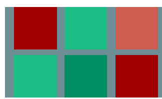
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ORIGINAL RESEARCH

Root canal configurations of third molar teeth. A comparison with first and second molars in the Turkish population

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Keywords
mandibular molar teeth, maxillary molar teeth, morphology, root canal.

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Abstract

The purpose of the current study was to determine the similarities of maxillary and mandibular third molars with the other molar teeth. A total of 2016 extracted maxillary and mandibular permanent teeth were evaluated. The teeth were divided into six groups. The teeth were stored in 5% nitric acid solution for 7 days, then placed in increasing concentrations of ethyl alcohol. The teeth were rendered transparent by immersion in xylene solution for 4 days until complete transparency was achieved. Three roots were present in 93.0% of the maxillary molars, and 91.3% of the second molars. Among the maxillary third molars, 35.5% were single-rooted and 24.9% of the mandibular third molars had single roots. Double roots were present in 69.2% of the mandibular third molars, and 5.4% had three roots. Four new root canal configurations were encountered in this study. The root canal configurations of the mandibular and maxillary teeth showed similarities with the results of other studies performed in different populations.

Introduction

Root canal morphology plays a substantial role in the overall success of endodontic treatment. In many studies, it has been reported that lack of sufficient knowledge about root canal anatomy and the complex structure of root canals may lead to failure in root canal treatment, even though basic principles of endodontic therapy are followed (1–6).

Weller *et al*. (7) reported that an isthmus between root canals may cause difficulties during endodontic treatment in multi-rooted teeth and are related with the relatively less success ratio in the endodontic management of multi-rooted teeth because of the presence of a complex structure among the isthmuses. Weine (6) indicated that although the apical foramen is obturated with a filling material that does not permit any leakage, a connection still exists between the root canal system and the periapical tissues by means of lateral canals.

These aforementioned problems have motivated researchers to perform studies on root canal morphology. These studies have focused on a specific tooth or group of teeth, or they have concentrated on a specific root of a tooth type (7–10).

Many investigations have examined the configurations of root canal systems. These have included various methods such as using polyester resin impressions, creating transparent samples and using radiographs in both *in vivo* and laboratory studies (3,9,11–16).

The aim of this study was to highlight the similarities of third molar teeth with other molars. Because third molars are believed to be very challenging teeth in terms of endodontic treatment, these teeth are generally extracted in clinical practice. By revealing these similarities, the hypothesis that these teeth are treatable would be supported.

Materials and methods

The teeth examined in this study belonged to the patients who were Turkish citizens and who were referred to the Maresal Military Hospital Dentistry Center and Gulhane

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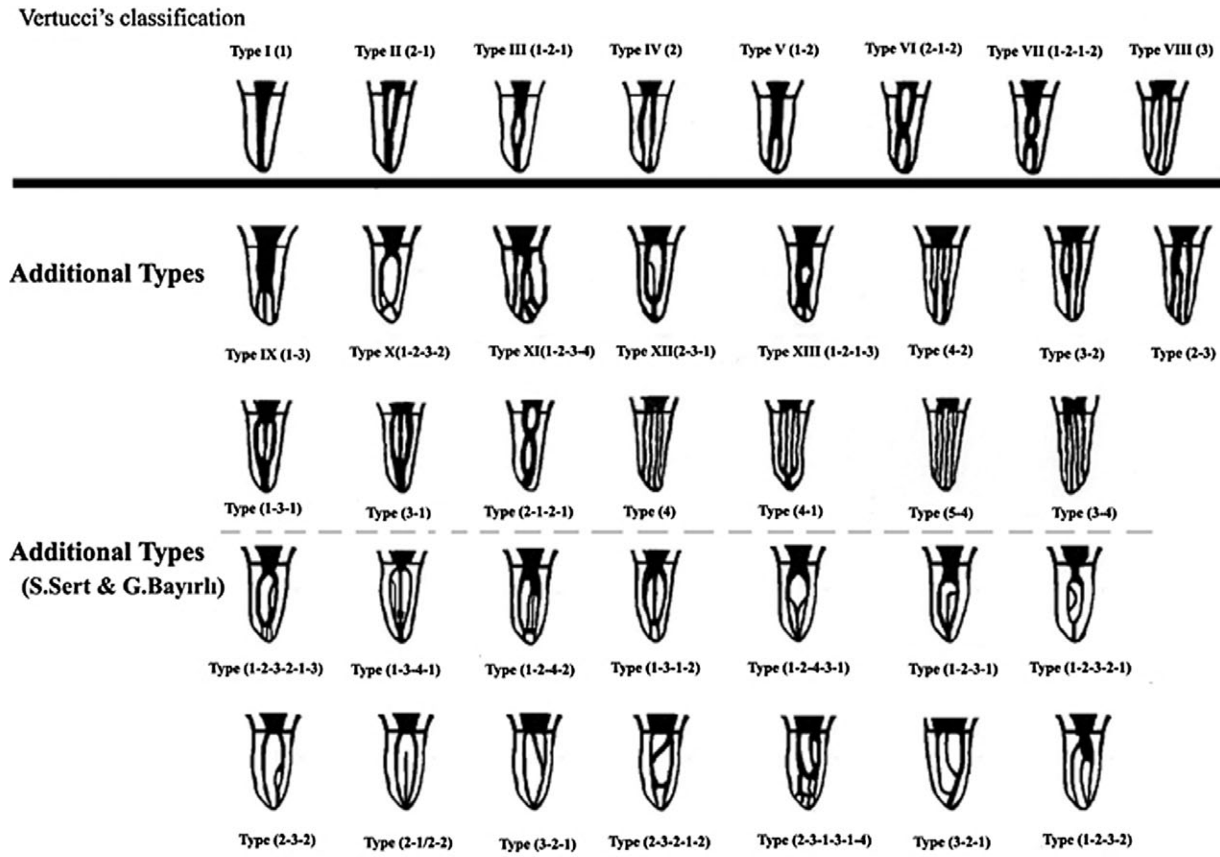

