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CONGRESS PROCEEDING

Micro-CT Analysis of the Root Canal Configuration of Maxillary Second Molars with Fusion

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Abstract

Purpose: The present study investigated the root canal configuration of maxillary second molars with root fusion using micro-computed tomography (micro-CT).
Materials & Methods: A total of 136 fused maxillary second molars were scanned with micro-computed tomography. Images were transferred to CTAn v.1.18.8 software (Bruker-microCT) to obtain three-dimensional models. The specimens were classified according to the fusion type. According to Vertucci, classification of the root canal configuration of fused roots was determined using CTVol v. 2.3.2.0 (Bruker-microCT) and DataViewer v.1.5.6 (Bruker-microCT) softwares. The specimens that could not be represented were also specified. The frequency of canal configuration according to the fusion type was calculated.
Results: For Type 1 fusion (n=40) and Type 2 fusion (n=22), the most common canal configuration for mesiobuccal (MB), distobuccal (DB) and palatal (P) canals was Type I. In type 3 fusion specimens (n = 21), DB and P canals were completely fused in 1 sample in accordance with Vertucci type IV, while in the remaining specimens, types II, I, V, VI and IV were observed in decreasing order in the MB canal. In type 4 fusion, MB and DB canals were completely fused in 4 of 21 specimens and showed Vertucci type VI, II, I and III configurations. In the remaining 17 samples, MB had Vertucci type I, II, IV, V, VI, VII configurations, while DB showed type I, V and III configurations. In 7 samples with type 5 fusion all canals displayed different configurations. In type 6 fusion, the canal configurations of 6 samples could not be classified. Type II, I, and V configurations were seen in 9 of the remaining 19 samples with a single canal.
Conclusion: Vertucci type I was the dominant canal configuration in the P and DB, however, MB showed much more diverse configurations either independently or when included in fusion. area and pulp volume to increase the accuracy of age estimation in adult Turkish individuals.

Key words: Canal configuration; root canal anatomy; Vertucci classification

Introduction

Root fusion, which occurs either by cement deposition between roots or an anomaly in the Hertwig root sheath development, could affect maxillary and mandibular molars.[1] Partial or total root fusion of maxillary molars has been reported in different forms from fusion of buccal roots to the complete fusion of all 3 roots presenting a conical-shaped single root.[1,2] The root fusions were initially investigated from periodontal or surgical perspectives, however with the development of cone beam computed tomography (CBCT) and micro-computed tomography (micro-CT) for the visualisation of root canal anatomy the subject has been much more relevant for endodontics.[2–7] Micro-CT has been utilised as the gold standard method for ex vivo evaluation of root canal anatomy with accurate and detailed information regarding fine anatomical elements of root canal system.[8] Classification of different fusion types into 6 groups was developed by means of this technology.[1] It was also revealed that fused roots commonly have complicated anatomy with apical deltas, isthmuses and C-shaped canal configurations by a recent micro-CT study.[2] Previous studies revealed different incidence of root fusion in different populations varying between 9% and 58% and also reported rare fusion types that did not fit the classification.[4–7] The present micro-CT study aimed to evaluate root canal configurations of fused maxillary second molars in terms of different types of fusion according to Vertucci and Gulabivala classifications.[9,10]

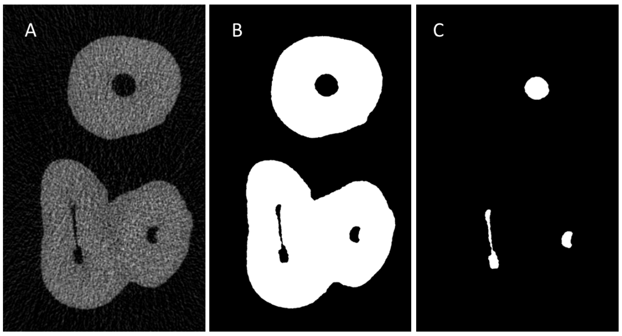

Figure 1. A: Axial cross-sections obtained by the reconstruction process after scanning **B:** Dentin with image processing **C:** Obtaining the root canal space with image processing.

Figure 2. Three-dimensional models of representative specimens with type 5 fusion **A:** showing an unusual connection between distobuccal and second mesiobuccal canals. **B:** A specimen with type 1 fusion showed Vertucci type III configuration with an abrupt apical curvature. **C:** This specimen has multiple orifices and very complex radicular anatomy.

