analysis and/or Interpretation – A.K.; Literature Review – A.K., C.K.; Writer – A.K., C.K.; Critical Review – A.K.

Conflict of Interest: No conflict of interest was declared by the authors.

Financial Disclosure: This study was funded by the Scientific and Technological Research Council of Turkey-TUBITAK (grant no. 114S002).

References

1. Villas-Bôas MH, Bernardineli N, Cavenago BC, Marciano M, del Carpio-Perochena A, de Moraes IG, et al. Micro-computed tomography study of the internal anatomy of mesial root canals of mandibular molars. J Endod 2011;37:1682-6. (Crossref)
2. Ordinola-Zapata R, Bramante C, Versiani M, Moldauer B, Topham G, Gutmann J, Nunez A, Hungaro Duarte MA, Abella F. Comparative accuracy of the Clearing Technique, CBCT and Micro-CT methods in studying the mesial root canal configuration of mandibular first molars. Int Endod J 2017;50:90-6. (Crossref)
3. Ahmed H, Versiani M, De-Deus G, Dummer P. A new system for classifying root and root canal morphology. Int Endod J 2017;50:760-7. (Crossref)
4. Keleş A, Keskin C. A micro-computed tomographic study of band-shaped root canal isthmuses, having their floor in the apical third of mesial roots of mandibular first molars. Int Endod J 2018;51:240-6. (Crossref)
5. Erpaçal B, Adıgüzel Ö, Cangül S. The use of micro-computed tomography in dental applications. Int Dent Res 2019;9(2):78-91. (Crossref)
6. Vertucci FJ. Root canal morphology and its relationship to endodontic procedures. Endod Topics 2005;10:3-29. (Crossref)
7. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol 1984;58:589-99. (Crossref)
8. de Pablo ÓV, Estevez R, Sánchez MP, Heilborn C, Cohenca N. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod 2010;36:1919-31. (Crossref)

9. Ahmed H, Abu-bakr N, Yahia N, Ibrahim Y. Root and canal morphology of permanent mandibular molars in a Sudanese population. Int Endod J 2007;40:766-71. (Crossref)
10. Al-Qudah A, Awawdeh L. Root and canal morphology of mandibular first and second molar teeth in a Jordanian population. Int Endod J 2009;42:775-84. (Crossref)
11. Nur BG, Ok E, Altunsoy M, Aglarci OS, Colak M, Gungor E. Evaluation of the root and canal morphology of mandibular permanent molars in a south-eastern Turkish population using cone-beam computed tomography. Eur J Dent 2014;8:154-9. (Crossref)
12. American Association of Endodontists Glossary of Endodontic Terms.http://ntxbook.com/ntxbooks/aae/endodonticglossary 2016/ Accessed in 2018.
13. Verma P, Love R. A Micro CT study of the mesiobuccal root canal morphology of the maxillary first molar tooth. Int Endod J 2011;44:210-7. (Crossref)
14. Liu N, Li X, Liu N, Ye L, An J, Nie X, Liu L, Deng M. A micro-computed tomography study of the root canal morphology of the mandibular first premolar in a population from southwestern China. Clin Oral Invest 2013;17:999-1007. (Crossref)
15. Versiani MA, Ahmed HMA, Sousa-Neto MD, De-Deus G, Dummer PMH. Unusual deviation of the main foramen from the root apex. Braz Dent J 2016;27:589-91. (Crossref)
16. Keleş A, Keskin C. Apical root canal morphology of mesial roots of mandibular first molar teeth with Vertucci Type II configuration by means of micro-computed tomography. J Endod 2017;43:481-5. (Crossref)
17. Paqué F, Laib A, Gautschi H, Zehnder M. Hard-tissue debris accumulation analysis by high-resolution computed tomography scans. J Endod 2009;35:1044-7. (Crossref)
18. Keleş A, Alçin H, Sousa-Neto MD, Versiani MA. Supplementary steps for removing hard tissue debris from isthmus-containing canal systems. J Endod 2016;42:1677-82. (Crossref)
19. Ricucci D, Siqueira JF. Biofilms and apical periodontitis: study of prevalence and association with clinical and histopathologic findings. J Endod 2010;36:1277-88. (Crossref)
20. Dummer PM, McGinn J, Rees DG. The position and topography of the apical canal constriction and apical foramen. Int Endod J 1984;17:192-8. (Crossref)
21. Ricucci D, Siqueira JF. Fate of the tissue in lateral canals and apical ramifications in response to pathologic conditions and treatment procedures. J Endod 2010;36:1-15. (Crossref)
22. Hess W. The anatomy of the root-canals of the teeth of the permanent dentition. J. Bale, Sons & Danielsson, ltd.; 1925.
23. Peiris H, Pitakotuwage T, Takahashi M, Sasaki K, Kanazawa E. Root canal morphology of mandibular permanent molars at different ages. Int Endod J 2008;41:828-35. (Crossref)