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Evaluation of the root canal morphology variations of maxillary premolars using cone-beam computed tomography

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SUMMARY

Introduction Maxillary premolars often undergo endodontic treatment, which requires detailed knowledge of their canal morphology. The aim of this study was to determine the most common number of roots of maxillary premolars by analyzing CBCT images, as well as to determine the most common root canal configuration in maxillary premolars in the population of Southeast Serbia using the new system for classifying root canal morphology by Ahmed et al.

Material and methods 55 CBCT images of male and 63 CBCT images of female patients were analyzed, which included 223 maxillary first premolars and 207 maxillary second premolars. The analysis was performed in the program Galileos. The number of roots of these teeth was determined and the canal morphology was classified in relation to the gender and side of maxilla.

Results The maxillary first premolars most often had two roots and configuration type ^{2}TNB^{1}P^{1}, while the most maxillary second premolars had one root and configuration type ^{1}TNB^{1}. No significant difference was observed in the number of roots and type of configuration between male and female, as well as between left and right sides.

Conclusion The classification of the tooth canal system according to Ahmed et al. emphasizes the advantage of simultaneous classification of the number of roots and the number of canals. Although most premolars do not pose a problem for treatment, there have been registered canal configurations of maxillary premolars that can be a challenge for endodontic treatment. A detailed analysis of the canal configuration can be performed using CBCT.

Keywords: endodontics; canal configuration; maxillary premolars; CBCT

INTRODUCTION

Missed root canals, which have not been endodontically treated, represent a source of infection that can compromise the outcome of the treatment and potentially endanger the entire organism. If canal system is incompletely instrumented and obturated, endodontic treatment is considered not successful [1]. Successful endodontic treatment is impossible without detailed knowledge of the number and position of the roots and canals. The exact localization of the entrance to the root canals dictates the preparation of the access cavity - an important phase of endodontic treatment. The preparation of access cavities in teeth covered with a crown requires extreme precision to avoid possible damage to the crown itself. Removal of ceramics, more than necessary, due to not knowing the exact localization of the root canal, can result in crown cracking [2]. The analyzes of variations in canal configuration within a population can provide clinicians with useful guidelines when planning and performing endodontic treatment on individual teeth. The need-to-know possible variations of the root canal configuration has contributed to the constant work on finding universal classifications, which would consider all possible combinations of tooth root canal configurations caused by the separation and fusion of the canals. Many authors tried to classify complex morphology of root canals by describing dozens of types of canal configurations [3]. In addition to already well-known classification according to Vertucci [4], the classification of canal configurations according to Ahmed [5], presented in 2017, stood out as useful. With its help, it is possible to identify canal configurations that were not documented or described in the literature.

Although any tooth can be a challenge to treat, maxillary premolars are one of the more demanding groups of teeth to perform endodontic treatment. The study that aimed to collect information on endodontic treatment carried out by Belgian dentists, indicated a much higher number of post-endodontic complications in premolars than incisors and canines [6]. According to the study by Zaatar et al. [7], maxillary premolars are teeth often subjected to endodontic treatment.

The aim of our study was to determine the most common number of roots of maxillary premolars by analyzing CBCT images, as well as to determine the most common configuration of canals in maxillary premolars in the population of Southeast Serbia using the new system for classifying root canal morphology by Ahmed et al. [5].

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Table 1. Proposal of code formulas that can be used to mark the configurations of the canals of single-rooted, two-rooted, and three-rooted premolars according to Ahmed et al. [5]
Tabela 1. Predlog formula kodova kojima se mogu obeležiti konfiguracije kanala jednokorenih, dvokorenih i trokorenih premolara po Ahmedu i saradnicima [5]

$^{1}TN^{O\text{-}C\text{-}F}$	Single-rooted teeth, as indicated by the superscript in front of the tooth number (TN) Jednokoreni zubi, na šta ukazuje superskripta ispred broja zuba
$^{2}TN\ B^{O\text{-}C\text{-}F}\ P^{O\text{-}C\text{-}F}$	Double-rooted teeth, as indicated by the superscript in front of the tooth number (TN) Dvokoreni zubi, na šta ukazuje superskripta ispred broja zuba
$^{3}TN\ MB^{O\text{-}C\text{-}F}\ DB^{O\text{-}C\text{-}F}\ P^{O\text{-}C\text{-}F}$	Three-rooted teeth, as indicated by the superscript in front of the tooth number (TN) Trokoreni zubi, na šta ukazuje superskripta ispred broja zuba

TN – tooth number; O – number of openings on the floor of the pulp chamber; C – number of canals; F – number of foramina; B – buccal root; P – palatal root; MB – mesiobuccal root; DB – distobuccal rootTN – broj zuba; O – broj otvora na podu pulpne komore; C – broj kanala; F – broj foramena; B – bukalni koren; P – palatinalni koren; MB – meziobukalni koren; DB – distobukalni koren

MATERIALS AND METHODS

The research was approved by the Ethical Committee of the Clinic for Dental Medicine in Niš (01-728/23). 118 CBCT images of patients at the Clinic for Dental Medicine in Niš (55 images of male and 63 images of female patients) were analyzed in the program Galileos (Sirona, Germany) with 223 maxillary first premolars and 207 maxillary second premolars included. The analysis was performed by two experienced clinicians, who determined the number of roots of maxillary premolars and classified the configuration of their canals according to Ahmed et al. [5]. Table 1 shows the code formulas that helped marking the configurations of the canals of maxillary premolars. Table 2 shows the codes, according to Ahmed et al. [5] for the configurations of the canals of maxillary premolars recorded in the literature and used in our research.