Figure 1 Classification of root canal system types.

Military Medicine Academy Department of Oral and Maxillofacial Surgery for extractions. A total number of 2016 teeth were examined in this study. The teeth were divided into six groups; mandibular first, second and third molars, and maxillary first, second and third molars.

During the evaluation of the samples, the gender and age of the patients were not considered. The samples were kept in 5.25% sodium hypochlorite for 30 min (Sultan Chemist's, Englewood, NJ, USA) for the removal of organic debris on their surfaces. Following this, the samples were stored in 10% formaldehyde until demineralisation and staining. The teeth were cleaned under running water before preparation. Access cavity preparations were prepared and the coronal pulp tissues were extirpated until the canal orifices. The samples were kept in 5% nitric acid solution for 7 days (Aksın Kimya, Istanbul, Turkey) as the first step in the demineralisation process. The solution was changed everyday. The reliability of the technique was assessed by the insertion of a needle in the coronal region. Radiographs were taken and the radiolucency observed on the radiographs confirmed that the technique was successful. The samples were then rinsed under running water for 3 h. As the second step of the demineralisation procedure, the teeth were kept in 70%, 80% and 95% ethylalcohol (Kimetsan, Ankara, Turkey) for 1 day. At the end of this period, it was observed that there was no opacity remaining on the tooth surfaces. The clearing procedure was completed by placing the samples in xylene (Riedel-de Haen, Seelze, Germany). At the end of the third day, a complete transparency was obtained. It was determined that the teeth lost their transparency in a short period after they were removed from xylene. India ink was injected into the root canals of the transparent teeth by 22-gauge syringe dental injectors. After the ink was completely dry, the root canal morphology of the teeth was examined according to the classification proposed by Vertucci (3). The samples that were not included in the classification (13,14,17–20; Fig. 1) were categorised and photographed.

Results

The classification of the teeth belonging to the six groups in terms of root canal systems, by taking the number of

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roots into consideration was demonstrated in Tables 1 and 2.

Four new root canal configurations were encountered in this study, which are not included in the classification of Vertucci (3) or other classification systems (13,14,17–20). These types are summarised as follows.

Canal type 3-1-2-1-2 mandibular first molar

Three canals leave the pulp chamber. These canals merge in the middle third of the root, continue as two canals (buccal and lingual), then merge again between the apical and middle third of the root and become one canal. This canal diverges again and ends as two canals and two foramina (Fig. 2a).

Canal type 2-3-4-2 mandibular first molar

Two canals leave the pulp chamber. The buccal canal gives off another branch at the middle third and this canal gives off another canal in the lingual portion. These three canals merge near the apex and end as two foramina (Fig. 2b).

