



ORIGINAL ARTICLE

Three-dimensional evaluation of root canal morphology of maxillary first premolars: Micro-computed tomographic study



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Received 3 March 2022; revised 13 July 2022; accepted 25 July 2022

Available online 29 July 2022

KEYWORDS

External morphology;
Furcation groove;
Maxillary first premolars;
Micro-computed tomography;
Root canal configuration

Abstract *Aim:* The aim of this *in vitro* study was to investigate the root and root canal morphology of maxillary first premolar teeth in a Kuwaiti population using micro-computed tomography (μ -CT).

Materials and methods: A total of 100 maxillary first premolars were scanned in a micro-computed tomographic device. The external anatomy (number of roots, distance from cemento-enamel junction to apex, and presence of a palatal groove) and internal anatomy (number of canals and presence of apical deltas, lateral canals, and isthmi) of teeth were analyzed using descriptive analysis.

Results: The number of roots was one root (57%), two roots (41%), and three roots (2%). The longest and shortest roots measured 17.7 and 11.2 mm, respectively. The palatal groove was present in 63.4% of the teeth. According to Vertucci's classification, type IV configuration was the most

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prevalent (53 %), followed by type II. A new root canal configuration type (1–2–1–2–1) was detected. Apical deltas, lateral canals, and isthmi were present in 33 %, 48 %, and 21 % of teeth, respectively.

Conclusion: Type IV canal configuration was the most common root canal configuration. A new root canal configuration type IX for (1–2–1–2–1) was proposed for Kuwaiti population. The μ -CT device could be a better diagnostic tool for understanding the anatomy of the root canal system.

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1. Introduction

A deep awareness of external and internal root canal morphology of human teeth and its variations is an extremely important for success root canal treatment. Failure to do and treat the whole root canal system might lead to no healing and post-treatment diseases (Vertucci, 2005, Cantatore et al., 2006). Thus, the dental practitioners should be intimate with root canal system morphology of different human teeth type to improve the outcome of the clinical cases (Friedman, 2002).

The maxillary first premolars typically have two roots and 2 root canals. In addition, these teeth may have three roots and three canals which were reported to be a rare variations (Ahmad and Alenezi, 2016). In fact, variations in root and root canal morphology may be attributed to a number of factors including ethnic background, gender and age of the study population, and the evaluation technique (Carns and Skidmore, 1973, Green, 1973, Vertucci, 1984, Pécora et al., 1991, Çalişkan et al., 1995, Zaatar et al., 1997, Kartal et al., 1998, Sert and Bayirli, 2004, Awawdeh et al., 2008, Cheng and Weng, 2008, Weng et al., 2009, Al-Nazhan et al., 2012, Tian et al., 2012, Elkady and Allouba, 2013, Abella et al., 2015, Dashrath et al., 2015, Wolf et al., 2020).

The state of Kuwait is located within the Middle East region and the population of Kuwait is approximately of 1.4 million. Up to date, only one published clinical study investigated the morphology of maxillary first premolars in the Kuwaiti population using a conventional radiographic technique (Zaatar et al., 1997). The aim of this *in vitro* study was to investigate the root and root canal morphology of maxillary first premolar teeth in a Kuwaiti population using micro-computed tomography (μ -CT).

2. Materials and methods

The approval of this study was obtained by the Ethics and Scientific Research Committee, IRB approval number (FPGRP/43433001/94). The sample size was determined using non-probability consecutive sampling technique “World Health Organization sample size calculator” with 95 % confidence interval (Lwanga and Lemeshow, 1991). One hundred (100) extracted maxillary first premolars were collected from various governorates dental clinics in within State of Kuwait. All teeth were washed with faucet water after extraction and were stored in a 10 % formalin solution until use. Teeth sample included in the study had intact clinical crowns and matured apices with no signs of attrition, erosion, fracture or root canal filling of Kuwaiti citizen. The gender, age and reasons for extraction were unavailable. All teeth were carefully cleaned of any adherent soft and hard tissues by using ultrasonic scaler. The samples were

washed under running tap water and were dried. Then, the external and internal anatomy of these teeth was examined by high spiral scan micro-CT scanner (Bruker SkyScan 1173, Kon-tich, Belgium) and the following evaluated:

2.1. External root morphology

- Number of roots.
- Presence of palatal grooves on buccal roots.
- Root lengths (from cemento-enamel junction to root tip)

2.2. Internal root canal morphology

- Total number of root canals per tooth.
- The root canal configuration in each tooth according to Vertucci's classification (Vertucci, 1984).
- Presence of Lateral canals, isthmi and apical deltas.

