VIA MEDICA

REVIEW ARTICLE

Folia Morphol.
Vol. 84, No. 1, pp. 48–60
DOI: 10.5603/fm.98475
Copyright © 2025 Via Medica
ISSN 0015–5659
eISSN 1644–3284
journals.viamedica.pl

Root anatomy and canal configuration of human permanent maxillary third molar — a systematic review

Anna Olczyk, Barbara Malicka, Katarzyna Skośkiewicz-Malinowska

Department of Conservative Dentistry with Endodontics, Wroclaw Medical University, Wrocław, Poland

[Received: 9 December 2023; Accepted: 19 May 2024; Early publication date: 18 June 2024]

Knowledge of the configuration of root canals is essential for the success of endodontic treatment. The main aim of this systematic review was to determine the number of roots and the number of root canals in maxillary third molars, as well as where possible to determine the Vertucci classification. This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines. The study protocol was registered and approved on PROSPERO, the International Prospective Register of Systematic Reviews (Reg. No: CRD42022366444), before the start of the study. 12 studies were included in the analysis, differing in sample origin and methodology. The combined studies were analysed based on the number of roots, the number of canals, and the root canal configurations, and the findings were compared to those of other international studies. Analysing the available research results regarding the root anatomy and canal configuration of the third maxillary molar, most commonly maxillary third molars had three roots (59.0%). Single-rooted teeth (24.2%) or double-rooted teeth (13.8%) were less common. In addition, we observed that maxillary third molars typically possessed three root canals (47.28%) and the MB (mesiobuccal), DB (distobuccal), and P (palatal) canals most often showed Vertucci Type I (59.53%, 95.83% and 98.61%, respectively) in three-rooted form.

Due to the small number of available studies, it is necessary to conduct further analyses taking into account demographic and ethnic differences that may affect the anatomical and morphological structure of the teeth. (Folia Morphol 2025; 84, 1: 48–60)

Keywords: maxillary third molars, root canal anatomy, root canal morphology, upper third molars, Vertucci classification

INTRODUCTION

Background

The ability to correctly localise, chemomechanically prepare, and obturate the root canal system, and then perform tight-seal reconstruction of the crown of the tooth, is the basis for the success of endodontic treatment [19, 36]. Familiarity with the anatomy and morphology of the root canal system is an essential part of endodontic treatment. It is imperative to anticipate and master the knowledge of internal anatomy relationships. The presence of morphological differences in the localisation of canal orifices, and the number of root canals as well as their structure and course, should be taken into

Address for correspondence: Anna Olczyk, Department of Conservative Dentistry with Endodontics, Wroclaw Medical University, ul. Krakowska 26, 50–425 Wrocław, Poland; e-mail: annaolczyk.dent@gmail.com

account. The outcome of endodontic treatment depends on knowledge of root canal configuration. It is necessary to use magnification and modern imaging techniques to achieve a positive therapeutic effect [4, 5, 25, 28, 44].

Familiarisation with the technique used to assess the morphology of the canal is the key to its understanding. In past studies, radiography, clearing technique, micro-computed tomography (micro-CT), and cone-beam computed tomography (CBCT) have been used as methods to describe root canal morphology [18, 19, 25]. The appropriate radiological assistance is essential when assessing the complexity of root canal systems. One cannot properly diagnose, then plan and obtain a positive outcome, in root canal treatment without radiography. The omission of root canals may be the result of an incomplete image provided by a two-dimensional (2D) standard radiography. A better alternative to traditional radiographs is cone-beam computed tomography (CBCT). This gives a high-resolution, detailed three-dimensional image of a tooth, with the possibility of measuring the root length, canal curvature direction, assessing the number of canals and size of periapical lesions, as well as giving the general picture of the neighbouring anatomical structures [5, 25, 28].

Several classifications of root canal morphology have been created. As early as 1969, Weine [53] categorised root canals into three types, and in 1982 [52] he added a fourth type to his classification. Vertucci's research in 1984 on maxillary second premolars distinguished a classification that included eight types of root canal [51]. A study on Burmese teeth in 2001 [29] added an additional seven canal types to the earlier classifications, and in 2004 Sert et al. [40] in turn introduced 14 different types of root canal.

Third molars are characterised by considerably varying anatomy, which significantly hinders therapeutic procedures. Maxillary third molars exhibit distinct anatomical characteristics when juxtaposed with their mandibular counterparts, thereby precluding a direct comparative analysis between the two [16, 41, 46]. As dentistry has developed, in many clinical situations it is possible to perform endodontic treatment of third molars for restorative, orthodontic, and prosthodontic reasons. Third molars may be used as abutment teeth for fixed partial dentures or in cases of teeth that cannot be restored, and then an autotransplantation procedure may take place [6].

There have been numerous publications concerning the anatomy of maxillary and mandibular molars [9, 23, 32, 48] but papers concerning the anatomy of maxillary third molars are scarce. As a result of the small number of studies devoted to this issue, and due to the differences in the anatomical structure of the maxillary and mandibular third molars, we decided to prepare a review of the available literature in order to systematise the knowledge regarding the structure of the third molars of the maxilla. Since there has been no published review article regarding the root anatomy and canal configuration of the third maxillary molar, this systematic review was conducted on the investigations and retrospective studies that have been published concerning the anatomy and morphology of the root canal system of the maxillary third molar.

Objective

The main purpose of this study was to analyse the number of roots and the number of root canals in maxillary third molars, and, where possible, to determine the Vertucci classification.

MATERIALS AND METHODS

Selection criteria

Study design. The primary aim of this systematic review was to inspect the prevalence of root morphology, root number and, where possible, root canal configurations of permanent maxillary third molars based on the Vertucci classification.

This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement guidelines [33]. The study protocol was registered and approved on the PROSPERO International Prospective Register of Systematic Reviews (Reg. No: CRD42022366444) before the start of the study.

The study protocol was approved by the Bioethics Committee of Wroclaw Medical University (permission no. KB 206/2022) under the Declaration of Helsinki.

Inclusion criteria

A literature search was conducted to identify root anatomy in maxillary third molars. The literature review was carried out with the use of online electronic databases such as PubMed, Embase, Web of Science, and Science Direct, each time using the following phrases: 'maxillary third molars', 'root canal anatomy', and 'root canal morphology'. A total of

34 results from PubMed, 21 from Embase, 34 from Web of Science, and 143 from Science Direct were compiled. Additionally, the search was extended to include journals not listed in Journal Citation Reports. This revealed 34 more studies, of which 11 reports were sought for retrieval. After assessment for eligibility, four studies were excluded due to lack of clear information on the number of roots, which led to the inclusion of a final total of 12 studies (Fig. 1).