Canal type 3-1-2 mandibular first molar

Three canals leave the pulp chamber, merge in the mid-root region and become a single canal. They continue as buccal and lingual canals and finally end as two foramina (Fig. 2c).

Canal type 2-5-1 mandibular third molar

Two canals leave the pulp chamber. The buccal canal gives off three branches at the middle third, continues as five canals and ends at the apex as one foramen (Fig. 2d).

Discussion

Although various techniques have been used thus far in root canal morphology studies, the most detailed and reliable results have been obtained by demineralisation and staining techniques (3,21,22). In most of these studies, the classification of Vertucci (3) has been used as a reference. In this study, additional root canal configurations (13,14,17–20) along with the classification of Vertucci were also taken into consideration.

In the studies that have examined the morphology of root canal systems, while some have taken the maxillary and mandibular teeth into consideration separately, some have examined them together (3,13,15,16,23,24). In one study, gender was also designated as a parameter (20), whereas the other studies have not evaluated the morphology of root canal systems in relation with gender. The population sample, methodology and gender have significant effects on the results of morphologic studies (10,20,25–32).

There are many studies in the literature, which examine the morphologic variations of maxillary molars (10,20,21,24,33–35). Weine *et al.* (25) were the first to investigate the influence of morphologic variations on the success of endodontic treatment. They examined 208 teeth and determined that 48.5% had type I, 37.5% had type II and 14.0% had type III configurations. Vertucci (3) examined the mesiobuccal roots of 100 teeth and determined that 45% had type I, 37% had type II and 18% had type IV configurations. The author reported that 100% of the distobuccal and palatinal roots had type I canal configurations. Calıskan *et al.* (15) examined 100 teeth and observed that 34.4%, 41.0%, 11.5%, 1.6% and 11.5% were type I, type II, type IV, type V and type VI, respectively. In the present study, type I was present in 17%, type II in 47.3%, type III in 10.1%, type IV in 16.6%, type V in 3.4%, type VI in 2.4%, type VII in 1.7%, type X in 0.6%, type XVI in 0.3% and type XIX in 0.6. These findings reveal that more variation are observed in the mesiobuccal root of maxillary first molars in the studies conducted in Turkey.

While Hartwell and Bellizzi (36) encountered two canals in the mesiobuccal roots of maxillary molars in 18% of 538 cases; this ratio was as high as 39% and 77.2% in the studies by Weller and Hartwell (37) and Neaverth *et al.* (21), respectively. Stropko (31) reported that the possibility of determining a second canal increased because of the utilisation of the operating microscope.

Imura *et al.* (27) encountered a mesiolingual canal in 80.9% of maxillary first molar teeth. Weine *et al.* (32) determined Weine's type I configuration in 42% of the mesiobuccal roots of 293 teeth. They also reported the incidence of different variations as 58%. The differences between the results of Imura *et al.* (27) and Weine *et al.* (32) may be attributed to racial differences.

Calıskan *et al.* (15) examined 100 teeth and determined 34.4% as type I, 41.0% as type II, 11.5% as type IV, 1.6% as type V and 11.5% as VI. Of the distobuccal roots, 98.4% were type I and 1.6% were type VI canal configurations. Among the palatal roots, 93.4% were type I, 3.3% were type II, and 3.3% were type V.

Pineda and Kuttler (26) examined 262 maxillary first molars radiographically and found the incidence of two canals as 4% and a single canal 96% in the distobuccal root.

Kulild and Peters (10) investigated the root canal configurations in the mesiobuccal roots of the maxillary first and second molar teeth and detected type I in 4.8%, type II in 49.4% and type III in 45.8% of the cases.

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Table 1 Root canal classification of maxillary permanent teeth (taking the number of roots into consideration)