The following parameters were used for scanning: 73 kV tube voltage, 66 μ A current, Al 1.0 mm filter, 375 ms exposure time, 0.3 rotation step, 360 degree rotation step, and a frame averaging set at 4.

2.3. Reconstruction

The 3-dimensional reconstruction was carried out by —Insta Recon|| Software, Bruker SkyScan. 57 % Ring Artifact Correction and Beam Hardening Effect Reduction = 7 was set to produce the clear-cut image cross section.

2.4. Analysis

A transaxial Data Set was created and saved from the Data Viewer Software (Bruker SkyScan) to be the basis for initiating the Region of Interest. For the determination and measurement of Specified Anatomical Distances, the analysis was performed with the Data Viewer Software. The data set was loaded for 3D viewing, whereby the anatomical landmarks were established to determine particular distances by manipulating X, Y, Z axes and recording them accordingly. For the determination of the Root Dentin Volume, the analysis was performed with the CT Analysis Software (Bruker SkyScan).

2.5. 3D visualizations

Images were done using SkyScan CT-volume TM (CT-Vol) software as well as snap shop images to show the relevant points of interest for the research project.

2.6. Statistical analysis

Descriptive data of the anatomical root features were presented as frequencies and cumulative percentages.

3. Results

3.1. External root morphology

Among the 100 examined maxillary first premolars, 57 (57 %) had one root, 41 (41 %) had two separated roots and 2 (2 %) had three separated roots. developmental groove that located on the palatal aspect of the buccal root was detected in 26 (63.4 %) samples out of 41 of the bifurcated roots (Fig. 1). The root length of the samples was measured from cementoenamel junction to the root apex. The longest root was measured at 17.7 mm while 11.2 mm was the shortest.

3.2. Internal root canal morphology

Overall, 9 % of the samples had one root canal and 87 % had two canals, whereas the remaining 4 % was classified as having three root canals (Table 1). Type IV configuration was the most prevalent (53 %) followed by type II, VI, I, V, III, VIII and VII. In two samples of two-rooted teeth, one canal was observed in the palatal root, whilst the buccal root had two canals (Table 2). One single-rooted tooth showed (1–2–1–2–1) canal configuration (Fig. 2). An apical deltas, lateral canals and isthmi were found out in 33 %, 48 %, and 21 % of all cases, respectively (Fig. 3).

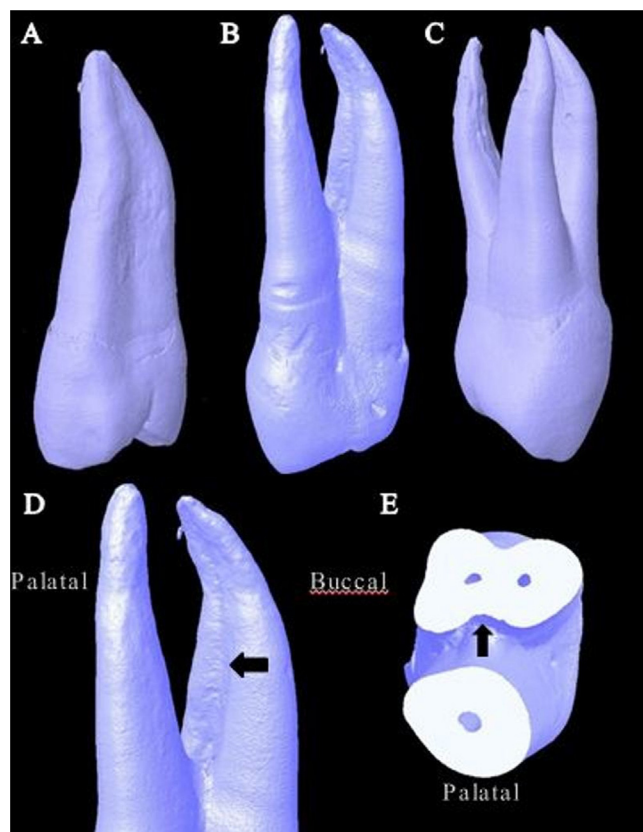


Fig. 1 External root morphology of maxillary first premolars. (A) Single root. (B) Two roots. (C) Three-separated roots (2 buccals).

