ROOT CANAL MORPHOLOGY OF MAXILLARY PREMOLARS IN BOSNIAN POPULATION

Džanković A*[1], Vuković A[2], Prcić-Konjhodžić A[1], Hasić-Branković L[1], Tahmiščija I[1], Zukić S[2], Bajsman A[2]

[1] Department of Dental Pathology and Endodontics, Faculty of Dentistry, University of Sarajevo, Sarajevo, Bosnia and Herzegovina
[2] Department for Dental Morphology, Anthropology and Forensics; Faculty of Dentistry, University of Sarajevo, Sarajevo, Bosnia and Herzegovina

***Corresponding author**

Aida Džanković, Ph.D.
Department of Restorative Dentistry and Endodontics
Faculty of Dentistry
University of Sarajevo
Bolnička 4a
71000 Sarajevo
Bosnia and Herzegovina
Phone: +387 33 214 249, ext. 118
E-mail: aidadzankovic@gmail.com

ABSTRACT

Objective: The aim of this study was to investigate root canal morphology of maxillary first and second premolars in Bosnian population using clearing technique.

Materials and methods: Total of 182 maxillary first and second premolars from Bosnian population were included in this study. The Indian ink was injected in the root canal system and the samples were rendered clear by demineralization and immersion into methyl salicylate. Data relating to root canal type (Vertucci classification, 1984), presence and position of lateral canals, presence and position of transverse anastomosis, position of apical foramina and frequency of apical deltas were analyzed using a magnifier and dissecting microscope (x10).

Results: The dominant root canal type of maxillary first premolars is the type IV, present in 56.5% of samples. Lateral canals were registered in 46.7% and transverse anastomosis in 8.6% of samples. The position of apical foramen maxillary first premolars was apicolateral at 60.86% of samples, while the apical delta present in 1.08% cases. The most frequent root canal of maxillary second premolars is type II (31.2%), followed by the type I and IV (20%). Lateral canals were recorded in one third of the total sample of maxillary second premolars (33.3%), dominantly in apical region. Transverse anastomoses were present in 23.3% of samples; the apical delta in 5.55% and position of the apical foramen was apicolateral at 71.11% cases respectively.

Conclusion: This study demonstrates anatomical complexities of maxillary premolars root canal system, confirming that the root with single tapering canal and apical foramen is an exception rather than the rule.

Keywords: root canal morphology, maxillary first premolar, maxillary second premolar, clearing technique

Introduction

The proper design of access cavity, identification and localization of the root canals, determination of work duration, principles of shaping and cleaning of the root canals are closely related to the knowledge of the root canal morphology. The failures in performing of all these stapes made at the beginning of treatment are multiplied in each subsequent stage and may lead to endodontic treatment failure.

Many factors have an impact on root canal morphology such as race [1], age [2,3] and sex [4]. Also, physiological and pathological processes (occlusion, caries, abrasion, erosion, attrition, periodontal disease, cavity preparation or cusp fracture), leading to dentinal exposure to the oral cavity, may induce changes of root canal morphology by production of secondary and tertiary dentin [5].

The simplest version of root canal system is root with a single canal and a single apical foramen. However, root canals may divide, rejoin and have additional ramification. Lateral canals were defined as branches of main canals or pulp chamber that communicates with the root exterior surface i.e. periodontal ligament [6,7]. Transverse anastomosis or inter-canal communications were defined as canal ramifications that run between the main canals but not communicate with root surface [6]. Apical delta is version of root canal morphology where the main canal divides into multiple accessory canals near the anatomical apex and apical part of main root canal can not be discernible [8,7].

The most important reference for different types of root canal configuration is Vertuccci's classification [9]. Vertucci et al described eight types of root canals, defining number of root canal and pulp space configuration for each permanent tooth (**Figure 1**,

