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Article *in* Heliyon · September 2023

DOI: 10.1016/j.heliyon.2023.e19477

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Heliyon 9 (2023) e19477

Contents lists available at ScienceDirect

Heliyon

journal homepage: www.cell.com/heliyon

Cone beam computed tomography analysis of the root and canal morphology of the maxillary second molars in a Hail province of the Saudi population

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ARTICLE INFO

Keywords:
Classification
Cone-beam computed tomography
Endodontics
Maxillary second molar
Canal anatomy

ABSTRACT

Background: The goal of the present research was to employ CBCT imaging to assess the root and canal anatomy of maxillary second molars in a population from the Hail province of Saudi. The effects of gender and side were taken into account.
Methods: The investigation included a sample size of 499 completely developed right and left untreated maxillary second molars obtained from 250 Saudi people. The root morphology of each tooth was evaluated. The examination also included an analysis of the canal morphology for each tooth, utilizing Vertucci's categorization. The effect of genders as well as sides was recorded. Results were analyzed using the Chi-square test.
Results: 464 teeth had three roots (93.0%), whereas 20 teeth (4.0%) had two roots. One root was recorded in 7 (1.4%) of the study sample, whilst 8 (1.6%) had four roots. Although there were no significant differences between the left and right sides ($p = .075$), gender had a significant influence on the number of roots ($p = .030$). 240 M (48.1%) had three canal orifices, and 247 (49.5%) had four root canal orifices. Eight molars (1.6%) had two canal orifices, while one and five canal orifices were found in 3 (0.6%) and one (0.2%), respectively. Gender had a significant impact on the number of root canal orifices ($p = .039$). The observed differences in the orifices of the root canals between the left and right sides were not statistically significant ($p = .059$). The prevalence of MB2 in maxillary second molars was found to be 49.7%. In the mesiobuccal root, the Vertucci type I configuration had the highest canal frequency (50.3%), followed by the Vertucci types II (14.4%), IV (13.8%), V (12.0%), and III (7.6%), and VI (1.8%). The prevalence of Vertucci type I canal configurations was found to be higher in the distobuccal root (99.4%) and palatal root (98.2%) of maxillary second molars.
Conclusions: Significant variations in root canal anatomy were observed within the Saudi population. The majority of the subjects from Saudi Arabia in this study exhibited the presence of maxillary second molars with three roots. Approximately half of the sample under investigation exhibited the presence of the four canals.

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https://doi.org/10.1016/j.heliyon.2023.e19477
Received 29 April 2023; Received in revised form 8 August 2023; Accepted 23 August 2023
Available online 26 August 2023
2405-8440/

1. Introduction

The comprehensive removal of necrotic tissue and debris, as well as the complete filling of the root canal system in three dimensions, are essential elements for achieving favorable outcomes in endodontic treatment. Knowing the root canal configuration and whether there are any extra canals is essential to achieving these goals [1]. Wide variations in mesiobuccal (MB) root canal designs may be the cause of the highest clinical failure rates for maxillary molar root canal treatments [2,3]. The failure to address pre-existing MB2 canals has a negative impact on the long-term endodontic prognosis of maxillary molars [4].

Several methods have been employed to investigate the root canal morphology of maxillary molars [5]. Cone beam computer tomography (CBCT), traditional periapical films, and the use of magnification instruments are among the clinical techniques [6–10]. Retrospective patient records of root canal treatment solely were also evaluated. CBCT has a well-established place in both clinical endodontics and the study of endodontic anatomy. To help with treatment planning, diagnosis, and follow-up, CBCT has developed into a useful technique [11].

Endodontic therapy is more challenging for practitioners since root canal structural patterns differ by ethnicity [12–23]. The effective management of periapical infections is crucial for the successful outcome of endodontic therapy. These infections are caused by several anatomical features of root canals, including apical deltas, intercanal anastomoses, lateral canals, and complex canal designs [1]. The endodontist's responsibility is to use the proper canal and shaping procedures, a variety of medications, and irrigants to clean these canals of microbial biofilms. Understanding the anatomy of the root canals in great detail is necessary to accomplish this goal.

People from different nations and races can be found settling all over the world as a result of globalization and the closer integration of the globe. Their dental requirements and therapies attest to the fact that a clearer understanding of racial differences in root canal morphology will only make the treatment's outcome more predictable.