Exclusion criteria

Repeated studies, case reports, case series, reviews, and studies that did not describe the anatomy of maxillary third molars were excluded.

Search methods, data collection and data analysis

After comparing the results from the four databases, the titles and abstracts of the articles were examined by two independent reviewers. If it was deemed relevant, the corresponding full-text articles were then consulted. Articles that did not meet the inclusion criteria were excluded. Duplicates or repeated articles were rejected. Only articles in English were taken into consideration. Ultimately, 12 studies were incorporated into this review, focusing on the subject of maxillary third molars, and specifically addressing the number of roots and root canals. In addition, six of the included articles featured Vertucci's classification, which also comprised a variable in the study.

The frequency of root canal configurations, the number of teeth, the number of roots, and the place of origin of the samples analysed were presented in tables. Publication year and study details/characteristics of the participants at baseline were recorded when available. The corresponding results, including relevant aspects, were summarised in tables.

PICO [17]

P — Population: human permanent maxillary third molar,

O — Outcomes: root canal morphology according to the Vertucci and Sert et al. classifications,

S — Study design: *in vitro* and *in vivo* studies.

Quality assessment in individual studies

Two reviewers (AO and BM) manually searched the reference lists of all selected studies for additional relevant articles. Disagreements between the two reviewers were resolved by discussion. If disagreement persisted, the opinion of a third reviewer (KSM) was decisive.

The AMSTAR 2 (a critical appraisal tool for systematic reviews that includes randomised or non-randomised studies of healthcare interventions, or both) scale was used to evaluate the risk of bias (RoB) and methodological quality of the included studies which were evaluated independently by two authors [42]. The overall assessment of the methodological quality of this review was that it was high quality (++). The majority of the criteria were met, and little or no risk of bias was detected.

RESULTS

The 12 studies included in the analysis differed in their methodology and sample origin i.e. India [36], Myanmar [29], Thailand [2], China [54], Türkiye [41], Poland [50], Iran [13], USA [43], Russia [38], Jordan [3], and Romania [49]. Almost all of the studies were performed on extracted teeth, one was based on CBCT scans examination [38], while anatomy assessment was based on CBCT image [36, 38], micro-CBCT [50], two radiographs with an ISO 15 K file [13], perpendicular sections to the axis of the root in the cervical third and apical third [49], staining method with Indian ink [2, 3, 29, 41, 43, 45] or staining method with Chinese ink [54] (Tab. 1).

Out of a total of 2,123 teeth included in this analysis, maxillary third molars most commonly had three roots (59%). Single-rooted teeth (24.2%) and double-rooted teeth (13.8%) were less frequent, while four-rooted forms accounted for a negligible percentage (2.9%) and five-rooted teeth were extremely rare (0.03%) (Fig. 2). Four-rooted teeth occurred in seven nations — Myanmar, Thailand, Turkey, Iran, USA, Jordan and Romania. Five-rooted teeth occurred only in Jordan. The presence of C-type canals was found only in two studies [3, 36] where they accounted for 3.4% and 1.69% respectively of the examined teeth and for 0.46% of all examined teeth (Tab. 1, 2). Most frequently, maxillary third molars had three canals (47.28%) (Tab. 3).

Among single-rooted teeth, Vertucci type I was the most common (52.83%). According to Sert et al. [40], an additional classification is necessary due to the occurrence of root canal types not classified by Vertucci. This concerns types XV (8.29%), XVIII (0.19%), and XXIII (4%) (Tab. 4).

Among double-rooted teeth with two separate roots, both in the buccal and palatal regions, Vertucci type I was the most common configuration (71.65% and 86.09%, respectively) (Tab. 5). Among

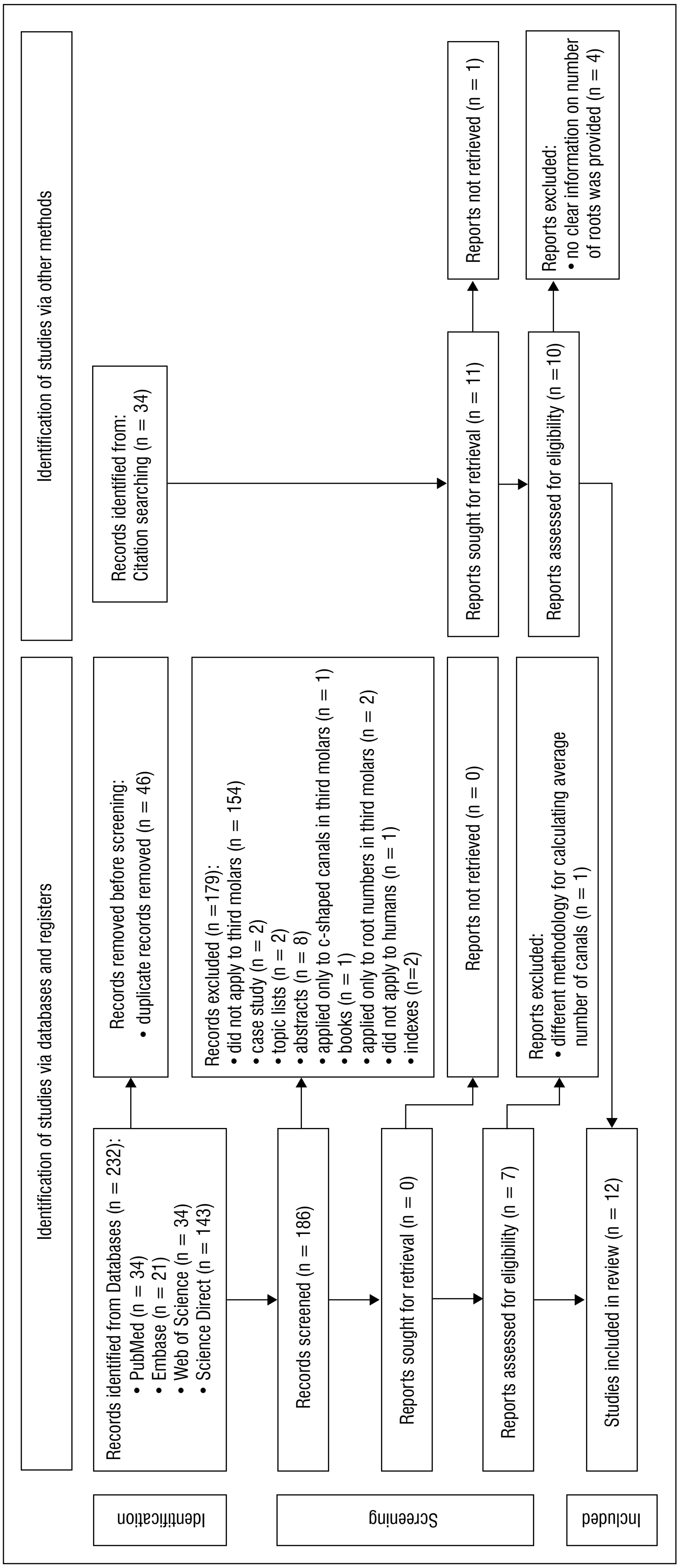

Figure 1. PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources (Source: [33]. For more information, visit: http://www.prisma-statement.org/).