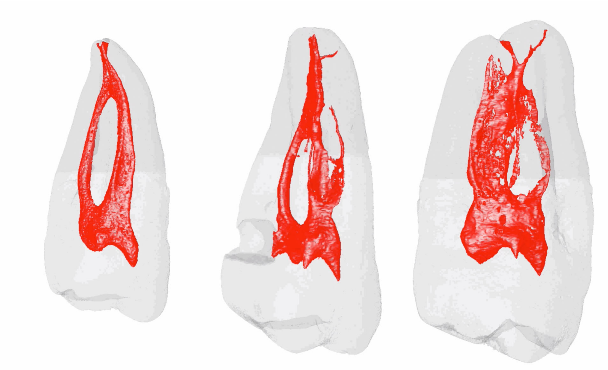

Figure 3. Representative three-dimensional models of specimens that could not be classified either Vertucci or Gulabivala classifications, show connections between roots, loop accessory canals, C-shaped cross sections and apical ramifications.

Methods

The study protocol was reviewed by local university ethical board with the approval number KAEK-2017-234. A total of 136 extracted fused maxillary second molar teeth with mature roots free of fractures, or deep caries extending to root dentine, were selected from Turkish subpopulation and stored at 37°C with 100% humidity. Samples were selected and classified as showing root fusion according to the distance between cementoenamel junction (CEJ) and the most coronal point of root furcation (if there were any) being more than 70% of the distance between anatomical apex and CEJ. The measurements were performed with digital calliper. The gender and age information of the patients were unavailable. The specimens were classified according to the fusion types as described by Zhang et al. as follows.[1] Type 1: MB root fused with distobuccal (DB) root, Type 2: MB root fused with palatal (P) root, Type 3: DB root fused with P root, Type 4: MB root fused with DB and P root fused with MB or DB, Type 5: P root fused with MB and DB roots, Type 6: MB, DB and P roots fused into a conical-shaped root. The teeth were scanned on a micro-CT device (SkyScan 1172, Bruker-microCT, Kontich, Belgium) at 9 µm (pixel size), 100 kV, 100 µA, 180° rotation range and 0.6° step, camera exposure time of 2200 ms and frame average of 1 with aluminium copper filters.[11] Data reconstruction was performed by NRecon v.1.10.6. software (Bruker-microCT) with a beam hardening correction of 65% resulting the images of the dentin and canal system space Figure 1. After the reconstruction, approximately 1300 two-dimensional axial cross-sectional images of each sample were obtained at 0.01 mm intervals. Images were transferred to CTAn software in order to obtain three-dimensional models. In CTVol (Bruker-microCT) software, dentin was made translucent and after the root canals were coloured, root canal configuration was evaluated visually. Canal configurations were classified according to Vertucci and Gulabivala et al. classification systems[9,10], and specimens that could not be represented with these systems were also specified. The data was analysed with frequency analysis using Excel (Microsoft Corporation, Redmond, WA, USA).

Results

A total of 136 specimens were evaluated. The distribution of the root canal configuration according to the fusion type was presented in Table 1. For Type 1 fusion (n=40), the most common canal configuration for mesiobuccal (MB), distobuccal (DB) and palatal (P) canals was Type I. In 9 specimens buccal (B) canal was detected with Vertucci I, II, III and V anatomy Figure 2. In specimens with Type 2 fusion (n=22), 2 specimens had fused MB-P canals with Vertucci type II and V configurations. Remaining specimens had majority of Type I configuration in MB, DB, and P canals. In type 3 fusion specimens (n = 21), DB and P canals were completely fused in 1 sample in accordance with Vertucci type IV, while in the remaining specimens, types II, I, V, VI and IV were observed in decreasing order in the MB canal. One MB canal had Gulabivala type 9 configuration. DB and P canals all showed type I configuration. In type 4 fusion, MB and DB canals were completely fused in 4 of 21 specimens and showed Vertucci type VI, II, I and III configurations. In the remaining 17 samples, MB had Vertucci type I, II, IV, V, VI, VII configurations, while DB showed type I, V and III configurations. Type I was seen in all of the P canals. In 7 samples with type 5 fusion, one of the B canals formed as a result of fusion showed Type III and the other type VII configuration. Types I, II, IV, V and VII were seen in MB canals, all of which can be seen in a single specimen. In the DB canals, 4 specimens were type I, 1 specimen was type II, while type I was detected in all P canals. In type 6 fusion, the canal configurations of 6 samples could not be classified. Vertucci type II, I, and V configurations were seen in 9 of the remaining 19 samples with a single canal. Type II, V and VI were detected in MB; while Type I was seen in all of the DB and P canals. Types II, V, VI and I were seen in specimens with a B canal. Figure 3 displays the three-dimensional models of representative non-classified specimens.

