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Anatomical characteristics of the furcation area and root surfaces of multi-rooted teeth: Epidemiological study

Anatomske karakteristike furkacija i korenova višekorenih zuba – epidemiološka studija

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Abstract

Background/Aim. Knowledge of numerous variations in anatomical features of furcation area is a prerequisite for the achievement of more predictable results in the therapy of multi-rooted teeth with furcation involvement (FI). The aim of the study was to evaluate the morphological characteristics of extracted molars of adult population in Belgrade, Serbia. **Methods.** In total, 468 extracted first and second molars, both mandibular and maxillary, were measured. The values of root trunk lengths and root lengths, diameter of furcation entrances (FE), distance between the roots and depth of root concavity were analysed. **Results.** The maxillary first molars had significantly higher root trunk lengths values than the second molars. As for the mandibular molars, FE was smaller than 1 mm. The distance between the roots was more than 2 mm at the third level of measurement. **Conclusion.** The buccal FE of maxillary molars was the lowest. The root concavity of the second mandibular molars was higher from the lingual aspect.

Key words:
furcation defects; molar; odontometry; tooth root.

Apstrakt

Uvod/Cilj. Poznavanje mnogobrojnih varijacija anatomskih karakteristika furkacija (furkacionih regija) je preduslov za postizanje predvidivih rezultata terapije furkacionih defekata višekorenih zuba. Cilj ovog istraživanja je bio procena morfološke karakteristike izvađenih zuba adultne populacije u Beogradu. **Metode.** Merenja su vršena na ukupno 468 izvađenih prvih i drugih molara i gornje i donje vilice. Analizirane su izmerene vrednosti dužine korenskog stabla i dužine korenova, prečnik ulaza u furkaciju, odstojanje između korenova i dubina korenskog konkaviteta. **Rezultati.** Prvi gornji molari su imali signifikantno veće vrednosti dužine korenskog stabla od drugih gornjih molara. Kod donjih molara, prečnik ulaska u furkaciju bio je manji od 1 mm. Na trećem nivou merenja, odstojanje između korenova imalo je vrednost veću od 2 mm. **Zaključak.** Prečnik ulaska u furkaciju sa bukalne strane gornjih molara bio je najmanji. Dubina korenskog konkaviteta drugih donjih molara bila je veća sa lingvalne strane.

Ključne reči:
furkacija, defekti; molari; odontometrija; zub, koren.

Introduction

During periodontitis, the process of periodontal tissue breakdown can affect the alveolar bone loss in furcations of multi-rooted teeth. The American Academy of Periodontology (AAP) has defined furcation as "an anatomical part of a multi-rooted tooth where roots begin forking" and a furcation involvement (FI) tooth is referred to as a tooth with "pathological resorption of the supporting alveolar bone within a furcation" [1].

Consequently, in the course of deepening the gingival sulcus and periodontal pocket formation, the root surface of the tooth becomes exposed, thus increasing the area suitable for the adherence of dental plaque and colonization of periodontopathic bacteria [2]. At the same time, the progression of periodontal lesion destruction depends on root morphology [3].

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Another specific feature of the periodontal pocket in the region of tooth furcation is the existence of its horizontal dimension, toward the interior part of the furcation as well as its vertical dimension along the root due to the bone and attachment loss. There is a clear classification of FI based on the degree of horizontal and/or vertical probe penetration [4].

The molars demonstrate the highest rate of periodontal destruction in untreated disease and suffer the highest frequency of loss for periodontal reasons [5–7]. On the other hand, the teeth with FI respond less favourably to the conventional periodontal therapy unlike the ones with no FI molars or one-rooted teeth [8]. The prognosis and treatment of those teeth can be challenging both for dentists when approaching adequate instrumentation of the affected area and for patients who are involved actively in maintaining the condition of periodontal tissues. However, a large number of treatment methods, including the nonsurgical and surgical mechanical debridement, furcation plasty, tunnelling procedures, hemisections, root resections and regenerative procedures can manage the anatomic area.

Both long-term retrospective studies as well as prospective studies showed less favourable reports for the FI molars. Hirschfeld and Wasserman [9] indicated that, in the period of 22 years, the patients included in a supportive periodontal therapy program lost 7.1% of all teeth for the periodontal reasons. The matching result for the multi-rooted teeth with FI was 31%. Other similar studies confirmed these findings, such as those by McFall [10], Goldman et al. [11]. The findings of the studies done by Loos et al. [12] and Claffey and Egelberg [13] showed that FI molars had a poorer response to non-surgical periodontal therapy and tend to lead to gradual attachment loss.