RESULTS

The highest number of maxillary first premolars had two roots. The analysis of the results showed that there was no statistically

Table 2. Codes marking premolar canal configurations according to Ahmed et al. [5] in this research
Tabela 2. Kodovi kojima su obeležene konfiguracije kanala premolara po Ahmedu i saradnicima [5] u ovom istraživanju

$^{1}T^{N}1$	Maxillary premolar with one root and one canal (Figure 1A) Gornji premolar sa jednim korenom i jednim kanalom (Slika 1A)
$^{1}TN^{1\text{-}2}$	Maxillary premolar with one root and one canal dividing into two canals (Figure 1B) Gornji premolar sa jednim korenom i jednim kanalom koji se grana (Slika 1B)
$^{1}TN^{1\text{-}2\text{-}1}$	Maxillary premolar with one root and one canal divinding into two canals and then reuniting into a single canal (Figure 1C) Gornji premolar sa jednim korenom i sa jednim kanalom koji se grana, a potom ponovo spaja u jedan kanal (Slika 1C)
$^{1}TN^{1\text{-}2\text{-}1\text{-}2}$	Maxillary premolar with one root and one canal divinding into two canals, then reuniting into one canal to finally separate into two canals (Figure 1D) Gornji premolar sa jednim korenom i sa jednim kanalom koji se grana, potom ponovo spaja u jedan kanal, da bi se naposletku odvojio u dva kanala (Slika 1D)
$^{1}TN^{2}$	Maxillary premolar with one root and two canals (Figure 1E) Gornji premolar sa jednim korenom i dva kanala (Slika 1E)
$^{1}TN^{2\text{-}1}$	Maxillary premolar with one root and two canals, merging into a single canal (Figure 1F) Gornji premolar sa jednim korenom i dva kanala, koja se spajaju (Slika 1F)
$^{1}TN^{2\text{-}1\text{-}2}$	Maxillary premolar with one root and two canals, which merge into one, and then separate into two canals (Figure 1G) Gornji premolar sa jednim korenom i dva kanala, koja se spajaju u jedan, koji se potom grana (Slika 1G)
$^{2}TN^{1}B^{1}P^{1}$	Maxillary premolar with the root which splits into two roots, and one canal from the floor of the chamber, which splits into two canals, one in each root (Figure 1H) Gornji premolar, čiji se koren razdvaja u dva korena; sa poda komore polazi jedan kanal, koji se razdvaja u dva kanala, po jedan u svakom korenu (Slika 1H)
$^{2}TNB^{1}P^{1}$	Maxillary premolar with two roots and two canals, one in the palatal root and the other in the buccal root (Figure 1J) Gornji premolar sa dva korena i dva kanala, jednim u palatinalnom korenu i drugim u bukalnom korenu (Slika 1J)
$^{2}TNB^{1\text{-}2}P^{1}$	Maxillary premolar with two roots and two canals, one in the palatal root and one in the buccal root, which divides into two canals (Figure 1K) Gornji premolar sa dva korena i dva kanala, jednim u palatinalnom korenu i drugim u bukalnom korenu, koji se grana (Slika 1K)
$^{3}TNMB^{1}DB^{1}P^{1}$	Maxillary premolar with three canals, one in each root (Figure 1L) Gornji premolar sa tri kanala, jednim u svakom korenu (Slika 1L)

TN – maxillary premolar (14, 24, 15, 25); B – buccal root; P – palatal root; MB – mesiobuccal root; DB – distobuccal root
TN – gornji premolar (14, 24, 15, 25); B – bukalni koren; P – palatinalni koren; MB – meziobukalni koren; DB – distobukalni koren

Table 3. Frequency distribution of the number of the maxillary first premolar roots according to gender and tooth position
Tabela 3. Distribucija frekvencije broja korenova gornjeg prvog premolara prema polu i poziciji zuba

	Maxillary first premolar Gornji prvi premolar	Single-rooted Jedan koren	Double-rooted Dva korena	Three-rooted Tri korena	Total Ukupno	Chi square Hi kvadrat
Gender Pol	Male / Muškarci	28 (27.2%)	74 (71.8%)	1 (1%)	103 (100%)	$\chi^2 = 1.25$; p = 0.53
	Female / Žene	35 (29.2%)	85 (70.8%)	0 (0.0%)	120 (100%)	
Tooth position Pozicija zuba	Right (14) / Desna (14)	33 (29.2%)	79 (69.9%)	1 (0.9%)	113 (100%)	$\chi^2 = 1.11$; p = 0.57
	Left (24) / Leva (24)	30 (27.3%)	80 (72.7%)	0 (0.0%)	110 (100%)	
	Total / Ukupno	63 (28.3%)	159 (71.3%)	1 (0.4%)	223 (100%)	

χ^2 – Chi square test value; p – the value of the probability of the Chi-square test
χ^2 – vrednost testa χ^2; p – vrednost verovatnoće testa χ^2

Table 3. Frequency distribution of the number of the maxillary first premolar roots according to gender and tooth position
Tabela 3. Distribucija frekvencije broja korenova gornjeg prvog premolara prema polu i poziciji zuba

	Maxillary first premolar Gornji prvi premolar	Single-rooted Jedan koren	Double-rooted Dva korena	Three-rooted Tri korena	Total Ukupno	Chi square Hi kvadrat
Gender Pol	Male / Muškarci	28 (27.2%)	74 (71.8%)	1 (1%)	103 (100%)	$\chi^2 = 1.25$; p = 0.53
	Female / Žene	35 (29.2%)	85 (70.8%)	0 (0.0%)	120 (100%)	
Tooth position Pozicija zuba	Right (14) / Desna (14)	33 (29.2%)	79 (69.9%)	1 (0.9%)	113 (100%)	$\chi^2 = 1.11$; p = 0.57
	Left (24) / Leva (24)	30 (27.3%)	80 (72.7%)	0 (0.0%)	110 (100%)	
	Total / Ukupno	63 (28.3%)	159 (71.3%)	1 (0.4%)	223 (100%)	

χ^2 – Chi square test value; p – the value of the probability of the Chi-square test
χ^2 – vrednost testa χ^2; p – vrednost verovatnoće testa χ^2

Table 4. Frequency distribution of the number of the maxillary second premolar roots according to gender and tooth position
Tabela 4. Distribucija frekvencije broja korenova gornjeg drugog premolara prema polu i poziciji zuba

	Maxillary second premolar Gornji drugi premolar	Single-rooted Jedan koren	Double-rooted Dva korena	Three-rooted Tri korena	Total Ukupno	Chi square Hi kvadrat
Gender Pol	Male / Muškarci	69 (74.2%)	24 (25.8%)	0 (0.0%)	93 (100%)	$\chi^2 = 0.60$; p = 0.44
	Female / Žene	79 (69.3%)	35 (30.7%)	0 (0.0%)	114 (100%)	
Tooth position Pozicija zuba	Right (15) / Desna (15)	78 (72.7%)	30 (27.8%)	0 (0.0%)	108 (100%)	$\chi^2 = 0.06$; p = 0.81
	Left (25) / Leva (25)	70 (70.7%)	29 (29.3%)	0 (0.0%)	99 (100%)	
	Total / Ukupno	148 (71.5%)	59 (28.5%)	0 (0.0%)	207 (100%)	

χ^2 – Chi square test value; p – the value of the probability of the Chi-square test
χ^2 – vrednost testa χ^2; p – vrednost verovatnoće testa χ^2

