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ORIGINAL ARTICLE

Determination of canal orifice co-ordinates and MB2 incidence of maxillary first molars in a Turkish sub-population

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Abstract

Objectives. To measure the co-ordinates of the root canal orifices and to determine the incidence of mesiobuccal-2 (MB2) in maxillary first molars in a Turkish sub-population. ***Materials and methods.*** Standard digital photographs were taken under a stereomicroscope from the occlusal aspect of each tooth (n = 176) before and after crown removal. Canal orifices were negotiated under moderate magnification using dental loupes. The coordinates of the orifices and the distances of each from the central fossa were measured by using geographic software. Intensity maps of the orifice locations were created by using the co-ordinates of all canal orifices. A representative map was drawn using the mean values of orifice locations and access projection area. ***Results.*** In the right maxillary first molars, the mean values for the (X, Y) co-ordinates were (0.67, 2.68) for mesiobuccal-1 (MB1), (0.81, 0.84) for MB2, (−1.12, 1.26) for distobuccal-1 (D1), (−0.89, 0.23) for distobuccal-2 (D2) and (0, −2.50) for palatinal (P); the corresponding mean values in the left maxillary first molars were (−0.78, 2.56), (−0.98, 0.90), (0.99, 1.18), (0.69, 0.78) and (0.00, −2.53), respectively. The average MB1–MB2 distance was 1.97 mm. Distobuccalcanal orifices were localized at the distal side of the center in 98.3% of teeth. The incidence of MB2 was 46.02%. ***Conclusions.*** The distobuccal canal orifice is mostly located on the distal side of the central fossa. Thus, it should be considered that the access cavity of the maxillary molars may not be always limited mesially. The incidence of MB2 in this sub-population was 46.02%, which is of great importance clinically.

Key Words: *co-ordinate, incidence, maxillary first molar, MB2, root canal orifices*

Introduction

The maxillary first molar is one of the largest teeth by volume and has the most complex root and root canal anatomy; it is also the most treated and least understood. Endodontic treatment of these teeth has high failure rates due to operators' failures to detect, debride or obturate the second canal in the mesiobuccal root [1-4]. The external outline form of the access cavity evolves from the internal anatomy of the tooth established by the pulp [4]. According to the major principles of endodontic access, the access outline of the maxillary first molars is entirely within the mesial half of the tooth, which means that the transverse ridge need not be invaded [5].

Diagnostic tools such as illumination and magnification can help locate the root canal orifices; a clinician may further improve the access cavity design by correlating the occlusal anatomy with the location of the root canal orifices [3]. Pre-operative predictors related to the detection of root canal orifices are important since they are the only information available before the initiation of root canal treatment [6].

First maxillary molars are investigated in terms of their root and canal morphology as well as the number and sizes of pulp chamber [1,7–11]. The current primary source of information is the study of Hess and Zürcher [3], who reported a 54% mesiobuccal-2 (MB2) incidence in maxillary molars. Clearing, sectioning, radiographic techniques and moderate magnification were used until the end of the 1990s. Since the 2000s, dental operating microscopes (DOMs) have been used as the most reliable aid in clinical practice. Although sectioning is regarded as the gold standard for *in vitro* studies, several computed tomographic (CT) devices are being developed