The architectural characteristics of the maxillary second molars (MSMs) have been extensively investigated in various research conducted in several countries [24,25]. MSMs are more likely to have anatomical changes than maxillary first molars [26]. The occurrence of anatomical disparities between genders and between distinct racial and ethnic groups has been highlighted in many research [27–29]. The majority of MSMs have three separate roots [29,30]. The scholarly literature has also examined the bilateral symmetry of anatomical structures; however, this area of research remains incompletely investigated due to the predominance of case reports and incidental observations in the published literature [29,31].

The intricate internal and external anatomy of roots and their canals is genetically determined and has a clear-cut significance in root canal therapy. Prior knowledge of teeth anatomy has a great impact on endodontic treatment outcome and prognosis. Quality of treatment provided and reduction of failure is directly connected to proper biomechanical preparation and subsequent obturation of all main and accessory pulp system anatomy.

The inner anatomical differences of MSMs have been extensively studied utilizing CBCT technology. Given the diversity of tooth roots' form and morphological variances of root canal systems among different cultures and racial groups, and the need of understanding this topic for effective endodontic treatment. Unfortunately, there are some publications on root canal anatomy of MSMs in the Saudi population in the literature at the moment [14,27,32–34]. The existing literature on Saudi subpopulations encompasses several regions throughout the country. However, it is worth noting that no research has been conducted in the Hail district, which is situated in the Northern region, as far as our current knowledge extends. Hence, the objective of this study was to provide a comprehensive description of the root and canal morphology of MSMs in a population from the Hail area in Saudi Arabia, utilizing CBCT imaging. The impacts of gender and side were taken into account while determining the rate of recurrence of root canal morphology.

2. materials and methods

To analyze the root and canal morphology of the MSMs, a retrospective cross-sectional observational investigation was accomplished in a Hail province of the Saudi population. The Medical Ethics Committee formally approved the University of Hail's School of Dentistry's compliance with medical ethics (No: H-2021-025). Between May 2020 and November 2022, CBCT pictures were captured. Because of the study's retrospective nature, the College of Dentistry's ethical council waived informed consent. In this investigation, the gender and bilateral similarity of the patients were noted. To safeguard the patient's privacy, the information was kept secret. Patients who underwent CBCT scanning for diagnostic purposes reported the sample of the current study.

Purposive nonprobability sampling was applied in this experiment, investigating a database involving 2000 CBCT images. The CBCT pictures that were used satisfied the following criteria: Clear CBCT scans, MSMs with completely formed roots, and patients ages 18 and 65 years. Images of teeth having full-coverage or metallic restorations, endodontic or post-coronal treatment, or scan artifacts were excluded from this study. Moreover, teeth with periapical issues, root resorption, calcification, and poor CBCT image quality were rejected.

The calculation of the sample size was determined using Cochran's formula for calculating sample size, which is expressed as follows:

$$N = (Z\alpha \times P\,(1 - P))/D\hat{2}$$

Where: The variables in question are as follows: N, which represents the minimum sample size; α, which is set at 0.05 and the corresponding critical value is 1.96; Zα, which denotes the normal distribution critical value at α/2, shown by a confidence level of 95%; P, representing the occurrence of the MB2 at 19.7%, as determined by a prior study [27]; and D, which signifies the degree of precision.

The suggested sample size for the study was 245 MSMs. Once 2000 images were reviewed for inclusion and exclusion criteria, 250 CBCT scans made up the study's final sample size. The final sample was 499 teeth.