Table 1. Characteristics of studies.

Authors	Method of study	Sample size	Location
Rawtiya et al. [36]	CBCT	116	Central India
Ng et al. [29]	Indian ink staining	72	Myanmar
Alavi et al. [2]	Indian ink staining	151	Thailand
Singh et al. [45]	Indian ink staining	100	India
Weng et al. [54]	Chinese ink staining	43	China
Sert et al. [41]	Indian ink staining	290	Ankara, Türkiye
Tomaszewska et al. [50]	Micro-CT	78	Krakow, Poland
Faramarzi et al. [13]	Two radiographs with K file number 0.15	179	Iran
Sidow et al. [43]	Indian ink staining	150	Georgia, USA
Razumova et al. [37]	CBCT	238	Russia
Al-Qudah et al. [3]	Indian ink staining	592	Jordan
Todor et al. [49]	Perpendicular sections to axis of root in cervical and apical third	114	Romania

CBCT — cone-beam computed tomography

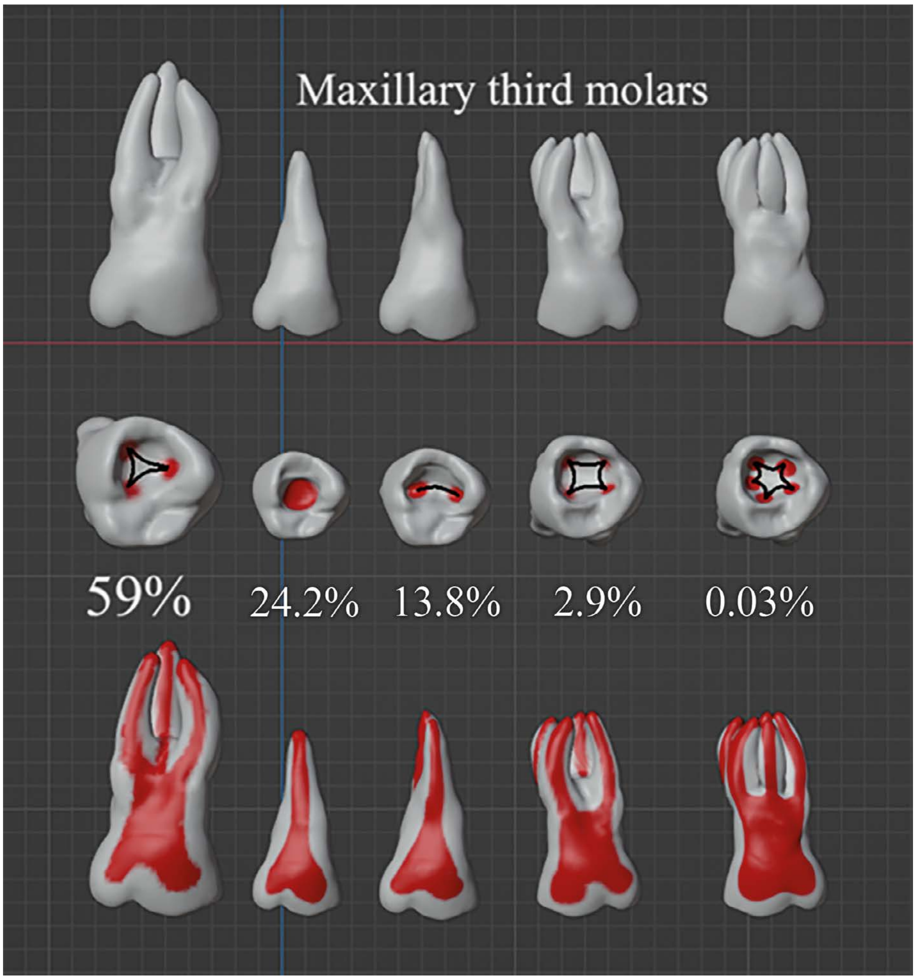

Figure 2. Distribution of root morphologies in maxillary third molars.

Table 2. Frequency [%] of roots in third maxillary molars.

Authors	Single rooted	Double rooted	Fused double rooted	Triple rooted	Fused triple rooted	Quadruple rooted	Fused quadruple rooted	Quintuple rooted
Rawtiya et al. [36]	31.0	13.00	0.00	55.20	0.00	0.00	0.00	0.00
Ng et al. [29]	19.44	19.44	19.44	55.56	30.56	5.56	5.56	0.00
Alavi et al. [2]	3.31	6.62	6.62	88.08	37.09	1.99	1.99	0.00
Singh et al.[45]	20.00	33.00	0.00	47.00	0.00	0.00	0.00	0.00
Weng et al. [54]	0.00	0.00	0.00	100.00	44.19	0.00	0.00	0.00
Sert et al. [41]	35.52	28.62	0.00	34.14	0.00	1.72	0.00	0.00
Tomaszewska et al. [50]	38.46	0.00	0.00	61.54	61.54	0.00	0.00	0.00
Faramarzi et al. [13]	15.08	11.73	0.00	67.60	8.94	5.59	0.00	0.00
Sidow et al. [43]	15.33	32.00	0.00	45.33	0.00	7.33	0.00	0.00
Razumova et al. [37]	47.90	0.00	0.00	52.10	0.00	0.00	0.00	0.00
Al-Qudah et al. [3]	10.81	9.80	5.24	69.93	28.89	9.12	8.11	0.34
Todor et al. [49]	53.51	11.40	11.40	31.58	3.51	3.51	0.00	0.00
Average	24.20	13.80	3.56	59.00	17.89	2.90	1.30	0.03

Table 3. Frequency [%] of canals in third maxillary molars.