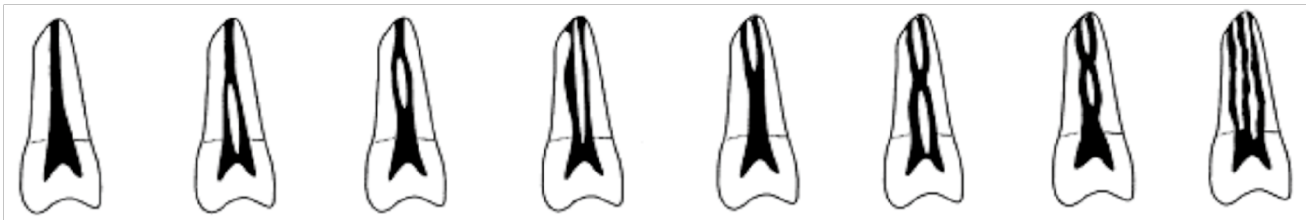

Figure 1. Classification of canal configurations according to Vertucci

Type I	A single canal extends from the pulp chamber to the apex (1).
Type II	Two separate canals leave the pulp chamber and join short of the apex to form one canal (2-1).
Type III	One canal leaves the pulp chamber and divides into two in the root; two than merge to exit as one canal (1-2-1).
Type IV	Two separate, distinct canals extend from the pulp chamber to the apex (2).
Type V	One canal leaves the pulp chamber and devides short of the apex into two separate distinct canals with separate apical foramina (1-2).
Type VI	Two separate canals leave the pulp chamber, merge into the body of the root, and redivide short of the apex to exit as two distinct canals (2-1-2).
Type VII	One canal leaves the pulp chamber, devides and than rejoins into the body of the root, and finally redivides into two distinct canals short of the apex (1-2-1-2).
Type VIII	Three separate, distinct canals extend from the pulp chamber to the apex (3).

Table 1. Vertucci 's classification, description

Table 1). There are additional classification systems for root canal configuration that do not match Vertuccci's classification such as Kartal et al [10], Gulabivala et al [11] and Sert&Bayirly [4] classifications.

All groups of teeth may have additional roots and/or canals, but possibility of the existence of aberrant communication canal is higher in premolars and molars [12]. Maxillary premolars have the most complicated apical morphology, the largest number and diameter of accessory canals (mean value 53.4 microns) [13]. The complex root canal anatomy must be regarded as one of the major challenges in infection control, because the pulp tissue and root dentin may be a reservoir for microorganisms and their toxins [14]. The maxillary first premolar is considered to be most difficult tooth for endodontic treatment due to roots and canals number, the longitudinal grooves direction, different configurations of the pulp space, and also because of difficult visualization of the apical region by radiography [15]. The maxillary second premolar is the only tooth of the permanent dentition which showed all eight possible configurations of the root canal system [1].

The complications of endodontic treatment are more often in the teeth with complex root canal morphology. The average dentine width of maxillary first premolar on the deepest invagination place of developmental groove is only 0.81 mm [16]. The possibility of fracture of the endodontically treated teeth increases proportionally to the amount of the defected dentin, and the risk is higher in oval or curved roots such as at maxillary premolars [17].

The data considering root canal morphology of the maxillary premolars in the Bosnian population aren't available, therefore the aim of this study is to perform detailed evaluation of maxillary premolars internal anatomy in the above mentioned population.

Material and methods

Sample selection

The maxillary first and second premolars, which were extracted for different reasons, were used as study material. The final sample consisted of 182 maxillary first premolars (92 maxillary first premolars and 90 maxillary second premolar) exclusively taken from the Bosnia and Herzegovina citizens. Sample collecting was made in 14 cities of the Federation of Bosnia and Herzegovina (in alphabetical order: Banovići, Čapljina, Gračanica, Gorazde, Kakanj, Konjic, Livno, Mostar, Sarajevo, Srebrenik, Travnik, Tuzla, Zenica, Živinice). Teeth with previous endodontic treatment and destroyed crown, damaged and/or broken root, incomplete root development and/or resorption were not included in the study.

Clearing technique protocol

All teeth were processed by clearing technique using method of Robertson et al [18] with modifications. After extraction, the samples were fixed in 10% formalin solution. To remove debris from the tooth surface, samples were immersed in 5.25% solution of sodium hypochlorite (Semikem, Sarajevo) for 24 hours. Pigmentation and concretements were taken off mechanically using an ultrasonic bath for 20 minutes (Pro's Kit®, Digital ultrasonic cleaner SS-802, Techopark, Co., Ltd., Hong Kong). Access cavity was made and pulpal tissue was removed by immersing overnight in 5.25% solution of sodium hypochlorite before being placed into an ultrasonic bath. India ink (Lefranc&Bourgeois, France) was injected into the root canals spaces coronary using 27 gauge needle (Romed® Holland, NL), assisted by vacuum suction apically. After the ink had dried, the samples were stored into 5% nitric acid solution (Semikem, Sarajevo) for 5 days with daily solution changing. Demineralization was assessed by needle insertion into the crown and by periodic radiographs. The samples were then rinsed under running water to remove traces of nitric acid, dried, and dehydrated successively using increasing ethanol solutions (70, 80, and 95%; Absolute Alcohol, Semikem, Sarajevo) for 12 hours. Finally, the teeth were rendered transparent by immersing into methyl salicylate (Semikem, Sarajevo). At the end of the third day, complete transparency was achieved.