The practical applications from the AAP Regeneration Workshop defined: “the factors other than systemic, which affect or limit successful treatment, are local and specific to the anatomy of the furcation region, such as root trunk length (RTL), root concavities (RC), root proximity/convergence, furcation entrance (FE) width” [14]. Furthermore, the local factors related to the course of periodontitis of multirooted teeth are the root length (RL), distance between the roots (DBR) and developmental abnormalities (e.g., enamel pearls, cement-enamel projections, accessory endodontic canals and bifurcation ridges) [15, 16].

RTL refers to the distance between the cement-enamel junction and furcation [17]. RTL in addition to the amount of bone loss were suggested to supplement the furcation classification [18]. Moreover, the root trunks can be classified into different types according to Hou and Tsai [19], based on the ratio of root trunk height to RL. The root trunk surface areas of the mandibular and maxillary molars comprise on average 31% and 32% of the total root surface area respectively [20, 21]. Therefore, a root body is compromised by the loss of horizontal attachment, which leads to furcation invasion, the consequence of which is the loss of one third of the total periodontal support of a tooth [22]. Debridement and maintenance of the furcation area are made difficult due to the size of FE. The study of dos Santos et al. [23] shows that the majority of FEs are smaller than the dimensions and curvature of the treatment curette.

Both prognosis and treatment plan are equally influenced by the position of roots of multi-rooted teeth affected by periodontitis[24]. The convergent roots, representing small DRT, are more difficult to regenerate and disease progression in the FI teeth is accelerated. In the case of some specific anatomical characteristics, a multi-rooted tooth implies the presence of the concavity in the furcation area. The role of RC in physiological conditions is to improve the resistance of a tooth to the strong mastication forces [25]. On the other hand, the presence of RC is an important additional local etiological factor supporting the retention of the biofilm.

The aim of the present study is to evaluate the most important anatomic features, such as RTL, RL, diameter of FE, DBR at different levels as well as the depth of RC of maxillary and mandibular molars of adult population in Belgrade, Serbia.

Methods

This epidemiological study included extracted permanent first and second molars: 134 first and 97 second mandibular molars, as well as 121 first and 116 second maxillary molars. The study was conducted in accordance with the Declaration of Helsinki 1975, as revised in 2002. The protocol was approved by the Ethics Research Committee of the Faculty of Dental Medicine, University of Belgrade, Belgrade, Serbia. The teeth were collected at the Department of Oral Surgery, Faculty of Dental Medicine, University of Belgrade, Belgrade, Serbia.

In order to be included in the study, the teeth should have intact crowns and complete roots as well as the preserved cemento-enamel junction, furcation area and the area coronal and apical from the furcation.

After extraction, the teeth were washed with water and immersed in 15% hydrogen peroxide for a period of 24 hours. The debris comprised of the periodontal fibers was removed by a hand curette and the residual supragingival and subgingival calculi were eliminated carefully by an ultrasonic scaler. The measurements were performed by using the electronic caliper (Electronic caliper; Orion 31,170, 210) and a compass with one screw.

The following parameters were measured on the selected molars: RTL corresponded to the area of tooth extending from the cement-enamel junction to the furcation entrance. On maxillary molars, this length was measured at the buccal, mesial and distal sides of the root trunk, and on the mandibular molars, at the buccal and lingual sides. RL represented the distance from the cement-enamel junction to the root apex. RL was measured for the mesial and distal roots of mandibular molars, and for all three roots of maxillary molars. The diameter of the FE was measured between the mesial and distal roots of mandibular molars from the buccal and lingual sides, while on the maxillary molars, it was measured between the mesial and distal roots, the mesial and palatal roots as well as the distal and palatal roots. DBR of each tooth were measured at five levels, from each side of tooth. The first level was located 1 mm apically from the furcation entrance and each subsequent measurement was performed 1 mm apically from the previous point. The last level of measurement was located 5 mm apically from the furcation entrance. The depth of the RC is located coronal from the furcation, on the roof of the furcation and apically from the furcation. Consequently, the concavity depth measurements were performed at three levels. The teeth were cut in the same furcation region followed by 2 mm coronary from the furcation and about 2 mm apically from the furcation. The cutting was done by a high power turbine handpiece (Kavo SUPERTORQUE lux 2 640db) using a fissure diamond drill of 0.12 mm in diameter. After noticing these concavities, they were measured at the deepest parts.