Authors	Single canal	2-canals	3-canals	4-canals	5-canals
Rawtiya et al. [36]	19.0	0	37.90	24.10	3.40
Ng et al. [29]	2.78	5.56	29.17	22.22	0.00
Alavi et al. [2]	9.93	7.95	31.79	6.62	0.00
Singh et al. [45]	19.00	33.00	43.00	5.00	0.00
Weng et al. [54]	27.91	11.63	44.19	16.28	0.00
Sert et al. [41]	n/a*	n/a*	n/a*	n/a*	n/a*
Tomaszewska et al. [50]	23.08	15.38	46.15	15.38	0.00
Faramarzi et al. [13]	12.85	10.61	68.72	8.94	0.00
Sidow et al. [43]	n/a*	n/a*	n/a*	n/a*	n/a*
Razumova et al. [37]	13.87	11.76	72.27	2.10	0.00
Al-Qudah et al. [3]	5.91	11.49	52.36	28.21	2.03
Todor et al. [49]	n/a*	n/a*	n/a*	n/a*	n/a*
Average	14.92	11.93	47.28	14.32	0.60

the two-rooted fused teeth, Vertucci type IV was the most common (51.43%), followed by types I and II (both 17.14%), and then type VIII (7.14%). In addition, 7.14% of the teeth had type XV roots according to Sert et al. [40] (Tab. 6).

As far as three-rooted maxillary third molars were concerned, the MB (mesiobuccal), DB (distobuccal) and P (palatal) roots most commonly showed Type I configuration (59.53%, 95.83%, and 98.61%, respectively) (Tab. 7). On average, in a three-rooted maxillary third molar with three separate roots, the mesiobuccal second (MB2) canal was present in 16.28% of cases. In cases of fusion of all three roots in the maxillary third molar, Types I (30.22%) and VIII (25.33%) according to Vertucci were the most prevalent (Tab. 8). In cases of fusion of only the buccal roots, the most frequent types in the fused MB and DB root were Types II and IV equally (both 31.25%), while the palatal root was present only in Type I according to Vertucci (Tab. 9).

In the rare cases of four-rooted maxillary third molars, when all roots were fused, Sert et al. [40] type XXIII was most common, while when there were

Table 4. Frequency (%) of root canal classification according to Vertucci [51] and Sert et al. [40] in single rooted third maxillary molar teeth.

Author	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VIII	Type XV (3–2)	Type XVIII (3–1)	Type XXIII (3–4)
Rawtiya et al. [36]	47.06	17.65	11.76	5.88	11.76	5.88	0.00	0.00	0.00	0.00
Ng et al. [29]	14.29	42.86	0.00	14.29	7.14	0.00	0.00	21.43	0.00	0.00
Alavi et al. [2]	40.00	0.00	0.00	0.00	0.00	0.00	20.00	20.00	0.00	20.00
Singh and Pawar [45]	90.00	0.00	5.00	0.00	5.00	0.00	0.00	0.00	0.00	0.00
Weng et al. [54]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sert et al. [41]	72.82	9.71	3.88	7.77	3.88	0.97	0.00	0.00	0.97	0.00
Average	52.83	14.04	4.13	5.59	5.56	1.37	4.00	8.29	0.19	4.00

Table 5. Frequency (%) of root canal classification according to Vertucci [51] and Sert et al. [40] in 2-rooted third maxillary molar.

Author	**Buccal root**					**Palatal root**		
	Type I	**Type II**	**Type III**	**Type IV**	**Type V**	**Type I**	**Type II**	**Type IV**
Rawtiya et al. [36]	42.86	14.29	0.00	42.86	0.00	62.50	0.00	37.50
Ng et al. [29]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Alavi et al. [2]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Singh et al. [45]	93.94	0.00	3.03	3.03	0.00	96.97	0.00	3.03
Weng et al. [54]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sert et al. [41]	78.15	20.48	3.61	6.02	4.82	98.80	1.20	0.00
Average	71.65	11.59	2.21	17.30	1.61	86.09	0.40	13.51

Table 6. Frequency (%) of root canal classification according to Vertucci [51] and Sert et al. [40] in 2-rooted fused third maxillary molar.

Author	**Type I**	**Type II**	**Type IV**	**Type VIII**	**Type XV (3–2)**
Rawtiya et al. [36]	n/a	n/a	n/a	n/a	n/a
Ng et al. [29]	14.29	14.29	42.86	14.29	14.29
Alavi et al. [2]	20.00	20.00	60.00	0.00	0.00
Singh et al. [45]	n/a	n/a	n/a	n/a	n/a
Weng et al. [54]	n/a	n/a	n/a	n/a	n/a
Sert et al. [41]	n/a	n/a	n/a	n/a	n/a
Average	17.14	17.14	51.43	7.14	7.14

four separate roots, each root was only Vertucci Type I (Tab. 10).

DISCUSSION

Our analysis of 12 studies [2, 3, 13, 29, 36, 38, 41, 43, 45, 49, 50, 54] found that maxillary third molars most often had three roots (59%) and three canals (47.28%). The presence of a second mesiobuccal canal (MB2) in the case of three-rooted maxillary third molars with three separate roots was observed in an average of 16.28% of cases. Of the 12 studies included in our review, half (six) concerned canal types according to Vertucci's classification which allowed the conclusion that in the case of three-rooted maxillary third molars, MB, DB and P roots most often showed type I (59.53%, 95.83%, and 98.61%, respectively).

A systematic review [14] on the anatomy of maxillary second molars found that three-rooted teeth are the most common, and four-rooted teeth are the least common. The most common root canal types in palatal and mesiodistal root was type I. The presence of a second mesiobuccal canal in different studies has ranged from 11.53% to 93.7% [14] and the most common canal configurations were Vertucci types I, II and IV [35]. Barbhai et al. [5] after analysing 533 studies, used 35 studies for data extraction, which

Table 7. Frequency [%] of root canal classification according to Vertucci [51] and Sert et al. [40] in 3-rooted third maxillary molar.
A. Mesiobuccal root

Author	Type I	Type II	Type III	Type IV	Type V	Type VI	Type VII	Type IX	Type XV
Rawtiya et al. [36]	43.80	15.60	0.00	40.60	0.00	0.00	0.00	0.00	0.00
Ng et al. [29]	61.11	11.11	0.00	22.22	0.00	5.56	0.00	0.00	0.00
Alavi et al. [2]	54.55	12.99	3.90	12.99	9.09	2.60	2.60	0.00	1.30
Singh et al. [45]	57.45	31.91	2.13	8.51	0.00	0.00	0.00	0.00	0.00
Weng et al. [54]	62.50	20.83	4.17	8.33	4.17	0.00	0.00	0.00	0.00
Sert et al. [41]	77.78	13.13	0.00	5.05	0.00	0.00	0.00	0.00	0.00
Average	59.53	17.60	1.70	16.28	2.21	1.36	0.43	0.00	0.22

B. Distobuccal and palatal root

Author	Distobuccal root					Palatal root		
	Type I	Type II	Type III	Type IV	Type V	Type I	Type III	Type V
Rawtiya et al. [36]	87.50	3.10	0.00	9.40	0.00	100.00	0	0
Ng et al. [29]	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Alavi et al. [2]	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Singh et al. [45]	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Weng et al. [54]	87.50	0.00	4.17	0.00	8.33	91.67	4.17	4.17
Sert et al. [41]	100.00	0.00	0.00	0.00	0.00	100.00	0.00	0.00
Average	95.83	0.52	0.69	1.57	1.39	98.61	0.69	0.69

Table 8. Frequency [%] of root canal classification according to Vertucci [51] and Sert et al. [40] in fused 3-rooted maxillary third molar.