	No. of teeth	No. of root	No. of teeth (%)	Canal type	MB	$MB_{root 2}$	DB	P
Maxillary I. molar	355	2	23 (6.47%)	Type I	10 (43.48%)	–	23 (100%)	23 (100%)
				Type II	10 (43.48%)	–	–	–
				Type III	3 (13.04%)	–	–	–
		3	330 (92.96%)	Type I	49 (14.85%)	–	316 (95.76%)	319 (96.67%)
				Type II	158 (47.88%)	–	4 (1.21%)	ND
				Type III	33 (10%)	–	6 (1.82%)	3 (0.91%)
				Type IV	59 (17.88%)	–	1 (0.30%)	2 (0.61%)
				Type V	12 (3.64%)	–	4 (1.21%)	5 (1.51%)
				Type VI	8 (2.42%)	–	ND	ND
				Type VII	6 (1.82%)	–	ND	ND
				Type IX	–	–	–	1 (0.30%)
				Type X	2 (0.61%)	–	ND	ND
				Type XVI	1 (0.30%)	–	ND	ND
				Type XIX	2 (0.61%)	–	ND	ND
		4	2 (0.57%)	Type I	2 (100%)	2 (100%)	2 (100%)	2 (100%)
Maxillary II. molar	252	1	3 (1.9%)	Type I	3 (100%)	–	–	–
		1	2 (0.79%)	Type I	2 (100%)	–	2 (100%)	2 (100%)
		2	4 (1.59%)	Type I	–	–	–	4 (100%)
				Type II	4 (100%)	–	–	–
		2	13 (5.16%)	Type I	12 (92.31%)	–	13 (100%)	13 (100%)
				Type II	1 (7.69%)	–	–	–
		3	230 (91.27%)	Type I	111 (48.26%)	–	227 (98.69%)	230 (100%)
				Type II	62 (26.95%)	–	2 (0.86%)	–
				Type III	17 (7.39%)	–	1 (0.43%)	–
				Type IV	25 (10.86%)	–	–	–
				Type V	5 (2.17%)	–	–	–
				Type VI	7 (3.04%)	–	–	–
				Type VII	1 (0.43%)	–	–	–
				Type VIII	1 (0.43%)	–	–	–
				Type X	1 (0.43%)	–	–	–
Maxillary III. molar	290	1	57 (19.65%)	Type I	36 (63.15%)	–	–	–
				Type II	7 (12.28%)	–	–	–
				Type III	4 (7.01%)	–	–	–
				Type IV	7 (12.28%)	–	–	–
				Type V	2 (3.50%)	–	–	–
				Type XVIII	1 (1.75%)	–	–	–
		1	26 (8.96%)	Type I	20 (76.92%)	–	–	26 (100%)
				Type II	3 (11.53%)	–	–	–
				Type IV	1 (3.85%)	–	–	–
				Type V	1 (3.85%)	–	–	–
				Type VI	1 (3.85%)	–	–	–
		1	20 (6.89%)	Type I	19 (95%)	–	20 (100%)	20 (100%)
				Type V	1 (5%)	–	–	–
		2	63 (21.72%)	Type I	38 (60.31%)	–	–	62 (98.42%)
				Type II	13 (20.63%)	–	–	1 (1.58%)
				Type III	3 (4.76%)	–	–	–
				Type IV	5 (7.93%)	–	–	–
				Type V	4 (6.34%)	–	–	–
		2	20 (6.89%)	Type I	16 (80%)	–	20 (100%)	20 (100%)
				Type II	4 (20%)	–	–	–
		3	99 (34.13%)	Type I	77 (77.77%)	–	99 (100%)	99 (100%)
				Type II	13 (13.13%)	–	–	–
				Type IV	5 (5.05%)	–	–	–
				Type V	4 (4.04%)	–	–	–
		4	5 (1.72%)	Type I	5 (100%)	5 (100%)	5 (100%)	5 (100%)

MB, mesiobuccal; DB, distobuccal; P, palatinal.

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Table 2 Root canal classification of mandibular permanent teeth (taking the number of roots into consideration)