The recommended protocol provided by the manufacturer was adhered to during the utilization of the Carestream CS 8100 3D imaging system, manufactured by Carestream Dent LLC, located in Atlanta, USA. The X-ray exposure parameters used in the study were 90 KV, 4 MA, and a duration of 6.15 s. The calculated dosage delivered during the exposure was 1 mGy cm^2, and the voxel size used for imaging was 180 μm. This apparatus possessed several features, including fields of view (FOV) of 4x4, 5x5, 8x5, and 8 × 8 cm, a CMOS sensor equipped with Dental Volumetric Reconstruction (DVR) capabilities, scan periods ranging from 3 to 15 s, and a minimum voxel size of 75 m. The photographs underwent evaluation utilizing the CS 3D Imaging Software (Internal Version 3.10.8.0, Carestream Dent LLC, Atlanta, USA). In order to optimize the quality of representation, the images underwent adjustments to enhance their sharpness, brightness, and contrast through the utilization of the image editing functionality provided by the software. The teeth were individually assessed at each of the three levels, namely the axial, coronal, and sagittal planes. CBCTs were evaluated for: (i) the overall count of roots, (ii) the total number of canals, (iii) the classification of canal morphology for each root according to Vertucci's system, and (iv) the distribution of root canal morphology based on gender and location. The classification of each tooth was further conducted according to the Ahmed et al. [6,35–37] classification system.

Prior to conducting the evaluation, the examiner engaged in calibration training. The examiners A.H.A., S.D.A., F.I.A., T.F.A., and A.M.A. were calibrated under the supervision of A.A.M., M.I.A., and S.M.A. using the standards and variations mentioned before the experimental reading. A random selection process was employed to evaluate a subset of the sample, comprising twenty percent. The evaluation was conducted by a group of examiners, namely A.H.A., S.D.A., F.I.A., T.F.A., and A.M.A., along with supervisors A.A.M., M.I.A., and S.M.A. The level of agreement between observers was assessed by computing the kappa coefficient, yielding a value of 0.89. The observers engaged in a simultaneous evaluation and discussion of cases of disagreement until a final consensus was achieved. Following the initial assessment, a subsequent testing was conducted by the same investigator, who remained unaware of the previous results. This second analysis involved roughly20% of the examined teeth and aimed to evaluate the intra-observer reliability. The intra-observer agreement had a value of 0.92.

Statistical Package for the Social Sciences from IBM Co. was used for the data analysis, which included frequency distribution and cross-tabulation. It analyzed how many roots there were overall and how the root canals were organized. Using the chi-square and Fisher's exact tests, it was determined whether there was a relationship between the patient's gender, location, and root and canal morphology. The threshold for significance was set at 5% ($p < .05$).

3. Results

The distribution of the number of roots in the MSMs for the study sample is shown in Table 1. In the study, 93.0% of the MSMs had three roots, as opposed to 4.0% with only two, 1.6% with four roots, and 1.4% with just one. The number of roots was significantly influenced by gender ($p = .030$). Although there were significant variations, it was observed that there were no noticeable differences in the number of roots between the left and right sides ($p = .075$).

The number of canal orifices of MSMs in men and women is shown in Table 2. Comparatively, 48.1% of the research sample had three root canal orifices (Fig. 1), whereas 49.5% of the MSMs, as demonstrated in Fig. 2, had four orifices. Females were more likely than males to have four canal orifices (25.9% vs. 23.6%). The gender difference in root canal orifices was significant ($p = .039$). However, there was no discernible difference in the orifices of root canals between the left and right sides ($p = .059$).

Table 3 and Fig. 3 display the distribution of various root canal geometries seen in MSMs. The predominant configuration of mesiobuccal roots was Vertucci type I, accounting for the majority at 50.3%. This was followed by Vertucci type II at 14.4%, Vertucci type IV at 13.8%, and Vertucci type V at 12.0%. Between the left and right sides (p = .020), as well as between men and women (p = .011), there were significant differences in the frequency of root canal configuration ($p < .05$). The predominant canal configuration in the distobuccal and palatal roots was Vertucci type I, accounting for 99.4% and 98.2% respectively. The presence of root canal layout in the distobuccal and palatal roots of MSMs was unaffected by gender (p = .133; p = .143, respectively) or sides ($p = 246$; p = .152, respectively).

Table 4 shows the distribution of MSMs configurations based on Ahmed et al.'s categorization. Two teeth were identified as having single canals and given the identifier ^{1}MSM^{1}. The last three teeth showed ^{1}MSM$^{2\text{-}3}$. The ^{2}MSM B^{1} P^{1} configuration (n = 15, 3.0%) was the most prevalent among the two-rooted MSMs. The most prevalent configuration in three-rooted teeth was ^{3}MSM MB^{1} DB^{1} P^{1} (n = 226, 45.32%). Seven teeth (1.4%) with four roots were given the code ^{4}MSM MB^{1} MDB^{1} DDB^{1} P^{1}.