Author	Type I	Type II	Type IV	Type VI	Type VIII	Type XV (3–2)	Type XVI (2–3)	Type XVIII (3–1)	Type XX (4)	Type XXI (4–1)	Type XXIII (3–4)
Rawtiya et al. [36]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ng et al. [29]	0.00	0.00	4.55	0.00	45.45	22.73	0.00	0.00	18.18	4.55	4.55
Alavi et al. [2]	27.50	7.50	12.50	0.00	20.00	12.50	5.00	5.00	0.00	0.00	10.00
Singh et al.[45]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weng et al. [54]	63.16	21.05	0.00	5.26	10.53	0.00	0.00	0.00	0.00	0.00	0.00
Sert et al. [41]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Average	30.22	9.52	5.68	1.75	25.33	11.74	1.67	1.67	6.06	1.52	4.85

showed that three-rooted maxillary first molars were most frequently reported. The distobuccal and palatal roots mostly had a single root canal, and type I of root canal configuration was the most frequent. The anatomy of the mesiobuccal canal appears to be more complex due to the high frequency of occurrence of the second mesiobuccal canal (68.2%) and the reported higher prevalence of Vertucci types I, II and IV in the mesiobuccal root [5].

The morphology of root anatomy is influenced by age, gender, number of teeth, and the methodology of the study. Information can be found in the literature that the anatomical structure of maxillary molars may be sex-dependent [5]. Several studies have conducted analyses to identify possible relationships between the morphology of the root canal and the gender and age of the patient. Based on the research by Naseri et al. [28] on maxillary first molars, there are no differences in canal configuration related to gender or age, nor in the frequency of roots or the number of canals. A study on a Yemeni [27] population on the same group of teeth also revealed no significant gender differences relating to the number of roots, as well as no gender predilection in complete fusion of teeth. The authors obtained the same conclusion

Table 9. Frequency [%] of root canal classification according to Vertucci [51] and Sert et al. [40] in 3-rooted maxillary third molar with fused MB and DB roots.

Author	Fused MB and DB roots							Palatal root
	Type I	Type II	Type IV	Type VI	Type XV (3–2)	Type XVI (2–3)	Type XXIII (3–4)	Type I
Rawtiya et al. [36]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ng et al. [29]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Alavi et al. [2]	6.25	31.25	31.25	12.50	6.25	6.25	6.25	100.00
Singh et al. [45]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weng et al. [54]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sert et al. [41]	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Average	6.25	31.25	31.25	12.50	6.25	6.25	6.25	100.00

DB — distobuccal; MB — mesiobuccal.

Table 10. Frequency [%] of root canal classification according to Vertucci [51] and Sert et al. [40] in 4-rooted maxillary third molar.

Author	Fused roots			Mesiobuccal root	Mesiobuccal 2 root	Distobuccal root	Palatal root
	Type XV (3–2)	Type XXIII (3–4)	Type XX (4)	Type I	Type I	Type I	Type I
Rawtiya et al. [36]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Ng et al. [29]	25	25	50	n/a	n/a	n/a	n/a
Alavi et al. [2]	0.00	100.00	0.00	n/a	n/a	n/a	n/a
Singh et al. [45]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Weng et al. [54]	n/a	n/a	n/a	n/a	n/a	n/a	n/a
Sert et al. [41]	n/a	n/a	n/a	100.00	100.00	100.00	100.00
Average	12.50	62.50	25.00	100.00	100.00	100.00	100.00

with the variations of the root canals in the context of Vertucci's classification of root canals. A study on a Saudi [26] population found statistically significant differences between the number of canals and canal variations between males and females in maxillary teeth. A study on a Korean [20] population found there was a higher prevalence of MB2 canal in males than females. A study on a Polish [30] population also concluded that MB2 canals were more frequent in males than females. Moreover, there were differences in age prevalence of MB2 canal. A higher prevalence was found in patients aged between 31 and 40 and between 21 and 30 in maxillary second molars, while the prevalence of MB2 canal in the maxillary first molars was nearly equally distributed in these two age groups (21–30 and 31–40 years). A study on a Thai [35] population also found greater prevalence of MB2 canal in males than in females. They found also a correlation between age groups and a higher prevalence in younger groups in first maxillary molars, while in second maxillary molars the highest prevalence was in older groups. A study on a Turkish [40] population found differences in the maxillary incisors: a second canal was more prevalent in females than in males.

Only two studies included in our analysis [36, 50] mentioned division of teeth based on sex. The analysis of Vertucci classification indicated that Type I was statistically significant and predominant in both male and female subjects with single-rooted maxillary third molars. Additionally in males was observed also Vertucci classification Types IV (14.3%), V (28.6%), and VI (14.3%) and in females Types II (30%) and III (20%), whereas in two rooted third maxillary molars females had predominantly Type IV (66.7%) and males Type I (75%) of Vertucci classification of root canal.

To sum up, it cannot be clearly stated whether features such as age and gender have a significant impact on the anatomical structure of the teeth.

The number of studies performed has been small and their results are not always consistent, which makes their general interpretation impossible.

Other factors influencing the results of a study may be the geographical location of specific populations and their ethnicity [12, 24, 25, 31, 32, 37, 44, 47]. Differences in the findings may be due to certain genetic predispositions [24, 34]. Unfortunately, the lack of suitable data in the papers included in the literature review prevented analysis of this aspect. Studies included in the review were mainly conducted in Asia — namely India [36, 45], Myanmar [29], Thailand [2], China [54], Türkiye [41], Iran [13], Jordan [3] and Russia [38]. There were two studies conducted in Europe: Poland [50] and Romania [49] and one in North America, namely USA [43].