	No. of teeth	No. of root	No. of teeth (%)	Canal type	M	M-Lingual	D	D-Lingual
Mandibular I. molar	417	2	411 (98.56%)	Type I	11 (2.67%)	–	217 (52.79%)	–
				Type II	196 (47.68%)	–	69 (16.78%)	–
				Type III	23 (5.59%)	–	75 (18.24%)	–
				Type IV	158 (38.44%)	–	29 (7.05%)	–
				Type V	5 (1.21%)	–	12 (2.91%)	–
				Type VI	1 (0.24%)	–	2 (0.48%)	–
				Type VII	2 (0.48%)	–	2 (0.48%)	–
				Type VIII	3 (0.73%)	–	2 (0.48%)	–
				Type X	5 (1.21%)	–	–	–
				Type XVIII	1 (0.24%)	–	1 (0.24%)	–
				Type XIX	1 (0.24%)	–	2 (0.48%)	–
				Type XXXI	2 (0.48%)	–	–	–
				New canal 3-1-2	1 (0.24%)	–	–	–
				New canal 2-3-4-2	1 (0.24%)	–	–	–
				New canal 3-1-2-1-2	1 (0.24%)	–	–	–
		3	6 (1.44%)	Type I	1 (16.66%)	6 (100%)	6 (100%)	–
				Type II	3 (50%)	–	–	–
				Type IV	1 (16.66%)	–	–	–
				Type X	1 (16.66%)	–	–	–
Mandibular II. molar	332	1	4 (1.20%)	Type I	4 (100%)	–	–	–
		1	10 (3.01%)	Type I	8 (80%)	–	10 (100%)	–
				Type II	2 (20%)	–	–	–
		2	318 (95.78%)	Type I	51 (16.03%)	–	256 (80.50%)	–
				Type II	119 (37.41%)	–	16 (5.03%)	–
				Type III	45 (14.15%)	–	32 (10.06%)	–
				Type IV	80 (25.15%)	–	8 (2.51%)	–
				Type V	10 (3.14%)	–	4 (1.25%)	–
				Type VI	3 (0.94%)	–	–	–
				Type VII	2 (0.62%)	–	2 (0.62%)	–
				Type X	6 (1.88%)	–	–	–
				Type XIX	2 (0.62%)	–	–	–
Mandibular III. molar	370	1	61 (16.48%)	Type I	40 (65.57%)	–	–	–
				Type II	9 (14.75%)	–	–	–
				Type IV	6 (9.84%)	–	–	–
				Type V	6 (9.84%)	–	–	–
		1	31 (8.37%)	Type I	23 (74.19%)	–	31 (100%)	–
				Type II	6 (19.35%)	–	–	–
				Type V	2 (6.45%)	–	–	–
		2	256 (69.18%)	Type I	151 (58.98%)	–	254 (99.22%)	–
				Type II	62 (24.21%)	–	2 (0.78%)	–
				Type III	7 (2.73%)	–	–	–
				Type IV	25 (9.76%)	–	–	–
				Type V	10 (3.90%)	–	–	–
				New canal 2-5-1	1 (0.39%)	–	–	–
		2	1 (0.27%)	Type I	1 (100%)	1 (100%)	1 (100%)	1 (100%)
		3	14 (3.78%)	Type I	14 (100%)	14 (100%)	14 (100%)	–
		3	6 (1.62%)	Type I	5 (83.33%)	6 (100%)	6 (100%)	6 (100%)
				Type II	1 (16.67%)	–	–	–
		4	1 (0.27%)	Type I	1 (100%)	1 (100%)	1 (100%)	1 (100%)

M, mesial; D, distal.

Wong (35) reported that the palatal root of a maxillary first molar had three separate root canals and apical foramina. Berna and Badanelli (34) determined the presence of six canals in a maxillary first molar tooth, with three in the mesiobuccal root, two in the distobuccal root and one in the palatal root. In previous studies, it has been reported that the frequency of two root canals in the mesiobuccal root of the maxillary first and second molars

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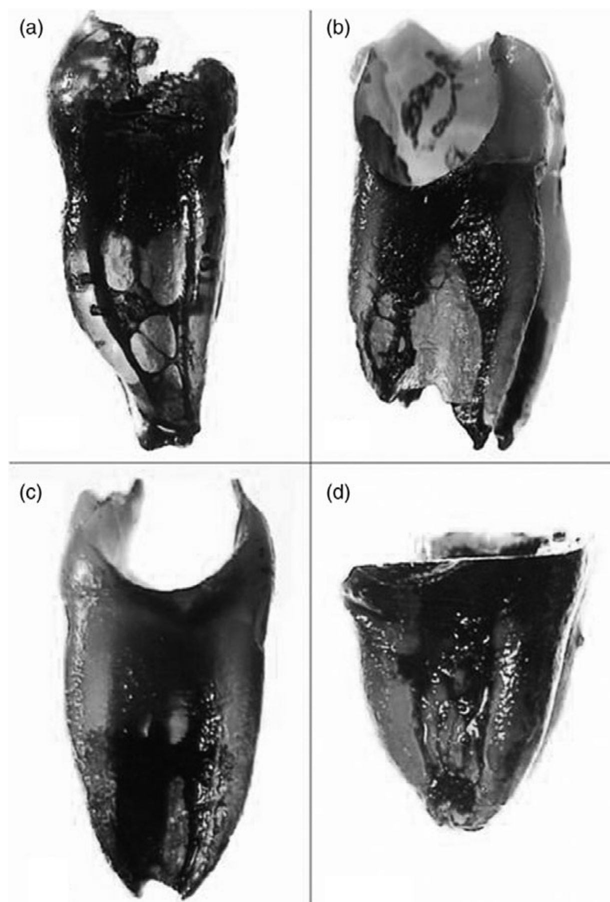