4. Discussion

The maxillary first premolars were considered the most difficult teeth type to be treated endodontically due to their extremely complex morphological structure (Pécora et al., 1991, Kartal et al., 1998). Also, the previously reported study of Zaatar et al. (1997) had two major limitations: Only 79 maxillary first premolar teeth of Kuwaiti patients were included and the morphology was assessed using the conventional two-dimensional radiographic technique. The present study attempted to overcome these limitations using the μ -CT technique which allows three-dimensional evaluation of the teeth.

This technology (μ -CT) is more accurate diagnostic tool compared with other radiographic techniques without the need of preparation, sectioning or destruction of the specimens (Rhodes et al., 1999, Peters et al., 2000, Versiani et al., 2012). Few studies investigated the morphology of maxillary first premolars by means of μ -CT (Liu et al., 2019, Wolf et al., 2020) in Chinese and Swiss-German population.

The age and gender of the patients were unavailable in the present study. In fact, most morphologic studies on human maxillary premolars did not report a significant differences to age groups (Vertucci, 1984, Zaatar et al., 1997, Awawdeh et al., 2008, Tian et al., 2012, Elkady and Allouba, 2013, Wolf et al., 2020). This variation requires more clinical study of the root and root canal anatomy.

The number of roots in the maxillary first premolars showed a wide variation in different population. In the current study, it was found that 57 % of maxillary first premolars had a single root. This finding was higher than other studies (Vertucci, 1984, Zaatar et al., 1997, Awawdeh et al., 2008, Abella et al., 2015, Wolf et al., 2020) and lower than the study of Liu et al. (2019). On other hand, the percentage of two-rooted maxillary first premolars in this study was 41 %, which showed a slightly lower percentage than studies conducted in Middle East, Europe and China (Zaatar et al., 1997, Kartal et al., 1998, Awawdeh et al., 2008, Abella et al., 2015, Wolf et al., 2020). Only two teeth were found in this study with three separated roots (2 %) that is rare variant in this tooth type. These differences are related to ethnicity.

An important external anatomic landmark feature of these teeth “furcation groove or developmental depression” was found on palatal surface of buccal root of two-rooted maxillary first premolars. The prevalence of this unique groove was reported to range between 62 % and 100 % of teeth with bifurcated roots (Gher and Vernino, 1980, Joseph et al., 1996, Tamse et al., 2000, Awawdeh et al., 2008, Li et al., 2013). In this *in vitro* current study, the furcation groove was detected in 63.4 % (26 out of 41) of the buccal roots of two-rooted maxillary first premolars. However, the presence of the developmental depression has most important clinical implication during different dental procedures. In addition, the average dentin width was very thin (0.81 mm) (Tamse et al., 2000). In this regarding, care should be taken into account during root canal preparation to avoid procedural accidents.