Table 5. Frequency distribution of maxillary premolars canal configuration according to tooth position
Tabela 5. Distribucija frekvence konfiguracije kanala gornjih premolara prema poziciji zuba

		Maxillary first premolar Gornji prvi premolari			Maxillary second premolar Gornji drugi premolari		
		14	15	Total Ukupno	24	25	Total Ukupno
Canal configuration types Tipovi konfiguracije kanala	$^{1}TN^{1}$	3 (2.7%)	8 (7.3%)	11 (4.9%)	40 (37.0%)	42 (42.4%)	82 (39.6%)
	$^{1}TN^{1-2}$	6 (5.3%)	3 (2.7%)	9 (4.0%)	8 (7.4%)	6 (6.1%)	14 (6.8%)
	$^{1}TN^{1-2-1}$	5 (4.4%)	3 (2,7%)	8 (3.6%)	5 (4.6%)	1 (1.0%)	6 (2.9%)
	$^{1}TN^{1-2-1-2}$	4 (3.5%)	0 (0.0%)	4 (1.8%)	3 (2.8%)	0 (0.0%)	3 (1.4%)
	$^{1}TN^{2}$	6 (5.3%)	8 (7.3%)	14 (6.3%)	9 (8.3%)	12 (12.1%)	21 (10.1%)
	$^{1}TN^{2-1}$	9 (8.0%)	8 (7.3%)	17 (7.6%)	8 (7.4%)	5 (5.1%)	13 (6.3%)
	$^{1}TN^{2-1-2}$	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (4.6%)	4 (4.0%)	9 (4.3%)
	$^{2}TN^{1}B^{1}P^{1}$	5 (4.4%)	10 (9.1%)	15 (6.7%)	1 (0.9%)	3 (3.0%)	4 (1.9%)
	$^{2}TNB^{1}P^{1}$	74 (65.5%)	70 (63.6%)	144 (64.6%)	29 (26.9%)	26 (26.3%)	55 (26.6%)
	$^{2}TNB^{1-2}P^{1}$	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	$^{3}TNMB^{1}DB^{1}P^{1}$	1 (0.04%)	0 (0.0%)	1 (0.4%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	Total Ukupno	113 (100%)	110 (100%)	223 (100%)	108 (100%)	99 (100%)	207 (100%)
	Chi square test Test χ^2	$\chi^2 = 10.86$; p = 0.21			$\chi^2 = 8.02$; p = 0.43		

TN – maxillary premolar; B – buccal root; P – palatal root; MB – mesiobuccal root; DB – distobuccal root; χ^2 – Chi square test value;
p – the value of the probability of the Chi-square test
TN – gornji premolar; B – bukalni koren; P – palatinalni koren; MB – meziobukalni koren; DB – distobukalni koren; χ^2 – vrednost testa χ^2; p – vrednost verovatnoće testa χ^2

significant difference in the number of roots between the left and right maxillary first premolars. Analysis of the number of roots of maxillary first premolars in relation to gender did not reveal a statistically significant difference between male and female patients (Table 3).

A single root was observed in most maxillary second premolars. No statistically significant difference was found in the number of roots between left and right maxillary second premolars. Also, the difference in the number of roots of maxillary premolars between male and female patients was not statistically significant (Table 4).

The most common canal configuration in the maxillary first premolars, according to Ahmed et al. [5], can be marked with the code $^{2}TNB^{1}P^{1}$, while in the maxillary second premolars the most common code was $^{1}TN^{1}$. No statistically significant difference was found in the canal configuration between the left and right premolars (Table 5). The analysis of the canal morphology of the maxillary premolars in relation to gender did not show a statistically significant difference between men and women (Table 6). Figures 2–5 show some of the CBCT images, which were analyzed in the research.

DISCUSSION

Although periapical radiographs are common during endodontic treatment, this way it is not always possible to fully see the canal morphology due to the complex three-dimensional

Table 6. Frequency distribution of maxillary premolars canal configuration according to gender
Tabela 6. Distribucija frekvence konfiguracije kanala gornjih premolara prema polu

		Maxillary first premolar Gornji prvi premolari			Maxillary second premolar Gornji drugi premolari		
		Male / Muškarci	Female / Žene	Total / Ukupno	Male / Muškarci	Female / Žene	Total / Ukupno
Canal configuratin types Tipovi konfiguracije kanala	$^{1}TN^{1}$	6 (5.8%)	5 (4.2%)	11 (4.9%)	38 (40.9%)	44 (38.6%)	82 (39.6%)
	$^{1}TN^{1-2}$	5 (4.9%)	4 (3.3%)	9 (4.0%)	5 (5.4%)	9 (7.9%)	14 (6.8%)
	$^{1}TN^{1-2-1}$	5 (4.9%)	3 (2.5%)	8 (3.6%)	0 (0.0%)	6 (5.3%)	6 (2.9%)
	$^{1}TN^{1-2-1-2}$	1 (1.0%)	3 (2.5%)	4 (1.8%)	0 (0.0%)	3 (2.6%)	3 (1.4%)
	$^{1}TN^{2}$	4 (3.9%)	10 (8.3%)	14 (6.3%)	15 (16.1%)	6 (5.3%)	21 (10.1%)
	$^{1}TN^{2-1}$	7 (6.8%)	10 (8.3%)	17 (7.6%)	6 (6.5%)	7 (6.1%)	13 (6.3%)
	$^{1}TN^{2-1-2}$	0 (0.0%)	0 (0.0%)	0 (0.0%)	5 (5.4%)	4 (3.5%)	9 (4.3%)
	$^{2}TN^{1}B^{1}P^{1}$	10 (9.7%)	5 (4.2%)	15 (6.7%)	2 (2.2%)	2 (1.8%)	4 (1.9%)
	$^{2}TNB^{1}P^{1}$	64 (62.1%)	80 (66.7%)	144 (64.6%)	22 (23.7%)	33 (28.9%)	55 (26.6%)
	$^{2}TNB^{1-2}P^{1}$	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)	0 (0.0%)
	$^{3}TNMB^{1}DB^{1}P^{1}$	1 (1.0%)	0 (0.0%)	1 (0.4%)	0 (0.0%)	0 (0,0%)	0 (0,0%)
	Total / Ukupno	103 (100%)	120 (100%)	223 (100%)	93 (100%)	114 (100%)	207 (100%)
	Chi square test Test χ^2	$\chi^2 = 7,99$; p = 0,21			$\chi^2 = 14,85$; p = 0,06		