Figure 2 Newly defined root canal morphology. (a) Canal type 3-1-2-1-2 mandibular first molar, (b) canal type 2-3-4-2 mandibular first molar, (c) 3-1-2 mandibular first molar and (d) canal type 2-5-1 mandibular third molar.

is quite high (25). In the study by Sert and Bayırlı (20), the incidence of mesiobuccal second canals was 94% in first molars and 59% in the second molars. In the present study, the corresponding ratios are 67% and 39%, respectively.

In the present study, 93.0% of maxillary first molars had three roots, 6.5% had two roots, and 0.5% had four roots. Of the second molars, 91.3% had three roots, 6.7% had two roots, and 2.0% had a single root. Yang *et al*. (38) reported fusion cases in 40.1% of the maxillary second molars and 6.2% in maxillary first molars. It has also been reported that root canal configurations of three-rooted maxillary molars and three-rooted second molars are very similar (3,6,30,39). Although rare, it is still possible to encounter four roots in maxillary second molars.

Eskoz and Weine (40) determined the incidence of double roots in 9% of 73 maxillary second molar teeth. They also reported that 67 of these teeth had 3 roots and 37.4% of the mesiobuccal roots had 2 canals.

There are a few studies conducted on the maxillary second molars in the literature (6,10,26,38,39). Various studies reported contrary results in terms of incidence rates. In the study conducted by Hartwell and Bellizzi (36) the incidence of mesiolingual canal in maxillary second molars was reported to be 9.6%, while it was determined to be 93.7% by Kulild and Peters (10), 21.4% by Weller and Hartwell (37) and 50.7% by Stropko (31). The enormous discrepancy between these results may be due to the different methodologies used.

According to classic morphologic knowledge, maxillary third molars are non-standard teeth that do not possess a specific root and canal anatomy. However; the loss of first and second molars increases the strategic significance of these teeth. Studies that focus on maxillary third molars have revealed that they do not differ from the other molars in terms of root and canal morphologies (26,30,31,41,42). In the present study, 35.5% of the maxillary third molars had one root, 28.7% had two roots, 34.1% had three roots, and 1.7% had four roots. The results of the present study support the results of other studies performed on third molars (1,42).

In the study of Green (41) conducted with the mesiobuccal roots in 100 third molars, 63% had type I, and 25% had type II canal configurations. In the present study, 73.5% were type I, 13.8% were type II, 2.4% were type III, 6.2% were type IV, and 4.1% were type V canal configurations. Pineda and Kuttler (26) examined 212 maxillary third molar teeth by *in vitro* radiographic methods and observed three canals only in 21%. In the present study, this ratio was determined to be 41.2% and the difference can also be attributed to the racial differences as well as the methodology used.

In a clinical study, Stropko (31) reported that among 25 maxillary third molars undergoing endodontic treatment, 20.5% had mesiolingual canals. Although it is a clinical study, it is consistent with the present study in terms of presence of two canals in the mesiobuccal roots.

Data in the literature concerning the mandibular molars also show many variations (3,9,12,15,26,28,29, 33,43). Vertucci (3) reported the incidence of the type I, II, IV, V and VI canal in the distal root of the mandibular first molars as 70%, 15%, 5%, 8% and 2%, respectively. Sert and Bayırlı (20) reported that 1% type I, 41% type II, 4% type III, 48% type IV, 3% type VIII and 3% type X root canals existed in the mesial roots of the male mandibular first molars. The corresponding values were 3% type I, 41% type II, 5% type III, 45% type IV, 2% type V, 2% type VI, and 2% type X for females. The results of the present study are in agreement with the results of these studies; however, a strong consistency was observed between the studies of Caliskan *et al*. (15) and, Sert and Bayırlı (20) which were conducted in Turkey.

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Walker (28) observed the presence of three roots in 15% of the mandibular first molars in China, whereas Yew and Chan (29) encountered three roots in 21.5% of the experimental teeth. In European populations, this rate was reported to be 2% (11). On the other hand, Skidmore and Bjorndal (44) reported the number to be 3.3%. In the present study, it was found to be only 1.4%.