Table 1
Number of roots for gender and tooth position.

Number of roots	Gender			Tooth position		
	Male	Female	Total	Left side	Right side	Total
One root *n (%)*	5 (1.0)	2 (0.4)	7 (1.4)	4 (0.8)	3 (0.6)	7 (1.4)
Two roots *n (%)*	2 (0.4)	18 (3.6)	20 (4.0)	11 (2.2)	9 (1.8)	20 (4.0)
Three roots *n (%)*	217 (43.5)	247 (94.5)	464 (93.0)	228 (45.7)	236 (47.3)	464 (93.0)
Four roots *n (%)*	6 (1.2)	2 (0.4)	8 (1.6)	3 (0.6)	5 (1.0)	8 (1.6)
Total	230 (46.1)	269 (53.9)	499 (100)	246 (49.3)	253 (50.7)	499 (100)
P value	P = .030			P = 0. 075		

Table 2
Number of canal office for gender and tooth position.

Number of roots	Gender			Tooth position		
	Male	Female	Total	Left side	Right side	Total
One-orifice *n (%)*	3 (0.6)	0 (0)	3 (0.6)	2 (0.4)	1 (0.2)	3 (0.6)
Two-orifice *n (%)*	0 (0)	8 (1.6)	8 (1.6)	4 (0.8)	4 (0.8)	8 (1.6)
Three-orifice n (%)	107 (21.4)	133 (26.7)	240 (48.1)	119 (23.8)	121 (24.2)	240 (48.1)
Four-orifice *n (%)*	118 (23.6)	129 (25.9)	247 (49.5)	122 (24.4)	125 (25.1)	247 (49.5)
Five-orifice n (%)	1 (0.2)	0 (0)	1 (0.2)	0 (0)	1 (0.2)	1 (0.2)
Total	229 (45.9)	270 (54.1)	499 (100)	247 (49.5)	252 (50.5)	499 (100
P- value	P = 0 .039			P = 0 .059		

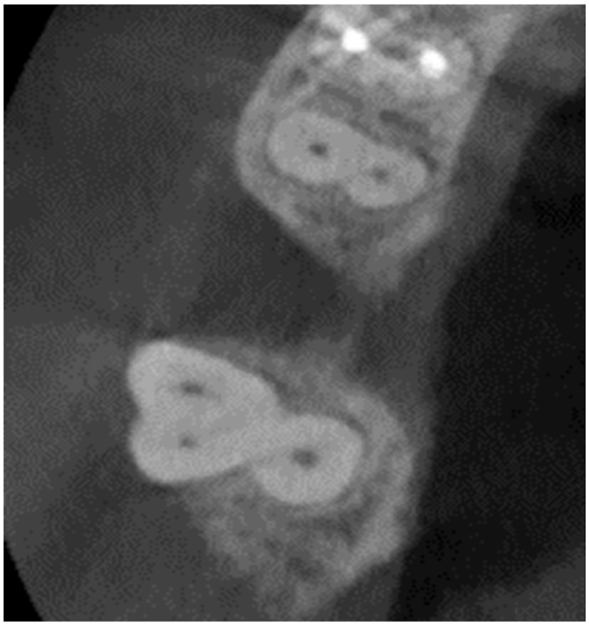

Fig. 1. Maxillary second molar with three roots and three canals.

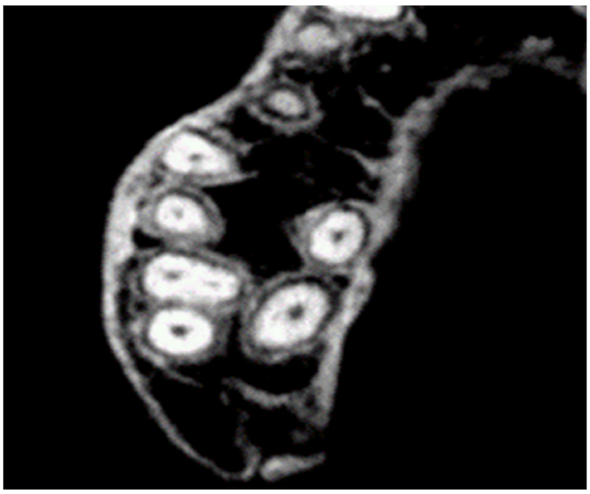

Fig. 2. Maxillary second molar with three roots and four canals.