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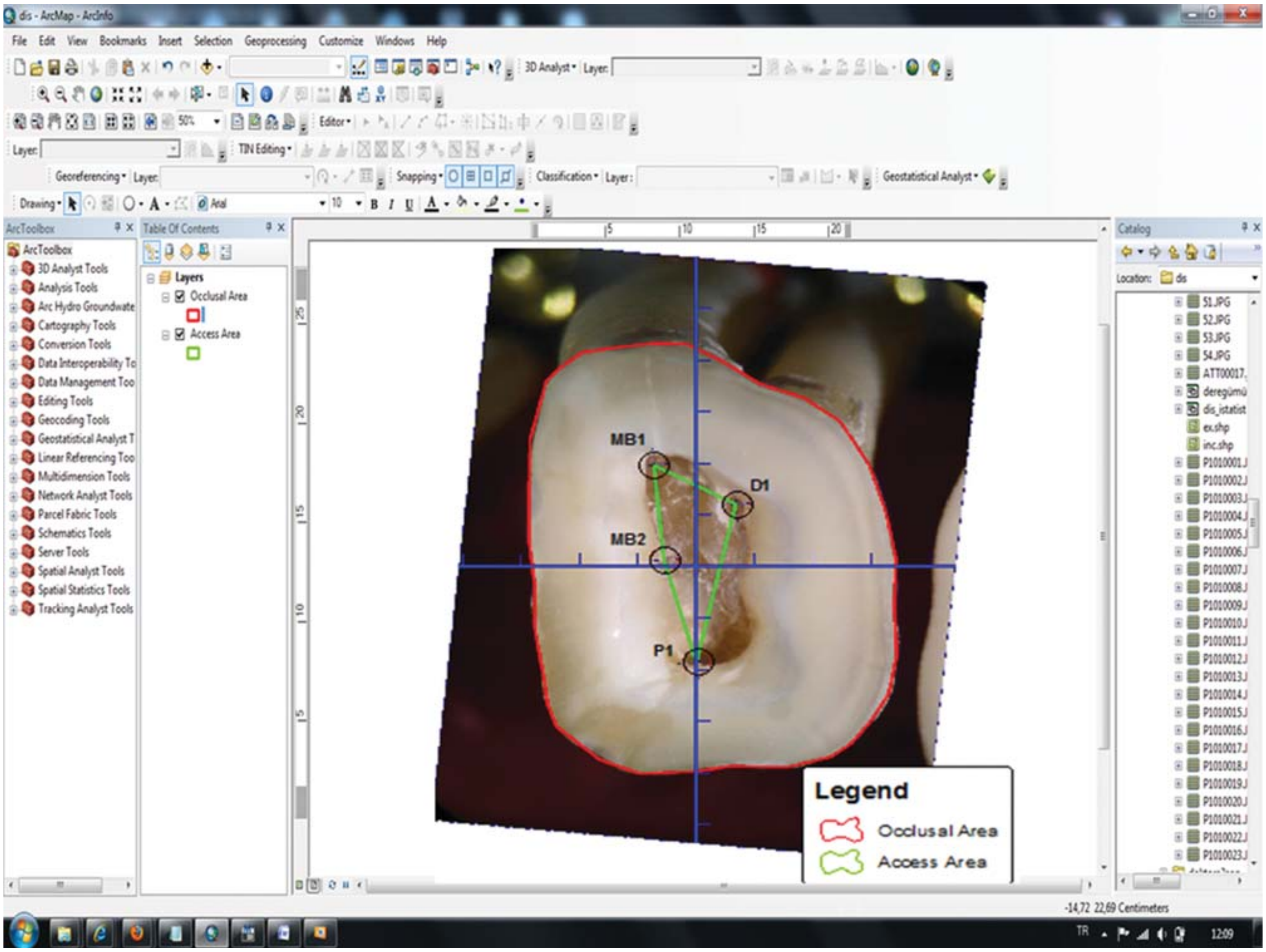

Figure 1. Screenshot of the ArcGIS software program showing the *x*,*y* plane, orifices and occlusal and access projection areas.

for use *in vivo* in the coming decade. Previous *ex vivo* and *in vivo* studies report MB2 incidences ranging from 2–96% and 18.6–93%, respectively [1,4,12–18]. Both magnification and dentine removal under magnification are more effective for detecting MB2 than direct visualization. The incidence of MB2 canals in first molars is reported to be more frequent in re-treatments (67%) than that in initial treatments (59%) [16]. However, no study describes the co-ordinates of their canal orifices or the distances between them.

The aims of the present study were to measure the co-ordinates of the root canal orifices and the distances between them and central fossa using geographic software, to determine the MB2 incidence of maxillary first molars under moderate magnification and to report the distribution of the orifices with respect to shape and number in a Turkish sub-population.

Materials and methods

In this study, 176 maxillary first molars extracted from urban inhabitants of Isparta were obtained from the dental clinics of the University and Government Hospitals in Isparta, Turkey. No information was available regarding the reasons for their extraction or the age or sex of the patients involved. Teeth with gross caries, fractures, cracks or immature apices were excluded. The selected teeth were stored in 0.02% sodium azide solution at room temperature until use.