TN – maxillary premolar; B – buccal root; P – palatal root; MB – mesiobuccal root; DB – distobuccal root; χ^2 – Chi square test value; p – the value of the probability of the Chi-square test
TN – gornji premolar; B – bukalni koren; P – palatinalni koren; MB – meziobukalni koren; DB – distobukalni koren; χ^2 – vrednost testa χ^2; p – vrednost verovatnoće testa χ^2

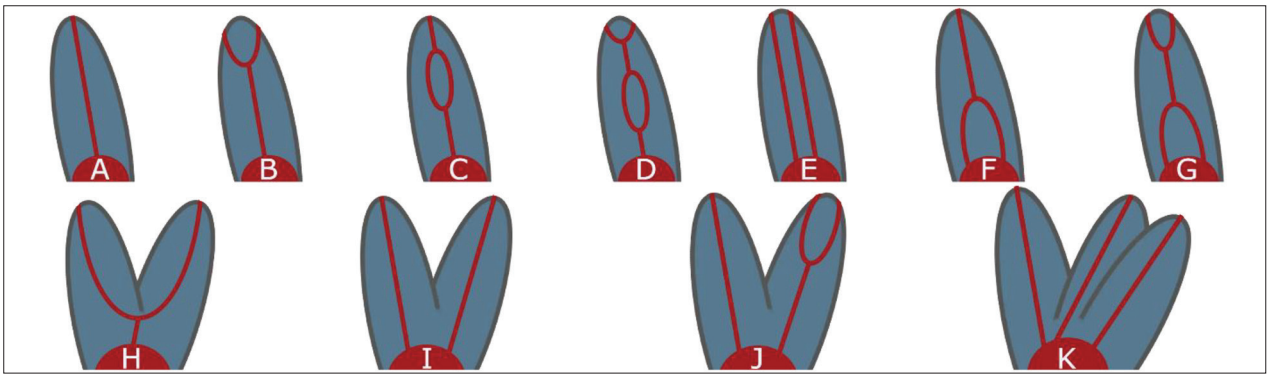

Figure 1. Schematic representations of maxillary premolar canal configurations, according to Ahmed et al. [5] are labeled as follows: **A** $^{1}TN^{1}$; **B** $^{1}TN^{1-2}$; **C** $^{1}TN^{1-2-1}$; **D** $^{1}TN^{1-2-1-2}$; **E** $^{1}TN^{2}$; **F** $^{1}TN^{2-1}$; **G** $^{1}TN^{2-1-2}$; **H** $^{2}TN^{1}B^{1}P^{1}$; **I** $^{2}TNB^{1}P^{1}$; **J** $^{2}TNB^{1-2}P^{1}$; **K** $^{3}TNMB^{1}DB^{1}P^{1}$
Slika 1. Šematski prikazi konfiguracija kanala premolara koje su prema Ahmedu i saradnicima [5] obeleženi na sledeći način: **A** $^{1}TN^{1}$; **B** $^{1}TN^{1-2}$; **C** $^{1}TN^{1-2-1}$; **D** $^{1}TN^{1-2-1-2}$; **E** $^{1}TN^{2}$; **F** $^{1}TN^{2-1}$; **G** $^{1}TN^{2-1-2}$; **H** $^{2}TN^{1}B^{1}P^{1}$; **I** $^{2}TNB^{1}P^{1}$; **J** $^{2}TNB^{1-2}P^{1}$; **K** $^{3}TNMB^{1}DB^{1}P^{1}$

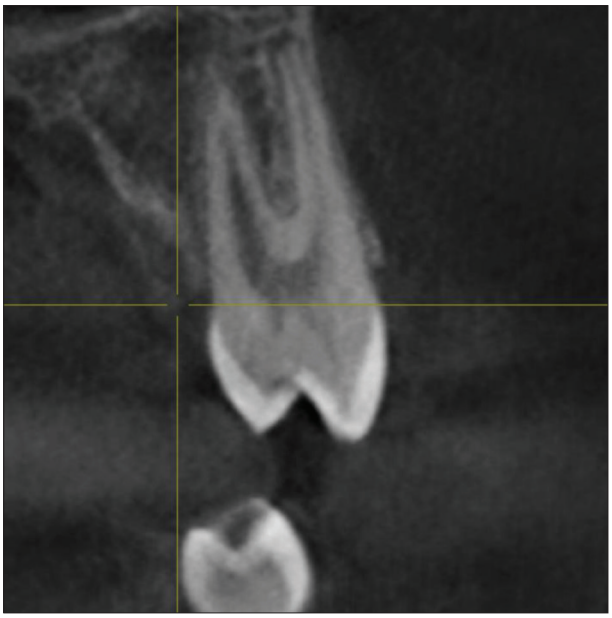

Figure 2. The most common canal configuration of the maxillary first premolar: $^{2}14B^{1}P^{1}$
Slika 2. Najčešća konfiguracija kanala gornjeg prvog premolara: $^{2}14B^{1}P^{1}$

structure of the tooth root canal. The superimposition of buccal and palatal roots on two-dimensional images prevents an adequate assessment of the number and position of the canals, making it difficult to plan therapeutic procedures in endodontics. This difficulty can be solved by analyzing images made by the cone beam computed tomography (CBCT) method [8]. These images provide a three-dimensional insight into the bone structures and tooth morphology, which eliminates the problems of superimposition on two-dimensional images. In addition to its wide clinical use, the analysis of CBCT images is recognized in the literature as extremely useful in many studies, which deal with the examination of morphological variations of individual teeth in different populations [9, 10]. Using this method, a larger number of teeth are available for examination, compared to research on extracted teeth, which limit the analysis to teeth extracted for certain orthodontic or prosthetic reasons.