In future, studies of maxillary third molars covering more countries in other continents and other races should be conducted in order to verify the hypothesis of anatomical differences between populations.

In studies aimed at assessing the morphology of the canal system, it becomes necessary to look at the technique used to evaluate this information. Clearing techniques, radiography, micro-computed tomography (micro-CT), and cone-beam computed tomography (CBCT), as well as classical radiography examination with endodontic files and cross-sections of the roots have been used in laboratory studies to establish root canal morphology [21, 22, 31, 47]. The ability to render the tooth transparent by demineralisation after injecting liquid materials like ink, gelatine, or molten metal made the clearing technique dominate the majority of earlier studies. The fundamental disadvantage of this technique is that it produces permanent changes in the tooth structure and creates artifacts which may distort the actual morphology of the root canal [31]. Kim et al. [21] compared two-dimensional (2D) and three-dimensional (3D) micro-CT image reformatting with standard tooth clearing for studying mandibular first molar mesial root canal morphology. Combined 2D and 3D micro-CT images yielded much more accurate canal configurations and fine anatomical structures than the clearing technique [21]. It is clearly beneficial to use the CBCT technique in assessing the anatomy of root canals, as it provides a three-dimensional image in high resolution with a relatively low radiation dose [47]. Domark et al. [10] found no difference in canal counts between micro-CT and CBCT. Both methods were better than digital radiography. To achieve the best image quality, Ordinola-Zapata et al. [31] used similar laboratory conditions for both imaging methods (micro-CT and CBCT). Even though both micro-CBCT and CBCT devices showed highly accurate images that allowed the authors to identify the canal configuration, some fine anatomical structures were not detected in CBCT images compared to micro-CT images.

It should be noted that most of the studies included in this review were performed using the staining technique, and only one evaluated anatomy with the use of CBCT, so differences in methodology may have influenced the results. The cross-sectional method of examining tooth root morphology, while useful in certain contexts, is associated with some disadvantages i.e. limitations of two-dimensional image, potential alteration of tissue structure, time-consuming and resource-intensive methods, risk of misinterpretation, and destruction of specimens.

When analysing the anatomical variability of third molars, it should be mentioned that tooth agenesis (the congenital absence of one or more teeth) occurs in c.20% of the population [1]. Based on data in the systematic review and meta-analysis by Carter at al. [7], the worldwide rate of agenesis was found to be 22.63%. The highest rate of agenesis of third molars, 29.7%, occurs in the Asian population, which would confirm the thesis about the influence of race on the variability of anatomy. Moreover, agenesis of third molars has been shown to be gender-dependent, occurring more commonly in women than in men. Some studies have shown that the absence of other teeth increases the chance of third molar agenesis [8, 11]. The frequency of agenesis of third molars (55.8%) in the European population, when agenesis of other teeth was diagnosed, was c.2.5 times higher than in the control group [39]. The origin of tooth agenesis is genetic, but agenesis of third molars is unclear, and the significant impact of both environmental and genetic factors should be taken into account.

Agenesis of third molars is not a developmental disturbance, but rather an evolutionary adaptation of the dentition. Due to the high prevalence of agenesis of third molars, the absence of third molars when all other permanent teeth are present is perceived as a normal phenotype. Gkantidis et al. [15] in 2021 found that missing one or more third molars is associated with a smaller maxilla, a smaller mandible, and a smaller overall facial configuration. The authors concluded that isolated agenesis of third molars is associated with a reduction in the size of the viscerocranium, which may be the result of an evolutionary process in humans leading to fewer and smaller teeth, as well as smaller facial structures.

CONCLUSIONS

The authors' analysis of the available research results regarding the root anatomy and canal configuration has revealed that, most commonly, maxillary third molars had three roots (59%). Single-rooted teeth (24.2%) or double-rooted teeth (13.8%) were less common. In addition, most commonly third maxillary molars had three root canals (47.28%) and the MB, DB, and P canals most often showed Vertucci Type I (59.53%, 95.83%, and 98.61%, respectively). Due to the small number of available studies, further analyses should be conducted taking into account demographic and ethnic differences that may affect the anatomical and morphological structure of the teeth.

ARTICLE INFORMATION AND DECLARATIONS

Data availability statement

The reported systematic review and meta-analysis are registered with PROSPERO reg. no.: CRD42022366444. The datasets used and analysed during the current study are available as Supplementary files.

Author contributions

AO: conceptualisation, methodology, data curation, formal analysis, investigation, writing — original draft, project administration; BM: conceptualisation, methodology, data curation, formal analysis, investigation, writing — original draft, validation, writing — review and editing, project administration; KS-M: supervision, validation, writing — review and editing, project administration, funding acquisition.

Ethics statement

The study protocol was approved by the Bioethics Committee of Wroclaw Medical University (permission no. KB 206/2022) under the Declaration of Helsinki.

Funding

This study was supported with funds from the Wrocław Medical University from the co-financing of tasks under the subsidy for the maintenance and development of research potential in 2022.

Conflict of interest

The authors declare no conflict of interest.

Supplementary materials

Supplementary material is available on Journal's website. This includes:

Supplementary Material 1. The datasets used and analysed during the current study.