The statistical analysis was performed using the STATGRAPHICS® Centurion XVI. I. The program was designed to compare two samples of data and calculate various statistics and graphs for each sample. The extracted teeth were used as units of analysis. RTL, RL and FE diameter were reported using the parameters of central tendency (mean, median) and variations (standard deviation, min, max), and 99.9% confidence interval (CI). One Way ANOVA was used for evaluating the mean values of the distance between the roots and depth of RC. The statistical significance of differences in the observed parameters between the groups, at each observation point, was analyzed by using the paired samples: *t*-test, F-test, W-test. The Kolmogorov-Smirnov test was used to compare distributions of the two samples. The test was performed by calculating the maximum distance between the cumulative distributions of the two samples. In the Multiple Range Tests, these intervals were used to determine the significant difference of the mean values. The statistical significance of all the tests was defined as $p < 0.001$.

Results

There was a statistically significant difference between the buccal and lingual sides of the RTL in the group of mandibular first molars (Table 1). Unlike the lingual side, the mean values of RTL at the buccal side of the first molar were significantly lower compared to the buccal sides of the second molar. The RTL value for the first maxillary molars was significantly higher compared to the second molars regarding the RTL at the mesial aspect. Both in the first and the second molars, RTL on the distal aspect was significantly bigger compared to the RTL on either mesial or buccal aspect.

The mean value of mesial and distal RL of the second mandibular molars was significantly higher than the value of the first molars (Table 1). The mean value of mesiobuccal and palatal RL-s of the first maxillary molars was significantly higher compared to the second molars, in contrast to distobuccal. For the maxillary first molars, the mean lengths of mesiobuccal and palatal roots (12.36 ± 1.71 mm and 13.09 ± 1.74 mm, respectively) were longer than the distobuccal roots (11.8 ± 1.73 mm). As opposed to that, the mean length of the mesiobuccal root of the maxillary second molar was shorter (11.53 ± 0.11 mm) compared to the mean length of distobuccal and palatal roots (12.50 ± 0.13 mm and 12.66 ± 1.43 mm, respectively).

The results in Table 1 demonstrate that a statistically significant difference was measured between the mean values of the buccal and the lingual FE of the mandibular molars. The buccal FE was wider on the first molars than on the second molars.

Table 1

Root trunk length (RTL), root length (RL) of the first and second mandibular and maxillary molars and furcation entrance of mandibular and maxillary molars

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
Mandibular molars (1st and 2nd)				
RTL				
BRT				
1st	3.27 ± 0.71 (2.26–5.23)	3.03	21.89	0.000
2nd	3.66 ± 0.40 (2.76–4.36)	3.66	10.93	
LRT				
1st	4.30 ± 0.85 (3.01–6.94)	4.12	19.86	0.039
2nd	3.73 ± 0.43 (2.9–4.58)	3.67	11.47	
RL				
M				
1st	12.80 ± 1.68 (9.35–16.34)	12.98	13.15	0.000
2nd	13.62 ± 0.65 (11.25–14.35)	13.81	4.75	
D				
1st	12.83 ± 1.66 (9.54–16.01)	13.01	12.96	0.000
2nd	13.67 ± 1.15 (11.23–23.0)	13.78	8.40	

Table 1 (*continued*)