During classification of maxillary premolars canal configurations according to Vertucci [4], many authors faced a problem, since this type of classification does not provide insight into the number of roots. This means that, based on the classification itself, it is not possible to conclude how many roots a

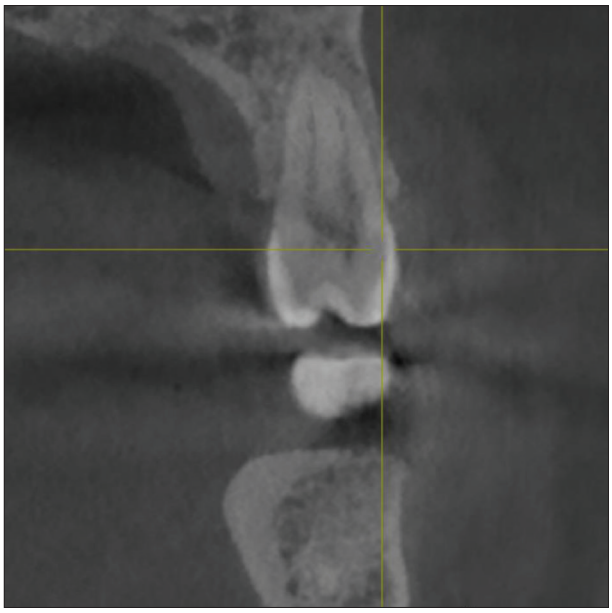

Figure 3. Canal configurations of the maxillary first premolar: $^{1}14^{2}$
Slika 3. Jedna od konfiguracija kanala gornjeg prvog premolara: $^{1}14^{2}$

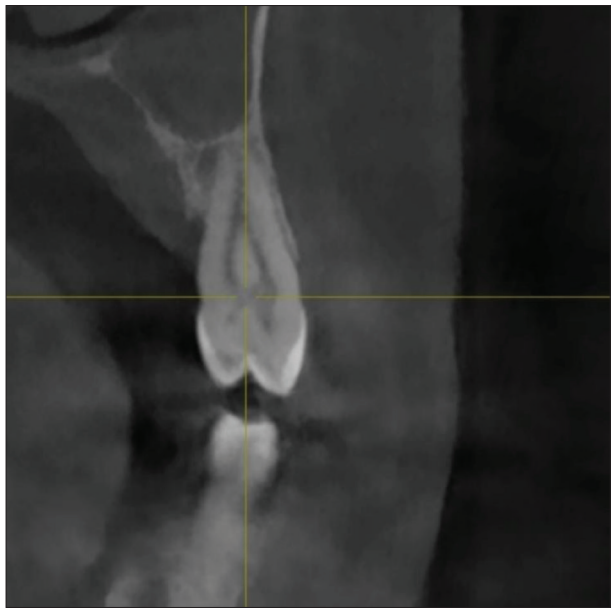

Figure 4. Rarer canal configurations of the maxillary first premolar: $^{1}14^{2\text{-}1}$
Slika 4. Jedna od ređih konfiguracija kanala gornjeg prvog premolara: $^{1}14^{2\text{-}1}$

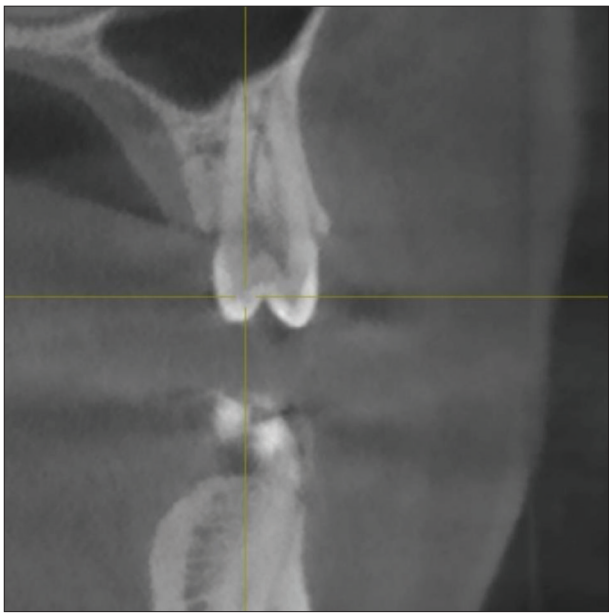

Figure 5. Rarer canal configurations of the maxillary first premolar: $^{1}14^{2\text{-}1\text{-}2}$
Slika 5. Jedna od ređih konfiguracija kanala gornjeg prvog premolara: $^{1}14^{2\text{-}1\text{-}2}$

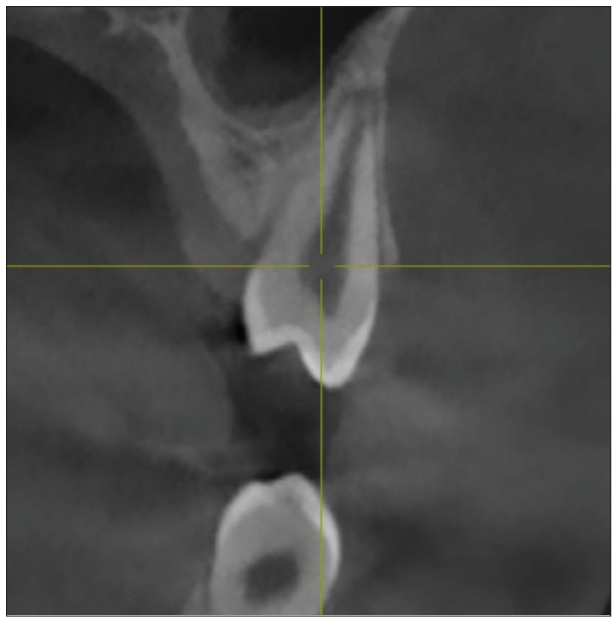

Figure 6. The most common canal configuration of the maxillary second premolar: $^{1}25^{1}$
Slika 6. Najčešća konfiguracija kanala gornjeg drugog premolara: $^{1}25^{1}$

particular tooth has [5]. Also, the progress of technology and the emergence of systems that allow three-dimensional representation of teeth have detected certain variations of canal systems, which due to their complexity could not be classified into already existing categories according to Vertucci. In the study by Filpo-Perez et al. [11], 13% of the distal roots that were examined could not be classified into any of the types of Vertucci's calcification. In 2017, Ahmed et al. [5] proposed a very thorough type of canal configuration classification, which is universal and can be applied to any tooth, regardless of the number of roots, the number of canals in the root, mutual connections, and separations of the canals in the roots.

Analysis of CBCT images in this study showed that the largest number of maxillary first premolars have two roots (71.3%). This is in agreement with the results of studies, which examined morphology on extracted maxillary premolars [12]. A similar prevalence of double-rooted maxillary first premolars was observed in a study conducted in the Polish population [10]. The study by Neelakantan et al. [13] showed that double-rooted first premolars dominated in the population of India in a significantly higher percentage compared to the results of our study. In contrast, the study by Tian et al. [14] showed a higher prevalence of single-rooted first premolars in Chinese population. Such differences in morphology can be explained

by data from the literature that indicate that during tooth root development, genes that differ between populations play a key role and are responsible for such population differences [15]. Within each population, a rare occurrence of three-rooted first premolars was observed, which was also shown by the results of this study [10, 14].