Pineda and Kuttler (26) examined 300 mandibular first molars obtained from a Mexican population sample. They observed type I configuration in 12.8% of the cases. Fabra-Campos (45) reported type VIII configuration in 2.6% of 760 mandibular first molars. In the present study, type VIII was encountered only in 0.7% of the cases. The differences between the results of these studies may be attributed to the racial differences.

Walker (28) investigated 100 mandibular first molars and determined the incidence of double-root canal configurations in the distal roots as high as 45%. In the present study, double-root canals occurred in 25.2% of mandibular first molars. The difference between the results of the present study and the study of Walker (28) may also be related to racial differences.

Mandibular second molars demonstrated some deviations in terms of root canal morphology compared with first molars (41). Weine *et al*. (9) and Bram and Fleisher (12) reported second molar teeth with different canal morphologies. In the present study, our findings regarding the mandibular second molars are similar to those of the first molars.

Sert *et al*. (16) reported two-rooted mandibular second molars had a single distal canal (76%) and two mesial canals (87.5%) that combined apically (53%). Similarly, Caliskan *et al*. determined the prevalence of a single distal canal to be 70% and two mesial canals as 90%; 41% of these mesial canals were reported to merge at the apex. According to Vertucci (3), single distal canal and two mesial canals were found in 92% and 73% of the cases, respectively, and 38% of these mesial canals merged at the apex. In the present study, two-rooted mandibular second molars had a single distal canal (80.5%) and two mesial canals (84%) that combined apically (50%). These data revealed that distinct results can be attributed to the racial differences.

Vertucci (3) reported the canal configurations of the mesial roots of 100 mandibular second molar teeth as 27% type I, 38% type II, 26% type IV and 9% type V. In the distal roots, 92% were type I, 3% were type II, 4% were type IV, and 1% were type V. Pineda and Kuttler (26) reported the incidence of type I configuration in the mesial roots of 300 mandibular teeth to be 58%. When these results are compared with those of the present study, the significant difference is likely due to the populations rather than the methodology.

Only a few studies have examined the root and canal morphologies of mandibular third molars (30,41,42). Green (41) examined 100 teeth using the grinding method and concluded that 74% of the examined teeth possessed type I configurations. Pineda and Kuttler (26) investigated 259 mandibular third molar teeth. In the mesial roots, 65.8% were type I, 17.7% were type II, 13.6% were type III, and 2.9% were type IV. In the distal roots, 92.2% were type I, 3.5% were type II, 2.8% were type IV, and 1.5% were type V. In the present study, 307 mandibular third molars were examined. In the mesial roots, 63.8% were type I, 21.1% were type II, 1.9% were type III, 8.4% were type IV, and 4.8% were type V. In the distal roots, 100% of the examined teeth exhibited type I canal configurations. In spite of methodological differences, the results of the present study are consistent with those of the other studies.

Although there are few studies that focus on mandibular third molars, the results are similar. When this data and the results of the present study are considered, it can be suggested that the majority of these teeth possess two roots and two canals (30,39,42).

Conclusion

In this study, the root canal configurations of maxillary and mandibular teeth and their distribution according to tooth types were evaluated. Interventions were performed to reveal the structural differences and similarities of third molars within their own groups.

According to our classic knowledge, maxillary first molars have three roots and three canals, and 93.0% of these teeth have three roots. Four canals exist in 67% of the cases, two of which are located in the mesiobuccal root. Three roots were observed in approximately 91.3% of the maxillary second molars, and four canals were observed in 39.7%. Among maxillary third molars, 34% had three roots and 41% had three canals.

The greatest amount of variation in terms of root canal structure among maxillary molars existed in the mesiobuccal roots of the first molars, whereas in the mesiobuccal roots of three-rooted maxillary third molars a poor diversity was observed. Among 897 maxillary molars examined, all had single palatal canals except for the maxillary first molars.

Of the mandibular third molars, 69.2% had two roots and two canals. Approximately one-third of these teeth exhibited different structures. The general anatomic configuration of the mandibular first and second molars was two roots and three canals. In this regard, the greatest variation in terms of root numbers was determined in mandibular third molars. Among the mandibular molar

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teeth, a second canal in the distal root was most frequently encountered in the third molars.

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