An ultrasonic hand scaler (SONICflex; KaVo Dental Corp., Biberach, Germany) was used to remove tissue remnants and calculus on the roots. The teeth were embedded into acrylic resin blocks with their vertical axes aligned perpendicular to the horizontal plane. Initial standard photographs were taken digitally (Olympus Camedia C-4000 Zoom; Olympus Optical Co., GmbH, Seoul, Korea) from the occlusal aspects of the teeth at 40 × magnification under a stereomicroscope (Olympus SZ6045TR Zoom Stereomicroscope; Olympus Optical Co, Tokyo, Japan). The teeth were classified as either divided into left ($n = 93$) or right ($n = 83$). The crowns were removed using a diamond disc at the proximal level of the cemento-enemal junction (CEJ) and pulp tissue was removed. Sodium hypochlorite solution (2.5%) for 30 min and 17% EDTA gel (Glyde File Prep; Dentsply Maillefer, Ballaigues, Sweden) for 3 min were applied to dissolve any pulp tissue or calcifications on the orifices [8]. Thereafter, the canal orifices were negotiated with a size 10 K-file (Dentsply/Maillefer, Ballaigues, Switzerland) under moderate magnification with 3.5 loupes (Carl Zeiss, Oberkochen, Germany). If the orifice of MB2 could not be located, the pulp chamber floor was removed (i.e. troughing) within 3 mm from the MB1 canal towards the palatal canal in a groove 2 mm deep using a long-shank round bur (ISO #006; Rosenthal, Miami, FL) [12,14,15,18]. Final digital images were taken from the occlusal aspect showing the access under the same magnification and exposure conditions.

Images were transferred to a geographical software program (ArcGIS 9.3; ESRI, Hawaii, CA) for measurement. All images were calibrated using a ruler image to determine the actual dimensions. Calibration was performed by comparing the ruler in the images and in reality. The mid-point of the central fossa was determined as the center of the occlusal area. Then, the initial image was superimposed onto the final one to transfer the center. This was carried out by overlapping these two layers using the same software program. To create an X–Y plane, a vertical line through the centers of the occlusal plane and the palatal orifice was drawn as the *y*-axis; a horizontal line perpendicular to it was drawn as the *x*-axis (Figure 1). Accordingly, the co-ordinates of all canal orifices were measured using the software. The distances from all canal orifices including mesiobuccal-1 (MB1), MB2, distobuccal-1 (D1), distobuccal-2 (D2) and palatinal (P) to the center and between MB1 and MB2 and D1 and D2 were also measured. The numbers and forms of the canal orifices were also recorded. The projection of the access was determined on the pulp floor by connecting the lines among the canal orifices. This area was measured and proportionally compared to the occlusal area (Figure 1). All images of right ($n = 83$) and left ($n = 93$) teeth were superimposed to constitute an intensity map of the orifice location of the maxillary first molars for this sub-population. Consequently, a representative map was drawn using the mean values of orifice locations and access projection area of teeth with or without MB2.

Statistical analyses

An independent *t*-test was used to determine whether MB2 existence changed the distances among the canal orifices and the occlusal and access projection areas. Pearson's correlation coefficients were calculated to determine correlations between the areas. All statistical analyses were performed using SPSS 11.5 (SPSS Inc., Chicago, IL).