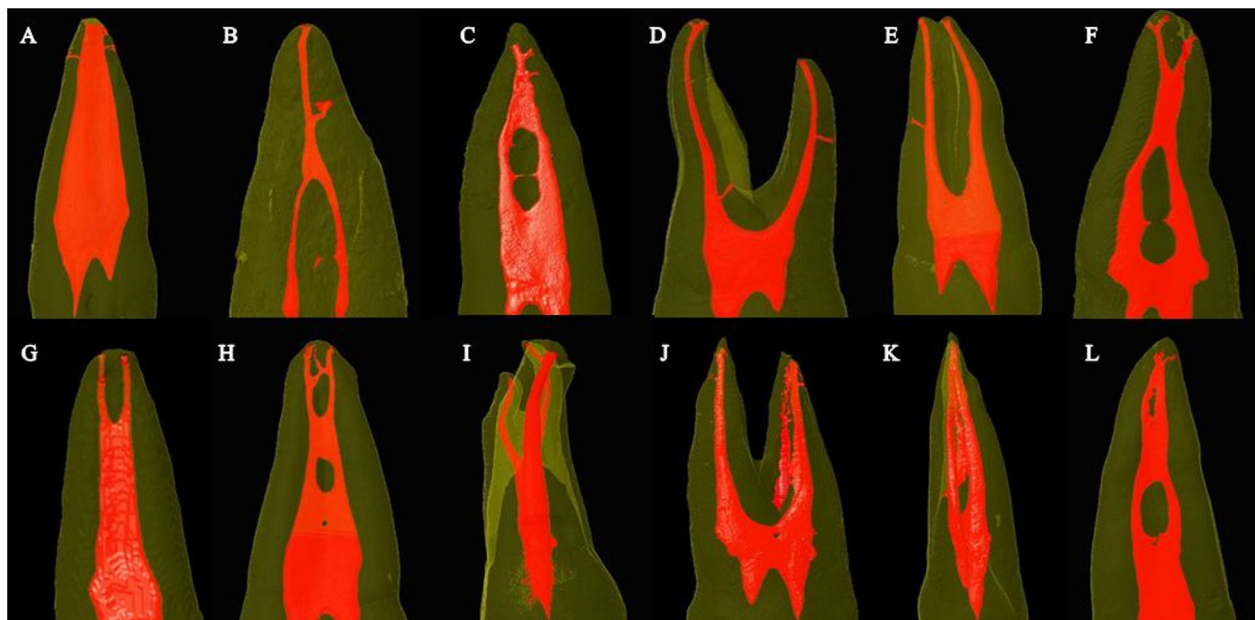
The number of root canals of the studied samples was similar to previous findings (Zaatar et al., 1997, Sert and Bayirli, 2004, Tian et al., 2012). Type IV configuration was the most prevalent followed by type II and I. However, regardless of the total number of roots, the predominance of maxillary first

Table 1 Total number of root canals per tooth.

	One root (%)	Two roots (%)	Three roots (%)	Total (%)
One canal (%)	9 (9.0)	0 (0.0)	0 (0.0)	9 (9.0)
Two canals (%)	48 (48.0)	39 (39.0)	0 (0.0)	87 (87.0)
Three canals (%)	0 (0.0)	2 (2.0)	2 (2.0)	4 (4.0)
Total (%)	57 (57.0)	41 (41.0)	2 (2.0)	100 (100.0)

Table 2 The root canal configuration in each tooth according to Vertucci's classification.

	One root (%)	Two roots (%)	Three roots (%)	Total (%)
Type I (%)	9 (9.0)	0 (0.0)	0 (0.0)	9 (9.0)
Type II (%)	11 (11.0)	0 (0.0)	0 (0.0)	11 (11.0)
Type III (%)	5 (5.0)	0 (0.0)	0 (0.0)	5 (5.0)
Type IV (%)	14 (14.0)	39 (39.0)	0 (0.0)	53 (53.0)
Type V (%)	5 (5.0)	0 (0.0)	0 (0.0)	5 (5.0)
Type VI (%)	11 (11.0)	0 (0.0)	0 (0.0)	11 (11.0)
Type VII (%)	1 (1.0)	0 (0.0)	0 (0.0)	1 (1.0)
Type VIII (%)	0 (0.0)	2 (2.0)	2 (2.0)	4 (4.0)
Additional canal configuration (%)	1 (1.0)	0 (0.0)	0 (0.0)	1 (1.0)
Total (%)	57 (57.0)	41 (41.0)	2 (2.0)	100 (100.0)

**Fig. 2** Internal root canal configurations of maxillary first premolar teeth according to Vertucci's classification. (A) Type I. (B) Type II. (C) Type III. (D) Two separated roots.

premolars had 2 separate canals and had 2 separate foramina at the root apex. Moreover, one additional type of root canal configuration was found in this study (1-2-1-2-1). This canal type (1-2-1-2-1) was only reported in a mandibular incisors of Brazilian population that was evaluated by μ -CT (Leoni et al., 2014). A root canal configuration type IX for (1-2-1-2-1) of maxillary first premolar teeth was proposed for Kuwaiti population.

The presence of lateral canals, isthmi or intercanal communications and apical deltas of the present study were higher

than previous studies (Çalışkan et al., 1995, Kartal et al., 1998, Sert and Bayirli, 2004, Awawdeh et al., 2008). These fine anatomical details inside the main root canal might interfere with the outcome of root canal therapy due to difficulties to reach it during cleaning and shaping as well as filling of the root canal system (Sjögren et al., 1990). However, differences between this study and other morphologic studies might be related to the difference of examination technique, classification systems, patient's age, gender, ethnic background, and sample size of the teeth.