Discussion

Comprehensive knowledge of root canal anatomy and associated anatomical variations is one of the most important factors for a successful root canal treatment.[10] For the Turkish population, several studies concerned with evaluating root canal morphology in different teeth have been carried out but only one study have evaluated molars with fusion using cone-beam computed tomography.[12] In

Table 1. Correlation between chronological age and the CBCT image measurement ratios according to Kvaal's method

Values	Maxillary central incisor tooth	Maxillary canine tooth
	Correlation coefficient (r)	Correlation coefficient (r)
M	-0.173	-0.217*
W	-0.126	-0.342**
L	0.154	0.175
P	0.035	0.082
R	0.242*	0.250*
A	-0.209*	-0.119
B	-0.088	-0.292**
C	-0.253	-0.298**
W-L	-0.152	-0.397**

P: pulp/root length ratio; R: pulp/tooth length ratio; A: ratio between width of pulp and root at cementoenamel junction; B: ratio between width of pulp and root at midpoint between levels C and A; C: ratio between width of pulp and root at mid-root level; W: mean value of width ratios from levels B and C; L: mean value of the length ratios P and R; M: mean value of all ratios.
* Correlation is significant at the 0.05 level.
** Correlation is significant at the 0.01 level.

maxillary second molars incidence of root fusion has been reported as 23.% in a recent CBCT study.[12] Clinically, the presence of root fusion in almost 1 out of every 4 teeth has also attributed importance in terms of canal configuration of this anatomical variation. Root canal morphology reports have been considered to be influenced by the evaluation technique, sample size, patient age and the population groups. No study has investigated root canal configuration of fused molars using micro-CT therefore, this study has aimed to examine root canal configuration of different fusion types using micro-CT. This study evaluated a total of 136 maxillary second molars including each fusion type 1 (n=40), 2 (n=22), 3 (n=21), 4 (n=21), 5 (n=7), and 6 (n=25) with the given sample distribution. Unfortunately, no information was available regarding the age and gender of the patients. In the present study Type 1 and 2 fusions have dominance of Vertucci type I configuration in DB, P, and MB canals, although less than half of the MB canals showed a variety of configurations as type V, II, IV, VI, VII. In type 2 fusions, totally fused canals of MB and P results in type II and V configurations in 2 specimens. Similarly, in type 3 fusion, total fusion of DB and P canals result in a type IV configuration. MB canals in type 3 fusion, which are independent showed a variety of configurations as type I, II, V, VI and VI in decreasing order. One specimen showed a configuration that could not be classified, with three orifices merging and terminating with a single apical foramen. In all specimens DB and P canals showed Type I canal configuration. Type 4 fusion also showed a variable configuration in non-merging MB canals and MB-DB fused canals such as type I, V, IV, II, III, VII and non-classified types. Type 5 fusion had a small sample size but all specimens showed different configuration types from themselves, which all could be classified by Vertucci. Type 6 fusion had the highest number of unclassified specimens and buccal root canal system. The high number of Vertucci type I configuration demonstrates the consistency of this study with the recent CBCT study conducted in Turkish population also. However, the present study was able show a greater variety in canal configuration types in the remaining specimens. That recent CBCT study categorized fused roots as having merging or non-merging canals, which both groups had MB canals with mainly Type I fusion followed by Type II.[12] In the present study, micro-CT examination revealed that merging canals and MB canals showed a greater variability in terms of root canal configurations. This study revealed that the mesiobuccal root is the most versatile root in the types of canal configuration that exist, which adding to the complexity of the root canal system. The differences between the results of the studies can be attributed to differences in the technique used (CBCT vs. micro-CT) or number of sample size. CBCT has been reported to underdiagnose fine structures of root canal system as shown in a previous study comparing CBCT with micro-CT in terms of their ability to represent actual canal anatomy.[13] Vertucci type I is the dominant canal configuration of the canal in the palatal and distobuccal roots irrespective of the fusion type. In several specimens, distobuccal canal system showed two canals when the distobuccal root was included in fusion.

Conclusion

The findings of the study reflect the high probability of encountering multiple canals in mesiobuccal roots and between fused roots during root canal treatment of the of the maxillary second fused molars.

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Author Contributions

Concept: C.K., A.K., Design: C.K., A.K., O.S.O. Data Collection or Processing: C.K., A.K., O.S.O., Analysis or Interpretation: C.K., Literature Search: C.K., A.K., O.S.O., Writing: C.K., A.K., O.S.O.

Conflict of Interest

Authors declare that they have no conflict of interest.

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