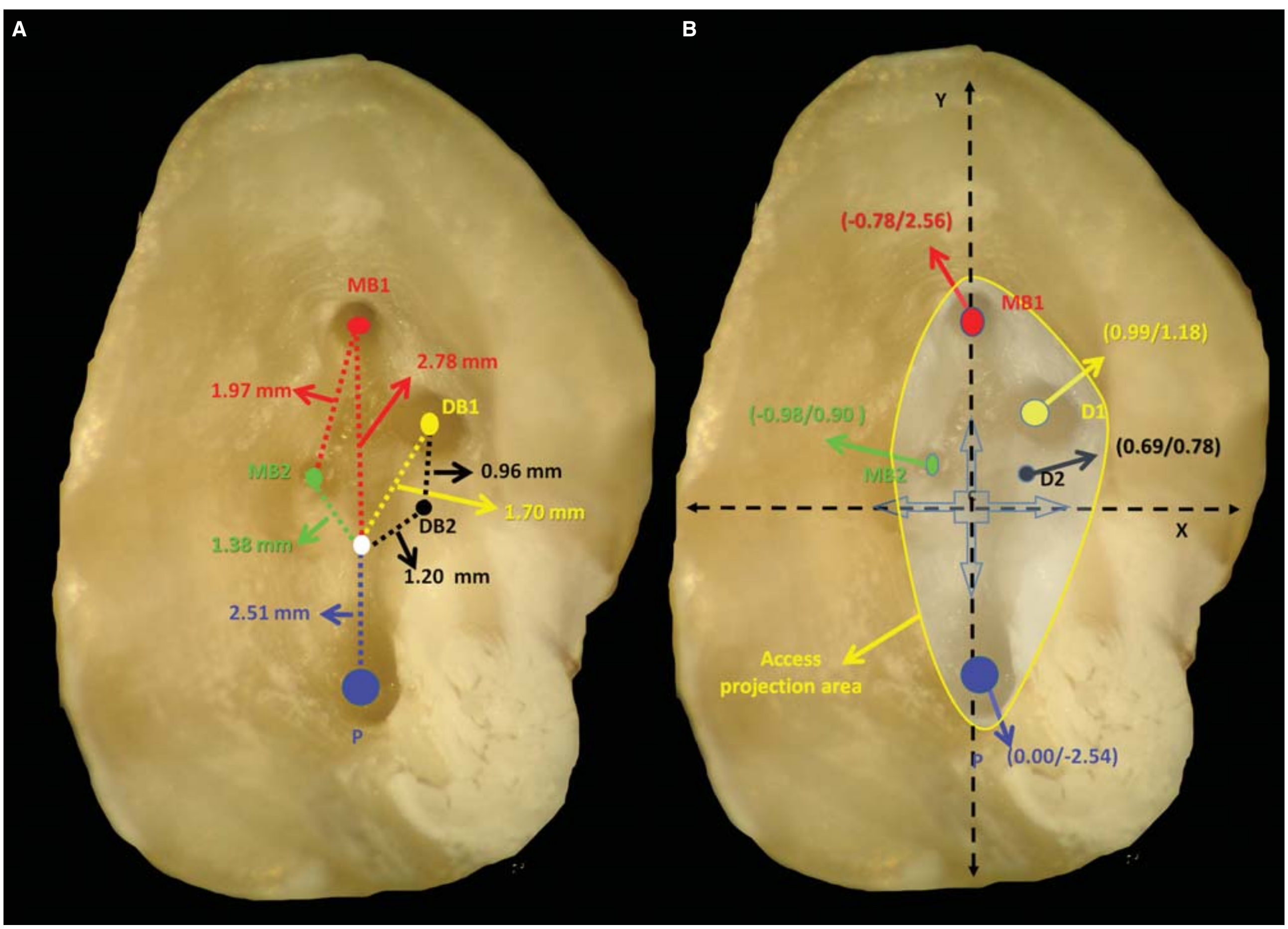

Figure 2. Representative images showing (A) the distances and (B) co-ordinates of the orifices in the left maxillary molars.

Table I. Mean co-ordinates (SD) of the root canal orifices of left and right maxillary first molars in millimeters.

		Mean co-ordinates (*x*, *y*) (SD)				
		MB1 (*x*, *y*)	MB2 (*x*, *y*)	D1 (*x*, *y*)	D2 (*x*, *y*)	P (*x*, *y*)
Right	Mean	0.67, 2.68	0.81, 0.84	−1.12, 1.26	−0.89, 0.23	0.00, −2.51
n = 83	(SD)	(0.51, 0.57)	(0.40, 0.65)	(0.50, 0.50)	(0.25, 1.13)	(0, 0.41)
Left	Mean	−0.78, 2.56	−0.98, 0.90	0.99, 1.18	0.69, 0.78	0.00, −2.54
n = 93	(SD)	(0.42, 0.74)	(0.52, 0.63)	(0.53, 0.49)	(0.04, 0.11)	(0, 0.47)

MB1, mesiobuccal-1; MB2, mesiobuccal-2; D1, distobuccal-1; D2, distobuccal-2; P, palatinal.

Table II. Overall values of measured areas and distances.