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
FE				
BFE				
1st	0.77 ± 0.05 (0.65/0.87)	0.78	6.43	0.000
2nd	0.57 ± 0.06 (0.45–0.7)	0.57	10.41	
LFE				
1st	0.67 ± 0.05 (0.54–0.8)	0.68	8.06	0.000
2nd	0.44 ± 0.05 (0.3–0.54)	0.44	11.80	
Maxillary molars (1st and 2nd)				
RTL				
BRT				
1st	4.53 ± 0.85 (3.24–7.21)	4.38	18.72	1.366
2nd	3.71 ± 0.41 (2.87–4.4)	3.67	10.93	
MRT				
1st	4.85 ± 0.87 (3.41–7.57)	4.75	17.90	0.000
2nd	4.57 ± 0.47 (3.74–5.56)	4.49	10.19	
DRT				
1st	3.91 ± 0.70 (2.45–5.80)	3.82	17.88	0.031
2nd	3.83 ± 0.40 (2.90–4.52)	3.80	10.39	
RL				
MB				
1st	12.36 ± 1.71 (9.12–16.5)	12.32	13.87	0.000
2nd	11.53 ± 0.11 (11.29–11.76)	11.54	0.95	
DB				
1st	11.80 ± 1.73 (8.74–16.84)	11.54	14.67	2.087
2nd	12.50 ± 0.13 (12.27–12.77)	12.49	1.06	
PAL				
1st	13.09 ± 1.74 (10.01–17.2)	12.81	13.29	0.000
2nd	12.66 ± 1.43 (9.75–16.86)	12.22	1.94	
FE				
BFE				
1st	0.60 ± 0.08 (0.43–0.79)	0.59	13.82	0.000
2nd	0.53 ± 0.06 (0.42–0.67)	0.53	11.14	
MFE				
1st	1.37 ± 0.08 (1.13–1.52)	1.38	5.67	0.848
2nd	1.37 ± 0.07 (1.21–1.53)	1.36	4.96	
DFE				
1st	1.14 ± 0.04 (1.04–1.25)	1.14	3.79	0.000
2nd	0.9 ± 0.07 (0.75–1.04)	0.9	7.43	

BRT – buccal root trunk; LRT – lingual root trunk; MRT – mesial root trunk; DRT – distal root trunk; M – mesial RL; D – distal RL; MB – mesiobuccal; DB – distobuccal; PAL – palatal; BFE – buccal furcation entrance; LFE – lingual furcation entrance; MFE – mesial furcation entrance; DFE – distal furcation entrance; SD – standard deviation.

The maximum measured value 0.87 ± 0.05 mm was at the buccal side of the first molar and the minimum 0.30 ± 0.05 mm at the lingual FE of the second mandibular molar. For the maxillary molars, FE was wider on the first molars compared to the second molars, except for the mesial FE. This FE was the widest and equal for both molars, approximately 1.37 ± 0.07 mm. The narrowest FE of 0.54 ± 0.05 mm was measured at the buccal side, which was, fortunately, more accessible area for scaling and root planning than the mesial or distal one.

DBR of the first mandibular molars was significantly higher than DBR of the second molars (Table 2). DBR measured at the buccal side 1mm apically from the FE was only 0.26 ± 0.04 mm, but at the fifth level of measurement (5 mm from the FE), it reached the value of 4.03 ± 0.14 mm. Lingual DBR ranged from 0.65 ± 0.06 mm to 3.67 ± 0.07 mm. DBR of maxillary first and second molars had a significant difference only regarding the values of distobuccal and palatal roots. The smallest values were measured between the mesiobuccal and palatal roots of the second molars (from 1.4 ± 0.06 mm to 2.53 ± 0.06 mm, that is, from the first to the fifth level, respectively). The highest values were measured between mesiobuccal and palatal roots of the first molars (Table 2). These values ranged from 2.23 ± 0.08 mm to 6.69 ± 0.013 mm from the first to the fifth level, respectively.

Table 2

The distances between the roots of first and second mandibular and maxillary molars and between maxillary molars

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
Mandibular molars (1st and 2nd)				
Bdm-d				
1d				
1st	0.86 ± 0.04 (0.26–0.87)	0.87	5.11	0.000
2nd	0.68 ± 0.06 (0.57–0.8)	1.54	8.50	
2d				
1st	1.53 ± 0.07 (1.37–1.68)	0.68	4.49	0.000
2nd	1.33 ± 0.05 (1.2–1.44)	1.33	3.70	
3d				
1st	2.19 ± 0.10 (1.89–2.6)	2.18	4.62	0.000
2nd	2.00 ± 0.05 (1.86–2.09)	1.99	2.32	
4d				
1st	2.83 ± 0.13 (2.53–3.25)	2.83	4.45	3.551
2nd	2.65 ± 0.05 (2.51–2.75)	2.65	1.73	
5d				
1st	3.61 ± 0.14 (3.17–4.03)	3.62	3.97	0.000
2nd	3.33 ± 0.05 (3.19–3.43)	3.34	1.42	
Ld m-d				
1d				
1st	0.79 ± 0.06 (0.65–0.92)	0.8	7.58	0.000
2nd	0.55 ± 0.05 (0.42–0.65)	0.55	8.98	
2d				
1st	1.46 ± 0.06 (1.32–1.6)	1.47	4.26	0.000
2nd	1.22 ± 0.05 (1.09–1.32)	1.22	4.02	
3d				
1st	2.14 ± 0.06 (2.0–2.29)	2.15	2.99	0.000
2nd	1.89 ± 0.05 (1.75–1.99)	1.89	2.63	
4d				
1st	2.82 ± 0.07 (2.68–2.98)	2.89	2.33	0.000
2nd	2.56 ± 0.05 (2.42–2.66)	2.56	1.96	