Assessment of root canal morphology

Root canal morphology was examined by using magnifying glass and stereomicroscope x10 (Novex RZ-series, Euromex microsopes BV, NL). The anatomy of root canal was observed and classified according to Vertucci' classification and additional classifications.

Maxillary premolar	Root canal type (%) *									Lateral canals (%)	Anasto-moses (%)	Apical delta (%)	Position of apical foramen	
	I	II	III	IV	V	VI	VII	VIII	Additional types				Lateral	Central
First premolar (n=92)	8.8I	18.5	-	56.5	4.3	4.3	1.1	2.2	-	46.7	8.6	1.08	60.86	33.69
Second premolar (n=90)	20	31.1	-	20	4.4	13.3	-	1.1	2.2	33.3	23.3	5.5	71.11	23.33

* Values represent persentage of total. The samples with root canal obliteration are not presented in table

Table 2. Root canal morphology of maxillary first and secon premolar in Bosnian population

Results

The summary of results are shown in **Table 2.** and **Figure 2.** It is evident that the dominant root canal type of maxillary first premolar is the type IV, identified in 56.5% of cases, followed by the type II (18.5%). Lateral canals (**Figure 3A**.) were registered in 46.7% of the samples and transverse anastomosis (**Figure 3B.**) in 8.6% of the samples. The position of apical foramen of maxillary first premolars was apicolateral at 60.86% of samples, while the apical delta (**Figure 3C**.) was seen in 1.08% cases.

The most frequent root canal type of maxillary second premolar is type II (31.2%), followed by the type IV and I (20%). Lateral canals were recorded in one third of the total samples of maxillary second premolars, usually in apical region (33.3%). Transverse anastomosis was present in 23.3% of samples, the apical delta in 5.55% and position of the apical foramen was apicolateral at 71.11 % cases respectively.

Root canal type could not be identified due the root canal obliteration in four samples of maxillary first premolar (4.3%) and in seven samples of maxillary second premolar (7.7%). Root canal type III was not found in any case of the total sample. One sample of maxillary second premolar (1.1%) showed Sert and Bayirli's type IX classification (1-3) (**Figure 2H**.). Also, one sample of maxillary second premolar (1.1%) did not match Vertucci's or any other additional classification. Its root canal configuration is 2-1-2-1-2-1 and could be describe as follows: two canals leave the pulp chamber and join at the gingival third of the root. From merging portion, root canals