	Areas (mm^2)		Distances (mm)						
	Occ. area	Acc. area	MB1–C	MB2–C	D1–C	D2–C	P–C	MB1–MB2	D1–D2
Mean	58.22	5.00.0	2.78	1.38	1.70	1.20	2.51	1.97	0.96
Min	34.54	1.14	1.55	0.36	0.57	0.74	3.66	0.67	0.58
Max	88.25	12.41	4.77	2.98	3.08	1.71	1.53	3.64	2.01

Occ, Occlusal; Acc, Access projection; MB1, mesiobuccal-1; MB2, mesiobuccal-2; D1, distobuccal-1; D2, distobuccal-2; P, palatinal; C, midpoint of the central fossa.

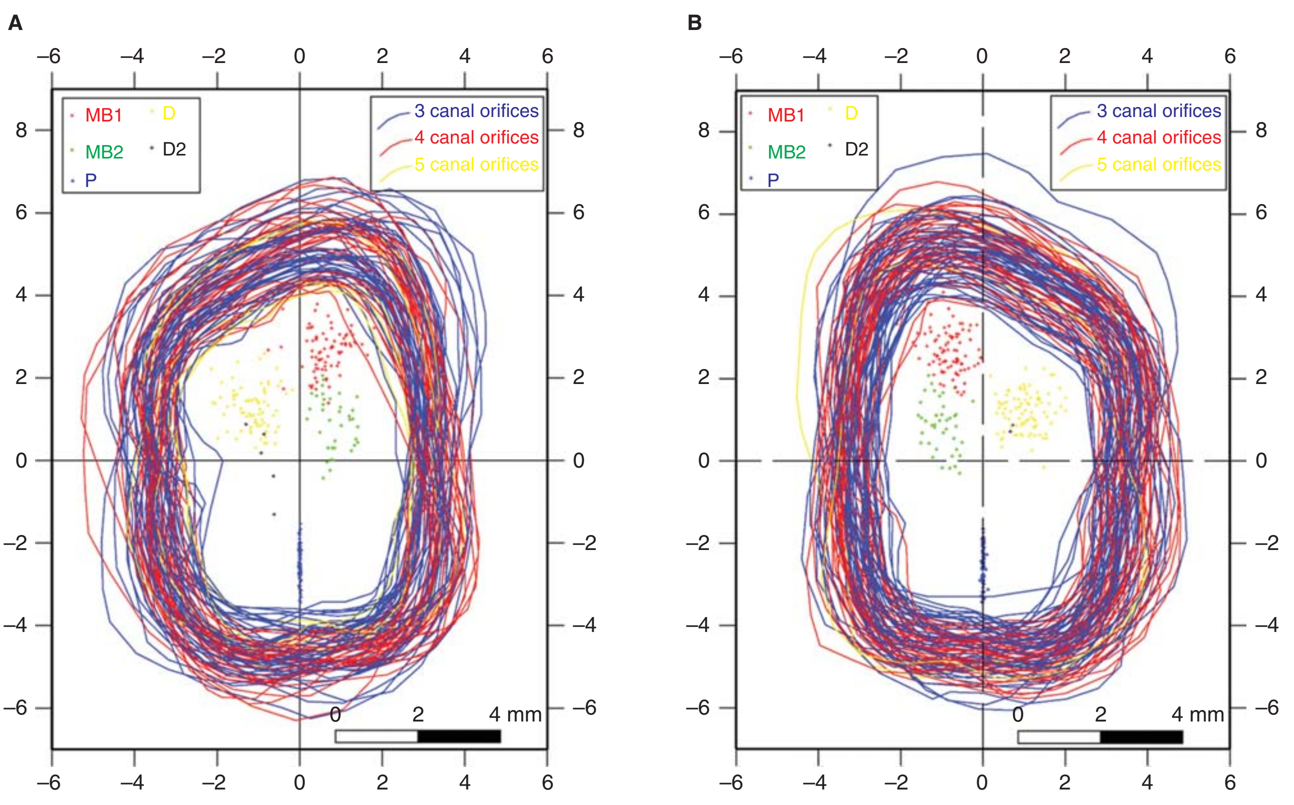

Figure 3. Intensity maps of the right (A) and left (B) maxillary first molars created with the geographic software program ArcGIS. They show the borders of the access projection areas and the locations of the canal orifices in different colors.

Table III. Mean areas and distances of right and left maxillary first molars with or without MB2.