Table 2 (*continued*)

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
5d				
1st	3.49 ± 0.07 (3.33–3.67)	3.50	1.99	0.000
2nd	3.24 ± 0.05 (3.1–3.34)	3.24	1.59	
Maxillary molars (1st and 2nd)				
mb-db				
1d				
1st	2.09±0.08 (1.84–2.23)	2.09	3.59	2.256
2nd	2.09±0.07 (1.84–2.23)	2.08	3.19	
2d				
1st	1.65 ± 0.07 (1.49–1.78)	1.65	4.34	0.000
2nd	1.51 ± 0.06 (1.4–1.64)	1.51	3.83	
3d				
1st	2.15 ± 0.08 (1.99–2.3)	2.15	3.64	2.445
2nd	2.05 ± 0.06 (1.94–2.18)	2.05	3.02	
4d				
1st	2.69 ± 0.09 (2.5–2.89)	2.69	3.40	
2nd	2.60 ± 0.06 (2.48–2.73)	2.60	2.37	2.336
5d				
1st	2.72 ± 0.09 (2.54–2.93)	2.72	3.40	1.747
2nd	2.64 ± 0.06 (2.53–2.78)	2.65	2.35	
db-pal				
1d				
1st	1.66 ± 0.04 (1.56–1.76)		2.61	0.000
2nd	1.42 ± 0.07 (1.27–1.55)		4.66	
2d				
1st	2.70 ± 0.05 (2.57–2.8)		1.73	0.000
2nd	2.45 ± 0.06 (2.31–2.59)		2.58	
3d				
1st	1.65 ± 0.07 (1.49–1.78)		4.34	0.000
2nd	1.42 ± 0.07 (1.27–1.55)		4.66	
4d				
1st	4.02 ± 0.10 (3.83–4.21)		2.54	0.000
2nd	2.45 ± 0.06 (2.31–2.59)		2.58	
5d				
1st	5.31 ± 0.10 (5.14–5.51)		1.94	0.000
2nd	1.42 ± 0.07 (1.27–1.55)		4.66	
mb-pal				
1d				
1st	2.09 ± 0.08 (1.84–2.23)		3.59	0.806
2nd	2.09 ± 0.07 (1.95–2.25)		3.19	

Table 2 (*continued*)

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
2d				
1st	2.74 ± 0.06 (2.49–2.89)		2.26	0.464
2nd	2.75 ± 0.07 (2.64–2.9)		2.42	
3d				
1st	4.09 ± 0.07 (3.84–4.23)		1.67	0.597
2nd	4.09 ± 0.07 (3.96–4.25)		1.71	
4d				
1st	5.16 ± 0.12 (4.12–5.33)		2.29	0.219
2nd	5.14 ± 0.16 (4.38–5.33)		3.05	
5d				
1st	6.51 ± 0.13 (5.47–6.69)		1.93	0.689
2nd	6.50 ± 0.16 (5.73–6.7)		2.43	

Bd m-d – distance between mesial and distal root from buccal side; Ld m-d – distance between mesial and distal root from lingual side; mb-db – distance between mesiobuccal and distobuccal root; db-pal – distance between distobuccal and palatal root; mb-pal – distance between mesiobuccal and palatal root; 1d – first level of measurement; 2d – first level of measurement; 3d – third first level of measurement; 4d – fourth first level of measurement; 5d – fifth first level of measurement.