REFERENCES

1. Alamoudi R, Ghamri M, Mistakidis I, et al. Sexual dimorphism in third molar agenesis in humans with and without agenesis of other teeth. Biology (Basel). 2022; 11(12), doi: 10.3390/biology11121725, indexed in Pubmed: 36552235.
2. Alavi AM, Opasanon A, Ng YL, et al. Root and canal morphology of Thai maxillary molars. Int Endod J. 2002; 35(5): 478–485, doi: 10.1046/j.1365-2591.2002.00511.x, indexed in Pubmed: 12059921.
3. Al-Qudah AA, Bani Younis HA, Awawdeh LA, et al. Root and canal morphology of third molar teeth. Sci Rep. 2023; 13(1): 6901, doi: 10.1038/s41598-023-34134-7, indexed in Pubmed: 37106025.
4. Aung NM, Myint KK. Diagnostic accuracy of CBCT for detection of second canal of permanent teeth: a systematic review and meta-analysis. Int J Dent. 2021; 2021: 1107471, doi: 10.1155/2021/1107471, indexed in Pubmed: 34335767.
5. Barbhai S, Shetty R, Joshi P, et al. Evaluation of root anatomy and canal configuration of human permanent maxillary first molar using cone-beam computed tomography: a systematic review. Int J Environ Res Public Health. 2022; 19(16), doi: 10.3390/ijerph191610160, indexed in Pubmed: 36011794.
6. De Bruyn L, Vranckx M, Jacobs R, et al. A retrospective cohort study on reasons to retain third molars. Int J Oral Maxillofac Surg. 2020; 49(6): 816–821, doi: 10.1016/j.ijom.2019.10.003, indexed in Pubmed: 31703978.
7. Carter K, Worthington S. Morphologic and demographic predictors of third molar agenesis: a systematic review and meta-analysis. J Dent Res. 2015; 94(7): 886–894, doi: 10.1177/0022034515581644, indexed in Pubmed: 25883107.
8. Celikoglu M, Kazanci F, Miloglu O, et al. Frequency and characteristics of tooth agenesis among an orthodontic patient population. Med Oral Patol Oral Cir Bucal. 2010; 15(5): e797–e801, doi: 10.4317/medoral.15.e797, indexed in Pubmed: 20383097.
9. Cleghorn BM, Christie WH, Dong CCS. Root and root canal morphology of the human permanent maxillary first molar: a literature review. J Endod. 2006; 32(9): 813–821, doi: 10.1016/j.joen.2006.04.014, indexed in Pubmed: 16934622.
10. Domark JD, Hatton JF, Benison RP, et al. An ex vivo comparison of digital radiography and cone-beam and micro computed tomography in the detection of the number of canals in the mesiobuccal roots of maxillary molars. J Endod. 2013; 39(7): 901–905, doi: 10.1016/j.joen.2013.01.010, indexed in Pubmed: 23791260.

11. Endo S, Sanpei S, Ishida R, et al. Association between third molar agenesis patterns and agenesis of other teeth in a Japanese orthodontic population. Odontology. 2015; 103(1): 89–96, doi: 10.1007/s10266-013-0134-1, indexed in Pubmed: 23990107.
12. Estrela C, Bueno MR, Couto GS, et al. Study of root canal anatomy in human permanent teeth in a subpopulation of brazil's center region using cone-beam computed tomography — part 1. Braz Dent J. 2015; 26(5): 530–536, doi: 10.1590/0103-6440201302448, indexed in Pubmed: 26647941.
13. Faramarzi F, Shahriari S, Shokri A, et al. Radiographic evaluation of root and canal morphologies of third molar teeth in Iranian population. Avicenna J Dent Res. 2013; 5(1): 30–32, doi: 10.17795/ajdr-21102.
14. Ghasemi N, Rahimi S, Shahi S, et al. A review on root anatomy and canal configuration of the maxillary second molars. Iran Endod J. 2017; 12(1): 1–9, doi: 10.22037/iej.2017.01, indexed in Pubmed: 28179915.
15. Gkantidis N, Tacchi M, Oeschger ES, et al. Third molar agenesis is associated with facial size. Biology (Basel). 2021; 10(7), doi: 10.3390/biology10070650, indexed in Pubmed: 34356505.
16. Gulabivala K, Opasanon A, Ng YL, et al. Root and canal morphology of Thai mandibular molars. Int Endod J. 2002; 35(1): 56–62, doi: 10.1046/j.1365-2591.2002.00452.x, indexed in Pubmed: 11853239.
17. Huang X, Lin J, Demner-Fushman D. Evaluation of PICO as a knowledge representation for clinical questions. AMIA Annu Symp Proc. 2006; 2006: 359–363, indexed in Pubmed: 17238363.
18. Joshi PS, Shetty R, Sarode GS, et al. Root anatomy and canal configuration of human permanent mandibular second molar: A systematic review. J Conserv Dent. 2021; 24(4): 298–306, doi: 10.4103/jcd.jcd_642_20, indexed in Pubmed: 35282577.
19. Karobari MI, Parveen A, Mirza MB, et al. Root and root canal morphology classification systems. Int J Dent. 2021; 2021: 6682189, doi: 10.1155/2021/6682189, indexed in Pubmed: 33679981.
20. Kim Y, Lee SJ, Woo J. Morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a Korean population: variations in the number of roots and canals and the incidence of fusion. J Endod. 2012; 38(8): 1063–1068, doi: 10.1016/j.joen.2012.04.025, indexed in Pubmed: 22794206.
21. Kim Y, Perinpanayagam H, Lee JK, et al. Comparison of mandibular first molar mesial root canal morphology using micro-computed tomography and clearing technique. Acta Odontol Scand. 2015; 73(6): 427–432, doi: 10.3109/00016357.2014.976263, indexed in Pubmed: 25385684.
22. Lu TY, Yang SF, Pai SF. Complicated root canal morphology of mandibular first premolar in a Chinese population using the cross section method. J Endod. 2006; 32(10): 932–936, doi: 10.1016/j.joen.2006.04.008, indexed in Pubmed: 16982267.
23. Mahesh R, Nivedhitha MS. Root canal morphology of primary mandibular second molar: a systematic review. Saudi Endod J. 2020; 10(1): 1, doi: 10.4103/sej.sej_18_19.
24. Martins JNR, Gu Y, Marques D, et al. Differences on the root and root canal morphologies between Asian and white ethnic groups analyzed by cone-beam computed tomography. J Endod. 2018; 44(7): 1096–1104, doi: 10.1016/j.joen.2018.04.001, indexed in Pubmed: 29861062.
25. Mashyakhy M, AlTuwaijri N, Alessa R, et al. Anatomical evaluation of root and root canal morphology of permanent mandibular dentition among the Saudi Arabian population: a systematic review. Biomed Res Int. 2022; 2022: 2400314, doi: 10.1155/2022/2400314, indexed in Pubmed: 35958809.
26. Mashyakhy M, Gambarini G. Root and root canal morphology differences between genders: a comprehensive CBCT study in a saudi population. Acta Stomatol Croat. 2019; 53(3): 213–246, doi: 10.15644/asc53/3/5, indexed in Pubmed: 31749454.
27. Mufadhal AA, Madfa AA. The morphology of permanent maxillary first molars evaluated by cone-beam computed tomography among a Yemeni population. BMC Oral Health. 2023; 23(1): 46, doi: 10.1186/s12903-023-02752-2, indexed in Pubmed: 36703140.
28. Naseri M, Kharazifard MJ, Hosseinpour S. Canal configuration of mesiobuccal roots in permanent maxillary first molars in iranian population: a systematic review. J Dent (Tehran). 2016; 13(6): 438–447, indexed in Pubmed: 28243306.
29. Ng YL, Aung TH, Alavi A, et al. Root and canal morphology of Burmese maxillary molars. Int Endod J. 2001; 34(8): 620–630, doi: 10.1046/j.1365-2591.2001.00438.x, indexed in Pubmed: 11762499.
30. Olczak K, Pawlicka H. The morphology of maxillary first and second molars analyzed by cone-beam computed tomography in a polish population. BMC Med Imaging. 2017; 17(1): 68, doi: 10.1186/s12880-017-0243-3, indexed in Pubmed: 29284426.
31. Ordinola-Zapata R, Martins JNR, Plascencia H, et al. Optimizing endodontic irrigation: advantages of negative apical pressure technology. Dent Today. 2013; 32(5): 88, 90–88, 93, indexed in Pubmed: 23721002.
32. de Pablo OV, Estevez R, Péix Sánchez M, et al. Root anatomy and canal configuration of the permanent mandibular first molar: a systematic review. J Endod. 2010; 36(12): 1919–1931, doi: 10.1016/j.joen.2010.08.055, indexed in Pubmed: 21092807.
33. Page MJ, McKenzie J, Bossuyt P, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021; 372: n71, doi: 10.1136/bmj.n71.
34. PEIRIS R. Root and canal morphology of human permanent teeth in a Sri Lankan and Japanese population. Anthropol Sci. 2008; 116(2): 123–133, doi: 10.1537/ase.070723.
35. Ratanajirasut R, Panichuttra A, Panmekiate S. A cone-beam computed tomographic study of root and canal morphology of maxillary first and second permanent molars in a Thai population. J Endod. 2018; 44(1): 56–61, doi: 10.1016/j.joen.2017.08.020, indexed in Pubmed: 29061352.
36. Rawtiya M, Somasundaram P, Wadhwani S, et al. Retrospective study of root canal configurations of maxillary third molars in Central India population using cone beam computed tomography Part- I. Eur J Dent. 2016; 10(1): 97–102, doi: 10.4103/1305-7456.175690, indexed in Pubmed: 27011747.
37. Razumova S, Brago A, Howijieh A, et al. Evaluation of cross-sectional root canal shape and presentation of new