			Maxillary first molars with MB2		Maxillary first molars without MB2		Maxillary first molars with MB2							Maxillary first molars without MB2				
			Occ. area	Acc. area	Occ. area	Acc. area	MB1–C	MB2–C	D1– C	D2– C	P– C	MB1–MB2	D1–D2	MB1–C	D1– C	D2– C	P– C	D1–D2
Right	n = 83	Mean	59.11	5.97	57.59	4.24	2.89	1.29	1.78	1.15	2.60	2.02	1.08	2.70	1.77	1.71	2.41	0.58
		Min	34.54	2.47	37.62	1.49	1.76	0.35	0.71	0.74	3.67	0.66	0.60	1.55	0.90	1.71	3.23	0.58
		Max	83.39	12.41	88.25	10.23	4.77	2.13	2.81	1.56	2.0	3.64	2.01	4.65	3.08	1.71	1.53	0.58
Left	n = 93	Mean	59.36	6.07	57.11	4.02	2.92	1.45	1.74	1.05	2.61	1.91	0.84	2.65	1.54	—	2.46	—
		Min	37.81	2.44	36.79	1.13	1.74	0.57	1.0	0.97	3.43	0.95	0.77	1.68	0.57	—	3.62	—
		Max	83.52	11.0	86.47	8.37	4.21	2.98	2.69	1.12	1.73	3.15	0.91	3.77	2.68	—	1.64	—
Total	n = 176	Mean	59.24	6.02*	57.34	4.12*	2.91	1.37	1.76	1.12	2.60	1.97	1.01	2.67	1.65	1.71	2.44	0.58
		Min	34.54	2.44	36.79	1.13	1.74	0.36	0.71	0.74	3.67	0.66	0.60	1.55	0.57	1.71	3.62	0.58
		Max	83.52	12.41	88.25	10.23	4.77	2.98	2.81	1.56	1.73	3.64	2.01	4.65	3.08	1.71	1.53	0.58

Occ, Occlusal; Acc, Access projection; MB1, mesiobuccal-1; MB2, mesiobuccal-2; D1, distobuccal-1; D2, distobuccal-2; P, palatinal; C, midpoint of the central fossa.
*Significant difference between the access areas of teeth with and without MB2 ($p < 0.05$).

Results

Mean values for the (x, y) co-ordinates were (0.67, 2.68) for MB1, (0.81, 0.84) for MB2, (−1.12, 1.26) for D1, (−0.89, 0.23) for D2 and (0.00, −2.53) for P in right maxillary first molars and (−0.78, 2.56) for MB1, (−0.98, 0.90) for MB2, (0.99, 1.18) for D1, (0.69, 0.78) for D2 and (0.00, −2.53) for P in left maxillary first molars (Table I, Figure 2).

The mean MB2–C, MB1–MB2 and P–C (center) distances were 1.38 ± 0.49, 1.97 ± 0.61 and 2.51 ± 0.44 mm, respectively. Distobuccal canal orifices were localized 0.57–3.08 mm distal to the center (Table II) in 98.3% (n = 173) of teeth (Figure 2). None of the distances measured in this study were affected by MB2 existence ($p > 0.05$) (Table III). The representative occlusal views and intensity maps are shown in Figures 2 and 3, respectively.

Three (n = 94; 53.41%), four (n = 73; 41.47%), five (n = 8; 4.55%) or six (n = 1; 0.57%) canal orifices were located in the maxillary first molars investigated in this study. Of all orifices, 77% were round, 12.72% oval, 9.13% C-shaped and 0.97% kidney-shaped (Table IV, Figure 4).

The incidence of MB2 was 46.59% (n = 81): 21.59% (n = 38) in right teeth and 24.43% (n = 43) in left teeth ($p > 0.05$)

The mean area of access projection (4.12 ± 1.81 mm^2) of teeth without MB2 was significantly smaller than that of teeth with MB2 (6.02 ± 2.4 mm^2) ($p < 0.05$) (Table III). The area of access projection was significantly positively correlated with the occlusal area ($p < 0.05$; $R = 0.577$ and $R = 0.642$ for right and left maxillary molars, respectively). MB2 existence did not significantly affect the occlusal area ($p > 0.05$) (Table III). The occlusal area/access projection area proportion was 58.22/5.00 = 11.64 (Table II).