There was a statistically significant difference between the RC depth of the first and second molars, both at the buccal and lingual side. However, there was no proper distribution at each level in spite of the fact whether the RC depth was higher at the buccal or lingual side. The RC depth of distal roots, apically from the furcation, was the smallest one; the highest value of the RC depth was obtained at the buccal side of the mandibular second molar (Table 3). The mean values of the RC depth of maxillary molars were considerably lower than concavity of mandibular molars and did not exceed 2.74 ± 0.36 mm. RC was not found at the palatal root of maxillary molars, i.e., apically from the furcation (Table 3).

Table 3

The depths of root concavity of mandibular and maxillary molars

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
Mandibular molars (1st and 2nd)				
BKF				
1st	1.02 ± 0.07 (0.85–1.34)	1.01	1.76	0.000
2nd	0.93 ± 0.19 (0.62–1.56)	0.89	1.84	3.6
LKF				
1st	0.88 ± 0.08 (0.74–1.28)	0.88	2.41	0.000
2nd	1.19 ± 0.21 (0.78–1.72)	1.19	7.06	0.000
BNF				
1st	3.28 ± 0.02 (3.22–3.38)	3.28	3.35	0.000
2nd	3.82 ± 0.33 (3.1–4.61)	3.79	5.62	0.000
LNF				
1st	3.71 ± 0.02 (3.65–3.74)	3.71	15.48	0.000
2nd	3.25 ± 0.44 (2.48–4.23)	3.12	17.39	3.02

Table 3 (*continued*)

Parameters	Mean ± SD, mm (minimum-maximum)	Median, mm	Cofficient of variation (%)	*p*
m root				
1st	0.49 ± 0.02 (0.46–0.54)	0.49	13.87	0.000
2nd	0.55 ± 0.06 (0.43–0.68)	0.54	15.01	0.49
d root				
1st	0.71 ± 3.37 (0.26–2.8)	0.29	27.42	0.000
2nd	0.25 ± 0.04 (0.18–0.33)	0.26	21.65	0.18
Maxillary molars (1st and 2nd)				
KF				
1st				
Mc	0.62 ± 0.10 (0.35–0.92)	0.63	15.48	2.33
Dc	0.53 ± 0.09 (0.25–0.78)	0.53	17.39	0.000
Bc	0.69 ± 0.10 (0.41–0.99)	0.7	13.87	0.000
2nd				
Mc	0.55 ± 0.08 (0.4–0.71)	0.53	15.01	0.000
Dc	0.34 ± 0.09 (0.17–0.52)	0.36	27.42	0.000
Bc	0.44 ± 0.09 (0.21–0.61)	0.44	21.65	0.000
NF				
1st				
Mc	2.74 ± 3.60 (2.36–42.0)	2.42	13.21	0.85
Dc	1.18 ± 0.02 (1.13–1.22)	1.17	1.76	0.000
Bc	2.71 ± 0.05 (2.21–2.76)	2.71	1.84	0.000
2nd				
Mc	2.68 ± 0.06 (2.48–2.78)	2.69	2.41	0.75
Dc	0.87 ± 0.06 (0.74–0.98)	0.87	7.06	0.000
Bc	1.83 ± 0.02 (1.7–1.96)	1.82	3.35	0.000
AF				
1st				
MBc	0.35 ± 0.02 (0.29–0.4)	0.35	5.62	0.000
DBc	0.03 (0–0.06)	0.03	60.45	0.000
PALc	0	0	0	0.000
2nd				
MBc	0.28 ± 0.02 (0.14–0.4)	0.29	20.15	0.000
DBc	0.04 (0–0.1)	0.03	55.10	0.000
PALc	0	0	0	0.000

BKF – depth of buccal root concavity coronally from the furcation; LKF – depth of lingual root concavity coronally from the furcation; B NF – depth of buccal root concavity on the roof of the furcation; LNF – depth of buccal root concavity on the roof the furcation; m root – depth of mesal root concavity (apically from the furcation); d root – depth of distal root concavity (apically from the furcation); KF – depth of root concavity coronally from the furcation from the Mc - mesial, Dc - distal and Bc - buccal side; NF – depth of root concavity on the roof of the furcation; AF-NF – depth of root concavity apically of the furcation; MBc – depth of mesiobuccal root concavity (apically from the furcation); DBc – depth of distobuccal root concavity (apically from the furcation); PALc – depth of palatal root concavity (apically from the furcation).