classification of its changes using cone-beam computed tomography scanning. Appl Sci. 2020; 10(13): 4495, doi: 10.3390/app10134495.
38. Razumova S, Brago A, Khaskhanova L, et al. A cone-beam computed tomography scanning of the root canal system of permanent teeth among the Moscow population. Int J Dent. 2018; 2018: 2615746, doi: 10.1155/2018/2615746, indexed in Pubmed: 30356403.
39. Scheiwiller M, Oeschger ES, Gkantidis N. Third molar agenesis in modern humans with and without agenesis of other teeth. PeerJ. 2020; 8: e10367, doi: 10.7717/peerj.10367, indexed in Pubmed: 33240669.
40. Sert S, Bayirli GS. Evaluation of the root canal configurations of the mandibular and maxillary permanent teeth by gender in the Turkish population. J Endod. 2004; 30(6): 391–398, doi: 10.1097/00004770-200406000-00004, indexed in Pubmed: 15167464.
41. Sert S, Sahinkesen G, Topçu FT, et al. Root canal configurations of third molar teeth. A comparison with first and second molars in the Turkish population. Aust Endod J. 2011; 37(3): 109–117, doi: 10.1111/j.1747-4477.2010.00254.x, indexed in Pubmed: 22117717.
42. Shea BJ, Grimshaw JM, Wells GA, et al. Development of AMSTAR: a measurement tool to assess the methodological quality of systematic reviews. BMC Med Res Methodol. 2007; 7: 10, doi: 10.1186/1471-2288-7-10, indexed in Pubmed: 17302989.
43. Sidow SJ, West LA, Liewehr FR, et al. Root canal morphology of human maxillary and mandibular third molars. J Endod. 2000; 26(11): 675–678, doi: 10.1097/00004770-200011000-00011, indexed in Pubmed: 11469300.
44. Silva E, Prado M, Duarte M, et al. Prevalence of root canal system configurations in the Brazilian population analyzed by cone-beam computed tomography — a systematic review. Rev Port Estomatol Med Dent Cir Maxilofac. 2021; 62(2), doi: 10.24873/j.rpemd.2021.03.829.
45. Singh S, Pawar M. Root canal morphology of South Asian Indian maxillary molar teeth. Eur J Dent. 2015; 9(1): 133–144, doi: 10.4103/1305-7456.149662, indexed in Pubmed: 25713497.
46. Singh S, Pawar M, Podar R, et al. Root canal morphology of South Asian Indian mandibular first, second, and third molar: A dye penetration and clearing study. J Conserv Dent. 2020; 23(3): 284–288, doi: 10.4103/JCD.JCD_379_20, indexed in Pubmed: 33551601.
47. Singh S, Ramachandran N, Podar R, et al. Methods to study root canal anatomy: a systematic review. Int J Sci Res. 2021: 27–31, doi: 10.36106/ijsr/2506053.
48. Spioto MT, Juodzbalys G, Daugela P. Mandibular third molar impaction: review of literature and a proposal of a classification. J Oral Maxillofac Res. 2013; 4(2): e1, doi: 10.5037/jomr.2013.4201, indexed in Pubmed: 24422029.
49. Todor L, Matei RI, Muţiu G, et al. Morphological study of upper wisdom tooth. Rom J Morphol Embryol. 2018; 59(3): 873–877, indexed in Pubmed: 30534828.
50. Tomaszewska IM, Leszczyński B, Wróbel A, et al. A micro-computed tomographic (micro-CT) analysis of the root canal morphology of maxillary third molar teeth. Ann Anat. 2018; 215: 83–92, doi: 10.1016/j.aanat.2017.09.003, indexed in Pubmed: 28954209.
51. Vertucci FJ. Root canal anatomy of the human permanent teeth. Oral Surg Oral Med Oral Pathol. 1984; 58(5): 589–599, doi: 10.1016/0030-4220(84)90085-9, indexed in Pubmed: 6595621.
52. Weine FS. Endodontic therapy. 1st ed. Mosby, St. Louis, Mo., Maryland Heights 2004.
53. Weine FS, Healey HJ, Gerstein H, et al. Canal configuration in the mesiobuccal root of the maxillary first molar and its endodontic significance. Oral Surg Oral Med Oral Pathol. 1969; 28(3): 419–425, doi: 10.1016/0030-4220(69)90237-0, indexed in Pubmed: 5257186.
54. Weng XL, Yu SB, Zhao SL, et al. Root canal morphology of permanent maxillary teeth in the Han nationality in Chinese Guanzhong area: a new modified root canal staining technique. J Endod. 2009; 35(5): 651–656, doi: 10.1016/j.joen.2009.02.010, indexed in Pubmed: 19410077.