Discussion

The main aim of this study was to provide a guide for the detection and optimum access to canal orifices, especially MB2, which is more complicated to negotiate. According to established knowledge, the access cavity of the maxillary first molars should be entirely within the mesial half of the tooth and need not invade the transverse ridge; however, the buccal-to-lingual distance should be extensive enough to allow for the proper positioning of instruments and filling materials [5]. However, in this study, the distal border of the area of the access projection was located distal to the center in 98.3% (n = 173) of teeth. Besides, the MB2 was located more mesially than the MB1 and was not always on the MB1–P line. Thus, the cavity border should be shifted more distally than previously recommended. In addition, the cavity form must be changed from a triangular to a rhomboidal shape.

Table IV. Forms, numbers and incidence in percentage (%) of root canal orifices in maxillary first molars.

Shape	MB1	MB2	D1	D2	P	P2	Number of orifices (%)
Round	130 (73.86%)	63 (77.77%)	129 (73.29%)	4 (100%)	147 (83.52%)	1 (100%)	474 (77.20%)
Ovoid	23 (13.06%)	10 (12.34%)	19 (10.79%)	—	26 (14.77%)	—	78 (12.72%)
C-shaped	22 (12.5%)	8 (9.87%)	26 (14.77%)	—		—	56 (9.12%)
Kidney-shaped	1 (0.56%)	—	2 (1.13%)	—	3 (1.70%)	—	6 (0.97%)
Number o f teeth (incidence)	176 (100%)	81 (46.02%)	176 (100%)	4 (2.27%)	176 (100%)	1 (0.57%)	614 (100%)

MB1, mesiobuccal-1; MB2, mesiobuccal-2; D1, distobuccal-1; D2, distobuccal-2; P, palatinal; P2, palatinal-2.

In this study, some recommendations from previous studies were taken into consideration. Krasner and Rankow [19] demonstrated the existence of specific and consistent pulp chamber floor and wall anatomy and proposed laws to assist clinicians when identifying canal morphology. They noted that the cemento–enamel junction is the most important anatomic landmark for determining the location of pulp chambers and root canal orifices. The teeth were decoronized at the proximal level of the CEJ since the pulp ceiling and CEJ lie on the same level in 98% of the maxillary first molars [20]. In addition, the root canal ceiling–furcation distance is 3.85–5.97 mm [20] and troughing should be in 0.5–3 mm deep [3]. The MB2 should be negotiated carefully within safety limits since perforations may ultimately compromise the prognosis of root-filled teeth [18,21,22].

The maximum root canal number reported for maxillary first molars is eight [23]. In the present study, a maximum of six canal orifices was detected. Unexpected orifices were D2 in eight teeth (4.54%) and P2 (0.57%) in one tooth. A meta-analytic review reported the overall incidences of D2 and P2 to be 1.7% and 1.0%, respectively [24]. The incidences of C-shaped canals in maxillary first molars were 0.09% (two of the 2175 teeth) radiographically [25]. C-shaped root canal orifices were reported 4.9% in maxillary second molars in a Chinese population [26]. In the present study C-shaped root canal orifices were 9.12%. This high incidence may be attributed to the fact that only the shapes of the orifice were examined—not the whole canal until the apex. According to De Moor [25], C-shaped canals often occur in the distal portion of the pulp chamber. It is also reported that mesial and distal canals can join to form a single C-shaped canal in maxillary first molars [27]. Following the determination of the center, a line should be drawn to the palatinal orifice so that the values obtained in this study can be useful for clinicians, independent from the position of the tooth in the mouth. However, in cases with gross caries or heavily restored teeth, the center detection was complicated due to loss of original occlusal morphology. Although there are some data on the distances in the literature [12,28,29], no co-ordinates are described. A recent study investigated the co-ordinates in assessing the