Discussion

Anatomical features of furcation area may cause initiation and persistence of periodontal disease. The FI tooth leads to more difficult diagnosis and makes the treatment outcome less predictable. Johansson et al. [26] reported that the molars with FI were more frequently lost after 13–16 years of periodontal therapy compared to the molars without FI. It has been indicated that the teeth with FI respond less favorably to the conventional periodontal therapy compared to the noninvolved molars, or the one-rooted teeth [8]. The researches on the incidence of exacerbation over a two-year period following the nonsurgical periodontal therapy pointed that the probing attachment loss was two to three times more frequent in furcation defects compared to nonfurcation areas [27]. As for the individuals aged 40 and more years, every second molar was affected by the advanced periodontal destruction (Class II-III) in at least one furcation site [28]. Furthermore, the prevalence of molars with FI was found to be higher in the maxilla than in the mandible. The most commonly affected tooth site was the distal aspect of the first maxillary molars [29].

RTL has important impact on the pathogenesis of periodontal disease. This is one of the key anatomical factors that make molars particularly susceptible to periodontal disease [30]. If a root trunk is shorter, it will lead to the earlier occurrence and development of diseases; however, it will be easier to instrument a furcation lesion [31–34]. On the other hand, a long root trunk protects furcation from periodontal disease involvement in the initial stage of periodontitis [24]. If a furcation is affected, the prognosis is poorer for higher RTL, because the access for instrumentation is hampered [25]. Additionally, the FI molar with the short roots indicates the reduced chance of repair after the periodontal therapy and it could not be a candidate for the root apicectomy because the periodontal support of these teeth is lost in proportion with the furcation invasion [18, 24, 35]. Horwitz et al. [33] concluded that a long root trunk and wide FE decreased the chance of successful periodontal treatment.

According to our measurement, the highest RTL value of 7.57 ± 0.86 mm was found at the distal side of maxillary first molars and 6.94 ± 0.85 mm at the lingual side of mandibular first molars. On the other hand, the minimum value of the buccal side of mandibular first molar was 2.26 ± 0.71 mm and maxillary first molar 2.45 ± 0.70 mm at the distal side. This means that at the beginning of periodontitis, the consequences of furcation involvement may occur at the probing depth of 3–4 mm [36]. Furthermore, we found higher root trunks of the first maxillary molars compared to the second ones. It was opposite with the mandibular molars on the buccal side, where the second molars were of a higher RTL value than the first ones, which corresponded to the results of the study of Sanz et al. [37]. The results of our study regarding RTL also corresponded to the findings of Hou and Tsai [19] and Plagmann et al. [36]. They showed significantly higher RTL at the oral sides than at the buccal sides of mandibular molars as well as at the approximal sides than at the buccal sides of maxillary molars. The mandibular molars generally have shorter root trunks than the maxillary molars [38].

The prognosis for molars with short root trunks and more divergent roots is better when root resection is applied [39]. A short root trunk and a wide diameter of the furcation entrance are criteria for a tunnel preparation. Such a procedure is a part of resective furcation therapy used to enable a patient to manage postoperative plaque properly [18].

RL is directly related to the amount of a tooth attachment support [1]. In the present study, the mean RL of mandibular first molars was significantly smaller than that of the second ones, which matched the results obtained by Roussa [25] and Bower [40], while the RL of the maxillary molars showed different results. The highest mean value was measured for the palatal root, unlike the study of Roussa [25] which showed the highest RL of distobuccal root [40]. The distobuccal root of maxillary first molars and the distal root of the mandibular first molars had the smallest RL [40]. Therefore, when all other factor are identical, these roots are the first to be removed when root resection procedures are considered.

The diameter of the furcation entrance is another important factor. Svärdström and Wennström [28] found the highest frequency of FI at the distal side of maxillary first molars (53%), while the lowest frequency was with the mesial aspects of maxillary second molars (20%). The complexity of the area morphology after the attachment loss creates a favorable environment for bacteria plaque retention and contributes to the pathogenesis of the periodontal destruction [24, 28].