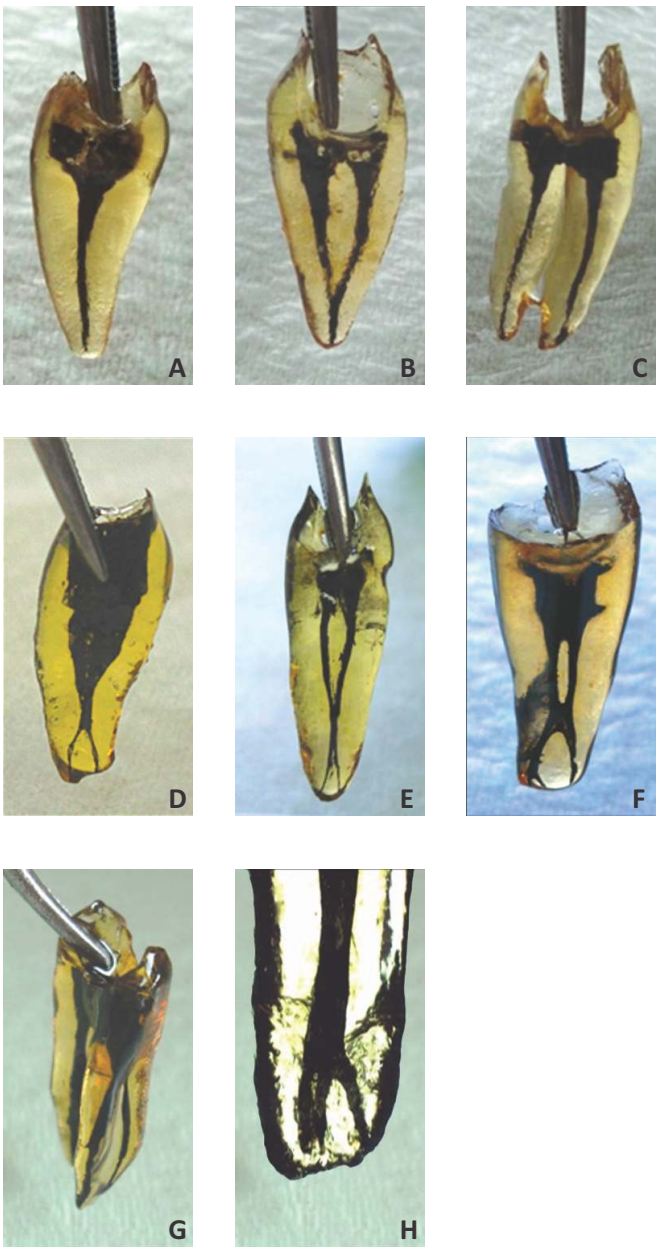

Figure 2. Transparent root canal appearance of maxillary premolars . (A) Type I, (B) type II, (C) type IV, (D) type V, (E) type VI, (F) type VII, (G) type VIII, (H) type IX (Sert's classification)

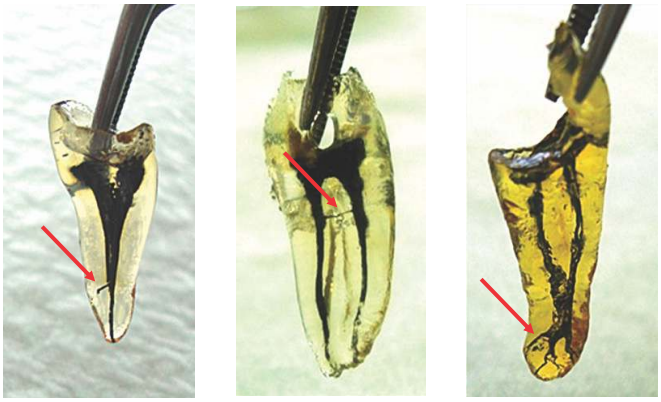

Figure 3.
(A) Lateral canal, (B) Transversal anstomosis, (C) Apical delta

Figure 4. Additional canal configuration is observed in this study, type 2-1-2-1-2-1

separate and join again at the middle third of the root. Once again, root canals separate and join at the apical third of root, ending as a single foramen (**Figure 4.**).

Discussion

The investigation of root canal morphology is possible using different techniques, but clearing technique provides the most detailed information [4] given that it enables three-dimensional observation and also preserved original form of the root canal. Therefore, the clearing technique is considered the gold standard method [19] for studying root canal anatomy.

Several studies attempted to classify root canal morphology of maxillary premolars using clearing technique. **Table 3.** and **Table 4.** summarize the main results of these studies.

The most prevalent root canal type of maxillary first premolar in Bosnian population is type IV (56.5%) and type II (18.5%), what was consistent with previous studies (**Table 3**.). The exception was study by Kartal et al [10] which was made in Turkish population, where the second most frequent root canal type was type V. Root canal configuration type III was not found in our study thus corresponding to results of Vertucci [9], Çaliskan [20] and Kartal [10]. The relatively low percentage (0-5, 9%) of root canal

Reference	No. of teeth	Root canal type maxillary first premolar (%)								Lateral canals (%)	Anasto-moses (%)	Apical delta (%)	Apical foramen location	
		I	II	III	IV	V	VI	VII	VIII				Lateral	Central
Vertucci et al (9) (1984)	400 (USA)	8.0	18.0	-	62.0	7.0	-	-	5.0	49.5	34.2	3.2	88.0	12.0
Çaliskan et al (20) (1995)	100 (Turkey)	3.9	5.9	-	78.4	5.9	5.9	-	-	33.3	17.6	21.6	66.7	33.3
Kartal et al (10) (1998)	300 (Turkey)	8.6	1.0	-	71.3	14.3	2.3	0.3	1.3	26.0	7.0	7.6	84.6	15.3
Sert&Bayirli (4) (2004)	200 (Turkey)	10.5	12.5	5.5	61.5	3.5	1.0	1.0	3.0	33.0	12.0	30.7	76.0	24.0
Awawdeh et al (16) (2008)	600 (Jordan)	3.3	10.2	0.3	79.7	2.0	2.3	-	1.5	19.3	7.0	4.3	40.0	60.0
Weng et al (21) (2009)	100 (China)	6.3	22.1	3.2	64.2	3.2	1.0	-	-	51.7	*	29.2	*	*
Present study (2015)	92 (BiH)	8.8	18.5	-	56.5	4.3	4.3	1.1	2.2	46.7	8.6	1.08	60.8	33.6