The results of our study showed a higher prevalence of single-rooted maxillary second premolars (71.5%) compared to two-rooted (28.5%). A similar ratio in the root morphology of the maxillary second premolars was observed in a CBCT study, which investigated the number of roots of these teeth in the population of Saudi Arabia [9].

Internal morphology of teeth largely follows the external morphology [4]. However, the results of this study showed that a significant number of teeth, despite having one root, had two canals, which was observed in 11.7% of male and 16.6% female. This is in agreement with the results of the study that analyzed extracted teeth and found that after preparation of the access cavity in single-rooted maxillary premolars, two canals are more often observed than one [16].

The results of our study showed great variability of the canal system of maxillary premolars, which is reflected in the fact that almost all types of configurations were found in these teeth. The largest number of examined maxillary first premolars (64.6%) was marked with the code ^{2}TNB^{1}P^{1} according to Ahmed's classification, which suggests that they have two roots with one canal each. This is in agreement with studies, that classified the canal system of maxillary first premolars this way [10, 15, 17]. Maxillary premolars that have two roots with one canal each, but also those that have one root with two canals, are classified according to Vertrucci [4] in the fourth type. In studies that classified the canal system according to Vetrucci, the largest number of maxillary first premolars had a fourth type canal configuration. This classification does not provide information on whether these premolars had one or two roots, but indicates that they had two canals that started from the floor of the pulp chamber, which was certainly the case in our examination [9, 18]. Two openings on the floor of the chamber were observed in the largest number of maxillary first molars in a study by AlZubaidi et al. [19], who evaluated the configuration of maxillary premolars using CBCT.

The largest number of maxillary second premolars in our study had a canal system that can be marked with the code ^{1}TN^{1}, which is in agreement with the study by Olczak et al. [20], who marked the morphology of the maxillary second premolars in Polish population according to Ahmed's classification. This data shows that one root with a single canal was observed in these teeth, which is in agreement with research, where the most common type of canal system of these teeth was type one according to Vertuucci [18]. A quarter of the maxillary second premolars in our study were coded ^{2}TNB^{1}P^{1}, which indicates teeth that have two roots with one canal each.

In our study, 5.4% of maxillary first premolars and 8.6% of maxillary second premolars had the most demanding canal systems for endodontic treatment, which includes canals that branch and reunite (^{1}TN$^{1\text{-}2\text{-}1}$, ^{1}TN$^{1\text{-}2\text{-}1\text{-}2}$, ^{1}TN$^{2\text{-}1\text{-}2}$). Teeth with such canal configuration, despite adequate diagnostics, can represent a challenge for endodontic treatment, which must be carried out with great caution since there is a risk of rotary endodontic instrument breakage during canal treatment due to overcoming resistance to cyclic fatigue when working in curved canals [21].

Analysis of the external morphology of the roots of the first and second premolars in relation to gender did not reveal a statistically significant difference in the number of roots between men and women, which is in agreement with the results of studies conducted in the Polish population [10, 20]. A significant difference between left and right sides in terms of the number of roots and configuration of the root canal was not observed, which may be of importance to therapists when endodontically treating the same group of teeth on the contralateral side in the same patients.

CONCLUSION

The classification of the tooth canal system according to Ahmed et al. emphasizes the advantage of the simultaneous classification of the number of roots and the number of canals, thus overcoming the ambiguities in this area. Most of the maxillary first premolars had two roots, while most of the second had one root. Due to the complexity of the canal morphology, every seventh maxillary premolar can be a challenge for endodontic treatment, so the analysis of the radiograph before endodontic intervention is imperative. This analysis can be performed in a very reliable way through CBCT images.

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Evaluacija varijacija u morfologiji kanala korena gornjih premolara pomoću kompjuterizovane tomografije konusnog zraka

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KRATAK SADRŽAJ

Uvod Gornji premolari se često podvrgavaju endodontskom tretmanu, što zahteva detaljno poznavanje njihove kanalne morfologije. Cilj ove studije je bio da se analizom snimaka napravljenih metodom kompjuterizovane tomografije konusnog zraka (CBCT) odredi najčešći broj korenova gornjih premolara, kao i da se pomoću novog sistema za klasifikaciju kanalne morfologije autora Ahmeda i saradnika odredi najčešća konfiguracija kanala kod gornjih premolara u populaciji jugoistočne Srbije.

Materijal i metode U studiji je analizirano 55 CBCT snimaka muškaraca i 63 CBCT prikaza žena, u kojima su obuhvaćena 223 gornja prva premolara i 207 gornjih drugih premolara. Analiza je obavljena u programu Galileos. Određen je broj korenova ovih zuba i izvršena je klasifikacija unutrašnje morfologije u odnosu na pol i stranu gornje vilice.

Rezultati Gornji prvi premolari su imali najčešće dva korena i tip konfiguracije ^{2}TNB^{1}P^{1}, dok su gornji drugi premolari imali najčešće jedan koren i tip konfiguracije ^{1}TNB^{1}. Nije uočena statistički značajna razlika u broju korenova i tipu konfiguracije između muškaraca i žena, kao i između leve i desne strane.

Zaključak Klasifikacija kanalnog sistema zuba po Ahmedu i saradnicima ističe prednost istovremene klasifikacije broja korenova i broja kanala. Iako većina premolara ne predstavlja problem za lečenje, registrovane su konfiguracije kanala gornjih premolara koje mogu biti izazov za endodontsko lečenje. Detaljna analiza kanalne konfiguracije se može izvršiti pomoću CBCT.