Proper instrumentation of furcation defects has always been a challenge for dentists due to the limited accessibility through furcation entrances. The blades of periodontal manual instruments, curettes have to be of a width that would produce a smooth and biologically acceptable surface, which would allow satisfactory healing [41, 42]. Various studies regarding the relationship of FE and blade widths confirmed such difficulty in the periodontal therapy of molar furcations [23, 40]. The diameter of FE was < 0.75 mm in about one half of the measured teeth; however, in more than 80% of the teeth such entrance diameters were < 1 mm and the active tip of an instrument (e.g.: Gracey curette), being 0.95–1.2 mm wide, does not fit to the furcation area [23, 40, 43, 44].

The results of our study showed that the mean values of FE for the mandibular molars, except buccal FE of the first ones, were lower than 0,75 mm as well as the buccal FE of the maxillary molars. Interestingly, the buccal FE of maxillary tooth was the narrowest. The mesial and distal FE of maxillary molars were higher than 1mm, except distal FE of the second molar.

A recent study of the radiographic characteristics of FI showed that narrow FE can have better outcome after the nonsurgical periodontal therapy. It probably resulted from the lower exposure to contaminants and less root irregularities [45]. With reduced root separation, the use of hand instruments cannot ensure effective root surface instrumentation in the furcation as a basis for successful healing. An ultrasonic scaler is smaller than curette tips and it is recommended for the periodontal treatment of furcation involvement [46, 47]. In such cases, the use of special instruments, e.g., diamond-coated air scaler tips for the odontoplastic method are recommended [48].

Regarding the regenerative therapy, Pepelassi et al.[49] showed that the distance between the roots of 2 mm, or greater ensures more favorable regenerative healing. The results from our study showed that DBR greater than 2 mm was at the third level of measurement, i.e., 3 mm from the FE, except for the first maxillary molar. It had such a distance even at the first level (between the mesiobuccal and palatal root). However, it was concluded that higher root divergence was associated with a larger furcation defect, which may be accompanied with the reduced horizontal bone gain, furcation closure and favorable regenerative outcome [14]. Moreover, Pontoriero, et al. [51] stated that the furcation width at radicular separation area greater than 4 mm² and the FE height of 3 mm, or greater failed to heal the complete defect closure. This means that it should be added to the list of making treatment decision whether the regenerative therapy is indicated or not in a specific region of FI teeth.

In case of a short root trunk, the occurrence of developmental grooves and trunk surface concavities are other factors to be considered as the contributors to the outcome of nonsurgical or regenerative periodontal therapy [52].

Interestingly, the RC of maxillary molars had the significantly higher measured values of mandibular molars. The palatal root demonstrated complete absence of the concavity. Lu [53] reported that the depth of root trunk developmental concavities was variable in 94% furcations. Our results do not correspond to those of Roussa [25] and Dunlap and Gher [20] study, who showed larger concavities at the buccal aspects both for the first and the second mandibular molar. The mean value of the RC of second mandibular molars was higher at the lingual aspects.

The RC increases the attachment area of the tooth, thus making it resistant to the torque forces. On the other hand, curettes alone would most probably fail to achieve adequate preparation of deep concavity of furcation. Additionally, the concavities may hamper complete coverage of root surfaces by membrane. Lu [53] measured the concavities at the level of 1–2 mm below the cement-enamel junction and found concavities ranging from 0.00 to 2.25 mm. Based on these observations, the author concluded that in the majority of molars, the subgingival application of a guided tissue membrane being 1–2 mm below the cement-enamel junction could not ensure complete adaptation of furcation defects.

According to the study of Schwendicke et al. [54] "the periodontal treatments aimed at tooth retention were found to be more effective and less costly than tooth replacement with implant supported crowns (ISCs) in the treatment of furcation class II/III. Despite long-term retention of FI molars, different intervals of supportive periodontal treatment and even surgical procedures, the costs were still less than implant supported crowns with the exception of root resection".

Conclusion

The value for the buccal RTL of mandibular first molars was the lowest, which could lead to an early appearance of FI. The buccal FE was the narrowest in the maxillary molars, and the distal FE was the most apically positioned, which could be rather challenging to be diagnosed. The mean value of RC of the mandibular second molar was the highest one. The palatal roots of the maxillary first and second molars were without concavities. The total of 468 teeth indicate the variability of furcation morphology, having thus considerable influence on the etiology and severity of periodontitis as well as on the therapeutic success and possible recurrence of the disease or disease progression.

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