* no avaible data

Table 3. Root canal classification morphology of first maxillary premolar

Reference	No. of teeth	Root canal type maxillary second premolar (%)								Lateral canals (%)	Anasto-moses (%)	Apical delta (%)	Apical foramen location	
		I	II	III	IV	V	VI	VII	VIII				Lateral	Central
Vertucci et al (9) (1984)	400 (USA)	48.0	22.0	5.0	11.0	6.0	5.0	2.0	1.0	59.5	30.8	15.1	77.8	22.2
Çaliskan et al (20) (1995)	100 (Turkey)	44.0	22.0	6.0	12.0	6.0	6.0	4.0	-	34.0	20.0	26.0	54.0	46.0
Kartal et al (10) (1998)	300 (Turkey)	48.6	6.3	-	37.9	5.6	0.6	-	0.6	19.0	12.3	52.0	77.0	23.0
Sert&Bayirli (4) (2004)	200 (Turkey)	32.0	20.0	10.0	25.5	6.0	1.5	3.0	1.5	31.0	20.5	6.5	63.5	36.5
Weng et al (21) (2009)	100 (China)	27.7	36.9	-	33.8	-	1.6	-	-	68.7	*	43.8	*	*
Jayasimha et al (22) (2010)	200 (India)	26.2	33.6	1.3	31.1	2.1	1.2	1.0	-	*	19.0	14.0	*	*
Present study (2015)	90 (BiH)	20.0	31.1	-	20.0	4.4	13.3	-	1.1	33.3	23.3	5.55	71.1	23.3

* no avaible data

Tabela 4. Root canal classification and morphology of second maxillary premolar

type VI, VII and VIII were reported in all previous studies being consistent to our research (**Table 3.**).

Literature review of maxillary second premolar internal anatomy has revealed a considerable variation in root canal morphology. The most prevalent type of root canals in maxillary second premolar is type II occurring in 31.1% followed by type IV (20%), and type I (20%). The combination „one root and one canal" (type I) was seen in 20% of samples. Similar findings were seen in studies by Weng et al [21] and Jayasimha et al [22], but different than results of earlier studies [9,20,10] where the most frequent type of root canals was type I. In present study, none of the samples had type III or type VII root canal configuration.

Lateral canals were commonly seen among samples of maxillary premolars in *in vitro* studies. Our results, concerning the number of lateral canals of maxillary first premolar, corresponded to the results reported in both American and Chinese population [9,21], and also, in studies of maxillary second premolar morphology, corresponding to results of previous studies by Çaliskan et al [20] and Sert&Bayirli [4] in Turkish population.

Most of maxillary premolars possess two canals and ramifications like transverse anastomosis could be expected. In literature, the prevalence of transversal anastomosis in maxillary first premolars ranged from 7%-34.2%, and in maxillary second premolar from 12.3-30.8% (**Table 3**. and **Table 4**).

Sert and Bayirli [4] reported the incidence of apical deltas to be 30.7% for first maxillary premolar while Weng et al [21] reported the incidence of apical deltas to be up to 68.7% for second maxillary premolar, being significantly higher than results of our study. The prevalence of apical deltas in Bosnian population was 1.08% in case of maxillary first premolar, respectively 5.5% in case of maxillary second premolar, similar to the results of Vetucci at al [9]. Apical foramina of maxillary premolars was located mainly on lateral side of the root and this observation is similar to those of many other studies.

In this study, additional root canal configuration was found. As it stated in the study of Awawdeh et al [16], additional root canal configurations are rare, but should be kept in mind when carrying root canal treatment.

Conclusion

Root canal morphology of maxillary premolars observed by clearing technique is much more complex than it could be seen in clinical situation. This study draw attention to the components of root canal morphology being not visible by using clinically available methods, although they really exist.

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