Ključne reči: endodoncija; konfiguracija kanala; gornji premolari; CBCT

UVOD

Neidentifikovani kanali korena, koji nisu endodontski tretirani, predstavljaju izvor infekcije koji može da kompromituje ishod lečenja i da ugrozi ceo organizam. Ukoliko je tokom endodontskog lečenja zuba kanalni sistem nepotpuno obrađen i opturisan, endodontski tretman se ne smatra uspešnim [1]. Iz ovog proizilazi da je efikasan endodontski tretman zapravo nemoguć bez detaljnog poznavanja broja i pozicije korenova i kanala zuba. Tačna lokalizacija ulaza u kanale korena diktira preparaciju pristupnog kaviteta – važnu fazu endodontskog tretmana. Formiranje pristupnih kaviteta kod zuba prekrivenih krunom zahteva izuzetnu preciznost kako bi se izbeglo eventualno oštećenje same krune. Uklanjanje keramike, više nego što je neophodno, usled nepoznavanja tačne lokalizacije kanala korena može rezultirati pucanjem krune [2]. Ispitivanja varijacija konfiguracija kanala u okviru neke populacije može kliničarima pružiti korisne smernice tokom planiranja i izvođenja endodontskog tretmana na pojedinim zubima. Težnja ka poznavanju mogućih varijacija konfiguracije kanala korena zuba je doprinela konstantnom radu na pronalaženju univerzalnih klasifikacija, koje bi sagledale sve moguće kombinacije kanalnih konfiguracija korena zuba izazvane razdvajanjem i spajanjem kanala. Veliki broj autora je pokušao da klasifikuje kompleksnu morfologiju kanala korena opisujući na desetine tipova kanalnih konfiguracija [3]. Pored već dobro poznate klasifikacije po Vertučiju [4], klasifikacija kanalnih konfiguracija po Ahmedu [5], predstavljena 2017. godine, izdvojila se kao izuzetno korisna. Posebno se istakla zbog specifičnosti da se uz pomoć nje identifikuju konfiguracije kanala koje do tada nisu bile dokumentovane niti opisane u literaturi.

Iako svaki zub može da predstavlja izazov za lečenje, gornji premolari predstavljaju jednu od zahtevnijih grupa zuba za izvođenje endodontskog tretmana. Istraživanje čiji je cilj bio prikupljanje informacija o endodontskom tretmanu, koje su sproveli belgijski stomatolozi, ukazalo je na mnogo veći broj postendodontskih komplikacija kod premolara nego sekutića i očnjaka [6]. Prema studiji koju su sproveli Zaatar i saradnici [7], gornji premolari predstavljaju zube koji se veoma često podvrgavaju endodontskom tretmanu, s obzirom na to da je pomenuto istraživanje zabeležilo da je svaki treći endodontski lečeni zub u gornjoj vilici bio premolar.

Cilj ove studije je bio da se analizom CBCT snimaka odredi najčešći broj korenova gornjih premolara, kao i da se pomoću novog sistema za klasifikaciju kanalne morfologije autora Ahmeda i saradnika [5] odredi najčešća konfiguracija kanala kod gornjih premolara u populaciji jugoistočne Srbije.

MATERIJAL I METODE

Istraživanje je odobreno od strane Etičkog odbora Klinike za dentalnu medicinu u Nišu (01-728/23). U studiji je analizirano 118 CBCT snimaka pacijenata Klinike za dentalnu medicinu u Nišu (55 snimaka muškarca i 63 snimka žena). Snimci su analizirani u programu Galileos (Sirona, Germany). U studiji su analizirana 223 gornja prva premolara i 207 gornjih drugih premolara. Analiza je urađena od strane dvoje iskusnih kliničara, koji su posmatrajući CBCT prikaze određivali broj korenova gornjih premolara i klasifikovali konfiguraciju kanala gornjih premolara prema klasifikaciji Ahmeda i saradnika [5]. U Tabeli 1 su prikazane formule kodova, uz pomoć kojih bi prema primenjenoj klasifikaciji mogle da se označe konfiguracije kanala gornjih premolara. U Tabeli 2 su prikazani kodovi uz pomoć kojih se po Ahmedu i saradnicima [5] mogu označiti

konfiguracije kanala gornjih premolara koje su zabeležene u literaturi i u skladu sa tim korišćene u ovom istraživanju.

REZULTATI

Najveći broj gornjih prvih premolara je imao dva korena. Analiza rezultata je pokazala da nije utvrđena statistički značajna razlika u broju korenova između levih i desnih gornjih prvih premolara. Analizom broja korenova gornjih prvih premolara u odnosu na pol nije utvrđena statistički značajna razlika između muških i ženskih pacijenata (Tabela 3).

Kod većine gornjih drugih premolara uočen je jedan koren. Nije utvrđena statistički značajna razlika u broju korenova između levih i desnih gornjih drugih premolara. Takođe, razlika u broju korenova gornjih drugih premolara između muških i ženskih pacijenata nije bila statistički značajna (Tabela 4).

Najzastupljenija konfiguracija kanala kod gornjih prvih premolara se po Ahmedu i saradnicima [5] može označiti kodom ^{2}TNB^{1}P^{1}, dok je kod gornjih drugih premolara najzastupljeniji kod bio ^{1}TN^{1}. Nije utvrđena statistički značajna razlika u kanalnoj konfiguraciji između premolara leve i desne strane (Tabela 5). Analiza kanalne morfologije gornjih premolara u odnosu na pol nije pokazala statistički značajnu razliku između muškaraca i žena (Tabela 6). Na slikama 2–5 prikazani su neki od CBCT snimaka koji su analizirani u istraživanju.

DISKUSIJA

Iako su retroalveolarni radiološki snimci uobičajeni prilikom endodontskog lečenja, na ovaj način nije uvek moguće potpuno sagledati kanalnu morfologiju zbog kompleksne trodimenzionalne strukture kanala korena zuba. Superponiranje bukalnih i palatinalnih korenova na dvodimenzionalnim snimcima onemogućava adekvatnu procenu broja i pozicije kanala, otežavajući planirane terapijske procedure u endodonciji. Ova poteškoća može da se reši analizom snimaka napravljenih metodom CBCT [8]. Na ovim snimcima omogućen je trodimenzionalni uvid u koštane strukture i morfologiju zuba, što otklanja probleme superponiranja na dvodimenzionalnim snimcima. Pored široke kliničke upotrebe, analiza CBCT snimaka je u literaturi prepoznata kao izuzetno korisna u mnogim istraživanjima koja se bave ispitivanjem morfoloških varijacijama pojedinih zuba u različitim populacijama [9, 10]. Pomoću ove metode ispitivanju je dostupan veći broja zuba, u poređenju sa istraživanjima na ekstrahiranim zuba, koja ograničavaju analizu na zube ekstrahovane iz određenih ortodontskih ili protetskih razloga.

Prilikom klasifikacije konfiguracija kanala gornjih premolara po Vertučiju [4], mnogi autori su se suočili sa problemom, s obzirom na to da ovaj vid klasifikacije ne pruža uvid u broj korenova zuba. Ovo znači da, na osnovu same klasifikacije, nije moguće zaključiti koliko korenova određeni zub ima [5]. Takođe, napredak tehnologije i pojava sistema koji omogućavaju trodimenzionalni prikaz zuba otkrili su određene varijacije kanalnih sistema, koje zbog svoje kompleksnosti nisu mogle da se svrstaju u već postojeće kategorije po Vertučiju. U studiji koju su sproveli Filpo-Perez i saradnici [11] 13% distalnih korenova koji su bili ispitivani nije moglo da se svrsta ni u jedan od tipova Vertučijeve klasifikacije. Ahmed i saradnici [5] predložili su 2017. godine veoma temeljan vid klasifikacije konfiguracije kanala, koji je univerzalan i može da se primeni na bilo kom zubu, bez obzira na broj korenova, broj kanala u korenu, međusobna spajanja i razdvajanja kanala u korenovima.