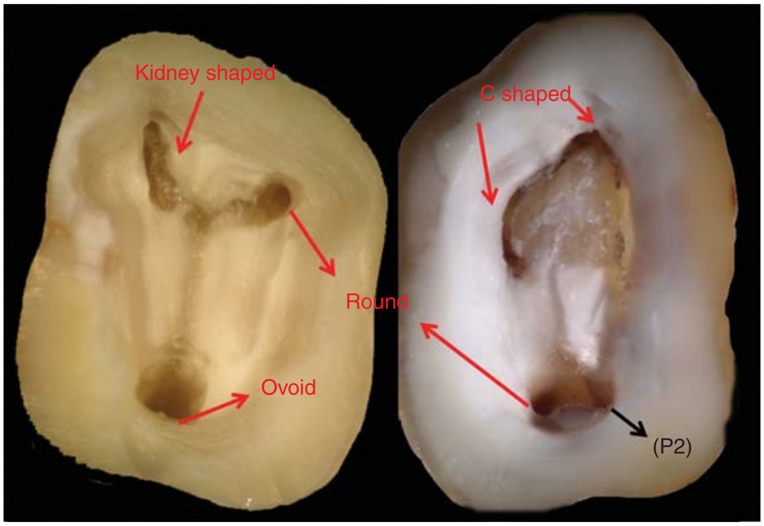

Figure 4. Shapes of the canal orifices.

location and distribution of orifices in mandibular second molars in a Turkish sub-populaton [30].

The mean values of the MB1–MB2 distance reported by Zhang et al. [31], Gilles and Reader [12] and Kulild and Peters [13] were 1.47, 1.82 and 2.31 mm, respectively; thus, the distance measured in the present study (1.97 mm) was comparable. However, the minimum and maximum values of the MB1–MB2 distance should also be considered during the location of MB2 (Tables II and III). Some authors reported that MB2 is mainly located mesial to MB1, which was corroborated by the results of the present study [15,32]. According to the *x*-co-ordinates of MB1 and MB2, MB2 orifices were located mesial to the main MB canal in 152 teeth (86.3%). These data and further studies can facilitate the localization of root canal orifices and an ideal access cavity preparation in clinical practice.

When the access projection on the pulp floor was drawn by connecting the orifices, the access form changed from the classical triangular shape to a more rhomboidal one in most of the teeth which is in agreement with the observations of Weller and Hartwell [33]. The significant correlation between the enlargement of the access area and MB2 existence in the present study can be attributed to this finding.

The long-term prognosis of root canal therapy is directly affected by the negotiation and entire obturation of all root canals. Long-term prognosis is reported as 90.02% [34] and 82.1% [35] for initial endodontic treatments and 83.0% [36] for non-surgical re-treatment cases. However, whether MB2 was treated or not is not mentioned in these studies. Wolcott et al. [4,16] reported a significant increase in the detection of MB2 between initial treatments (58–59%) and re-treatments (66–67%). Taken together, this could imply that negotiating and treating MB2 can improve the long-term prognosis.

It is often difficult to detect MB2 due to a ledge of dentine that covers its orifice, the inclination of its orifice on the pulpal floor and/or its pathway, which often takes one or two abrupt curves in the coronal part of the root [3]. Many authors reported that this difficulty can be overcome by enhancing anatomical knowledge, using instrumental aids [17,18,37]. Different methods have been used to detect MB2 root canals, including canal staining and clearing [8,18,38], radiographic examination [1], dentine troughing under magnification [18], DOM [39], scanning electron microscopy [12,40], CT [41,42] and micro-CT [43]. The wide range of the MB2 incidence (7–96%) reported in these studies is due to the variety of techniques and study populations used. The detection rate of MB2 in maxillary molars *in vivo* is lower than that in *ex vivo* studies [17,37]. The protocol used in the present study included 3.5 $\times$ loupe magnification and dentin troughing on the pulpal floor in an attempt to locate a second mesiobuccal canal since their effectiveness has already been demonstrated [13,18]. The MB2 incidence of the population in the present study was similar to that of the population studied by Yoshioka et al. [18] (42%) but lower than those studied by Kulild and Peters [13] (96%) and Buhrley et al. [17] (71%) who used similar methodology. Higher incidence is expected when clearing, CT, DOM or sectioning will be used in further studies.

In conclusion, distobuccal canal orifice is mostly located on the distal side of the center and MB2 on the mesial side of MB1. Thus, the projection of the access on the pulp floor was rhomboidal in most of the cases. Being aware of the co-ordinates and distances related to canal orifices can facilitate the access cavity preparation in clinical practice. The incidence of MB2 in this sub-population was 46.02%, which is of great importance clinically. MB2 existence was significantly correlated with the area and form of the access projection.

Declaration of interest: The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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