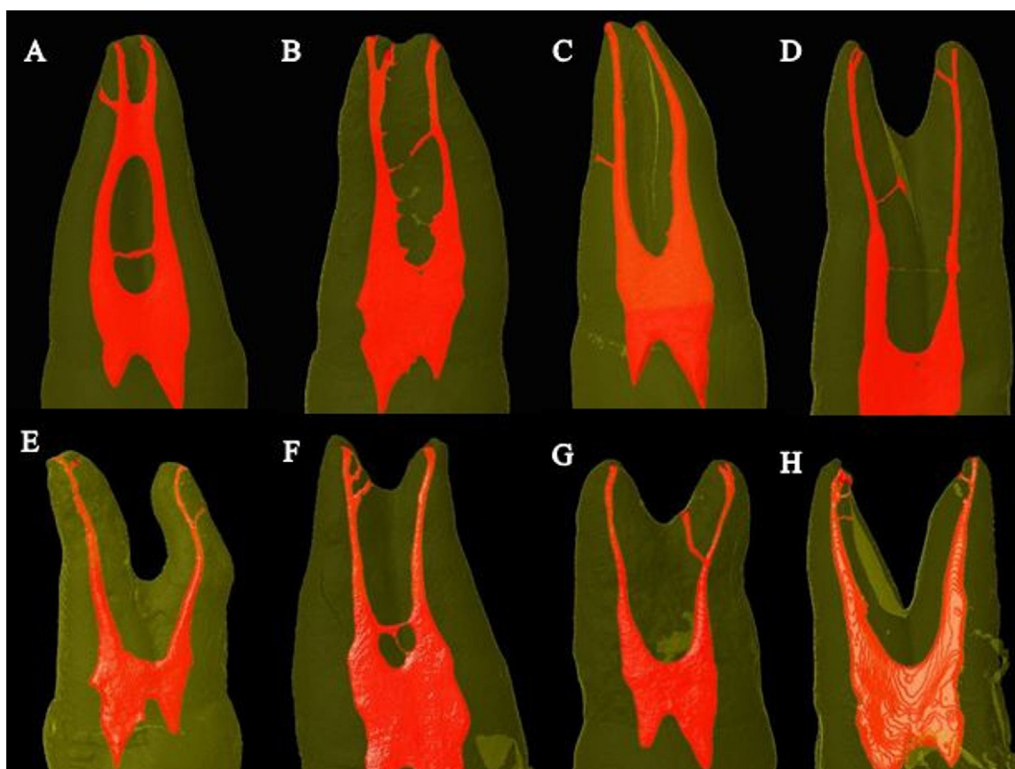


Fig. 3 Lateral canals (LC), apical deltas (AD) and isthmi in maxillary first premolars. (A) single root with isthmus and LC at apical third of the root. (B) Bifid root with AD and.

One of the main limitations of this study is its low sample size as it is difficult to collect sound teeth. The current study can provide baseline information to all practitioners to understand the morphology of the root canal system in the Kuwaiti population. A prospective study with large sample size is recommended.

5. Conclusion

Within the limitations of this study, maxillary first premolar teeth of Kuwaiti population showed a higher prevalence of single root and two root canals morphology. Type IV canal configuration was the most common root canal configuration followed by type II. A new root canal configuration type IX for (1-2-1-2-1) was proposed for Kuwaiti population. The μ -CT device could be a better diagnostic tool for understanding the anatomy of the root canal system.

Ethical statement

This study was conducted in full accordance with the World Medical Association Declaration of Helsinki and ethical clearance was obtained from the research center of Riyadh Elm University, Riyadh, Kingdom of Saudi Arabia. The research registration number is (FPGRP/43433001/94).

The knowledge of the human root canal morphology is an essential for successful the root canal treatment. This will help in access cavity preparation, locating an additional root canals, biomechanical preparation and obturation of the root canal system.

Author contribution

All authors have contributed significantly. All authors are in agreement with the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary material

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.sdentj.2022.07.004>.

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