Analiza CBCT snimaka u ovoj studiji je pokazala da najveći broj gornjih prvih premolara ima dva korena (71,3%). Ovo je u saglasnosti sa rezultatima studija koje su ispitivanje morfologije vršile na ekstrahovanim gornjim premolarima [12]. Slična zastupljenost dvokorenih gornjih prvih premolara je uočena u istraživanju sprovedenom u populaciji Poljske [10]. U studiji koju su sproveli Neelakantan i sar. [13] dokazano je da su dvokoreni prvi premolari dominirali u populaciji Indije u značajno većem procentu u odnosu na rezultate naše studije. Suprotno tome, studija koju su sproveli Tian i sar. [14] na populaciji Kine pokazala je veću zastupljenost jednokorenih prvih premolara. Ovakve razlike u morfologiji se mogu objasniti podacima iz literature koji ukazuju da tokom razvoja korena zuba ključnu ulogu igraju geni koji se razlikuju među populacijama, i koji su zaslužni za ovakve populacione razlike [15]. U okviru svake populacije je uočena retka pojava trokorenih prvih premolara, što su pokazali i rezultati ove studije [10, 14].

Rezultati ove studije su pokazali veću zastupljenost jednokorenih gornjih drugih premolara (71,5%) u odnosu na dvokorene (28,5%). Sličan odnos u korenskoj morfologiji gornjih drugih premolara uočen je u CBCT studiji koja se bavila ispitivanjem broja korenova ovih zuba u populaciji Saudijske Arabije [9].

Unutrašnja morfologija zuba u najvećoj meri prati spoljašnju morfologiju [4]. Međutim, rezultati ove studije su pokazali da je značajan broj zuba, uprkos jednom korenu, imao dva kanala, što je zapaženo kod 11,7% muških ispitanika i 16,6% ženskih ispitanika. Ovo je u saglasnosti sa rezultatima ispitivanja u kojima je analizom ekstrahovanih zuba zaključeno da se nakon formiranja pristupnog kaviteta kod jednokorenih gornjih premolara češće uočavaju dva kanala nego jedan [16].

Rezultati ove studije su pokazali veliku varijabilnost kanalnog sistema gornjih premolara, koja se ogleda u podatku da su kod ovih zuba pronađeni skoro svi tipovi konfiguracija. Najveći broj ispitivanih gornjih prvih premolara (64,6%) označen je kodom ^{2}TNB^{1}P^{1} po Ahmedovoj klasifikaciji, što sugeriše da imaju dva korena sa po jednim kanalom. Ovo je u saglasnosti sa studijama koje su kanalni sistem gornjih prvih premolara klasifikovali na ovaj način [10, 15, 17]. Gornji premolari koji imaju dva korena sa po jednim kanalom, ali i oni koji imaju jedan koren sa dva kanala, u klasifikaciji po Vertučiju [4] svrstavaju se u četvrti tip. U studijama koje su klasifikovale kanalni sistem po Vertučiju najveći broj gornjih prvih premolara je imao konfiguraciju kanala tip IV. Klasifikacija na ovaj način ne daje podatak da li su ti premolari imali jedan ili dva korena, ali ukazuje da su kod njih pronađena dva kanala koja su krenula sa poda komore, što je svakako bio slučaj i u našem ispitivanju [9, 18]. Dva otvora na podu komore su uočena kod najvećeg broja gornjih prvih molara u studiji AlZubaidija i saradnika [19], koji su procenjivali konfiguraciju gornjih premolara korišćenjem CBCT.

Najveći broj gornjih drugih premolara u ovoj studiji je imao kanalni sistem koji se može obeležiti kodom ^{1}TN^{1}, što je u saglasnosti sa studijom koju su sproveli Olczak i saradnici [20], koji su po Ahmedovoj klasifikaciji označavali morfologiju gornjih drugih premolara u populaciji Poljske. Ovakav podatak pokazuje da je kod ovih zuba uočen jedan koren sa jednim kanalom, što je u saglasnosti i sa istraživanjima u kojima je najčešći tip

kanalnog sistema ovih zuba bio tip I po Vertučiju [18]. Četvrtina gornjih drugih premolara u ovoj studiji je označena kodom ^{2}TNB^{1}P^{1}, kojim se označavaju zubi koji imaju dva korena sa po jednim kanalom.

U ovoj studiji 5,4% gornjih prvih premolara i 8,6% gornjih drugih premolara imalo je najzahtevniji kanalni sistem za endodontski tretman, koji podrazumeva kanale koji se granaju pa spajaju (^{1}TN^{1-2-1}, ^{1}TN$^{1-2-1-2}$, ^{1}TN^{2-1-2}). Zubi sa ovakvom konfiguracijom kanala i pored adekvatne dijagnostike mogu predstavljati izazov za endodontski tretman, koji se mora sprovoditi uz veliki oprez budući da i tokom mašinske obrade kanala postoji opasnost od pucanja instrumenta usled prevazilaženja otpornosti na ciklični zamor prilikom rada u zakrivljenim kanalima [21].

Analizom spoljašnje morfologije korenova prvih i drugih premolara u odnosu na pol nije uočena statistički značajna razlika u broju korenova između muškaraca i žena, što je u saglasnosti sa rezultatima studija sprovedenim u populaciji Poljske [10, 20]. Značajna razlika između leve i desne strane u pogledu broja korenova i konfiguracije kanala korena nije uočena, što može biti od značaja terapeutima prilikom endodontskog tretiranja iste grupe zuba na kontralateralnoj strani kod istih pacijenata.

ZAKLJUČAK

Klasifikacija kanalnog sistema zuba po Ahmedu i saradnicima ističe prednost istovremene klasifikacije broja korenova i broja kanala, prevazilazeći time nejasnoće u ovoj oblasti. Većina gornjih prvih premolara je imala dva korena, dok je većina drugih imala jedan koren. Zbog kompleksnosti kanalne morfologije, svaki sedmi gornji premolar može biti izazov za endodontsko lečenje, tako da analiza radiološkog snimka pre endodontske intervencije predstavlja imperativ. Ova analiza se na veoma pouzdan način može ostvariti putem CBCT snimaka.

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