Table 3
Distribution of root canal types according to Vertucci's classification.

Type		I	II	III	IV	V	VI	p-value
Mesiobuccal root	Male	110 (22.0)	30 (6.0)	18 (3.6)	39 (7.8)	28 (5.6)	4 (0.8)	.011
	Female	141 (28.3)	42 (8.4)	20 (4.0)	30 (6.0)	3 (6.4)	5 (1)	
Total		251 (50.3)	72 (14.4)	38 (7.6)	69 (13.8)	60 (12.0)	9 (1.8)	
Distobuccal root	Male	221 (46.4)	1 (0.2)	0 (0)	0 (0)	0 (0)	0 (0)	0.133
	Female	252 (52.9)	0 (0)	2 (0.4)	0 (0)	0 (0)	0 (0)	
Total		473 (99.4)	1 (0.2)	2 (0.4)	0 (0)	0 (0)	0 (0)	
Palatal root	Male	218 (44.7)	3 (0.6)	2 (0.4)	0 (0)	0 (0)	0 (0)	0.143
	Female	261 (53.5)	3 (0.6)	0 (0)	1 (0.2)	0 (0)	0 (0)	
Total		479 (98.2)	6 (1.2)	2 (0.4)	1 (0.2)	0 (0)	0 (0)	
Mesiobuccal root	Right	126 (25.3)	37 (7.4)	17 (3.4)	32 (6.4)	35 (7.0)	5 (1.0)	0.02
	Left	125 (25.1)	35 (7.0)	21 (4.2)	37 (7.4)	25 (5.0)	4 (0.8)	
Total		251 (50.3)	72 (14.4)	38 (7.6)	69 (13.8)	60 (12.0)	9 (1.8)	
Distobuccal root	Right	241 (50.6)	0 (0)	0 (0)	0 (0)	1 (0.2)	0 (0)	0.246
	Left	232 (48.7)	1 (0.2)	0 (0)	0 (0)	1 (0.2)	0 (0)	
Total		473 (99.4)	1 (0.2)	0 (0)	0 (0)	2 (0.4)	0 (0)	
Palatal	Right	242 (49.6)	4 (0.8)	1 (0.2)	0 (0)	0 (0)	0 (0)	0.152
	Left	237 (48.6)	2 (0.4)	1 (0.2)	1 (0.2)	0 (0)	0 (0)	
Total		479 (98.2)	6 (1.2)	2 (0.4)	1 (0.2)	0 (0)	0 (0)	

4. Discussion

Computed tomography can now be utilized to diagnose and assess root canal anatomy thanks to advancements in technology. Internal dental anatomy has been analyzed using a variety of techniques, including sectioning, canal staining, tooth cleaning, and radiographic techniques. Even though clearing methods have historically been thought of as the gold benchmark for the study of root canal anatomy, X-rays and CBCT are the clinical procedures used to examine the internal architecture of teeth [6].

Compared to X-rays, CBCT has many benefits [6]. Unlike computed tomography, which can create three-dimensional images of anatomical structures like teeth and their surrounding structures, X-rays are restricted to two dimensions. This enables a highly accurate study of the design of test items [6]. Naturally, the patient's welfare should always come first in every circumstance, and precautions must be made to ensure his or her safety. Primum Nocera and ALARA ("As Low as Reasonably Achievable") principles state that CBCT should only be carried out when absolutely essential and when the information it gives would significantly advance the patient's diagnosis or course of treatment [38]. The CBCT scans employed in the current investigation were not just designed for carrying out scientific work, but also for diagnostic purposes. In this work, the root and canal morphology of the MSMs in a Saudi population from the Hail province is thoroughly and completely examined in vivo using CBCT methods.

Root canal morphology has been classified by several researchers in the literature [6,37,39,40]. Based on the categorization proposed by Weine et al. (39), the root canal can be classified into four distinct patterns as it progresses from the floor of the pulp chamber to the apex of the root. Vertucci (40) further categorized the morphology of root canals into eight forms, providing a more comprehensive and precise categorization. In the present investigation, the Vertucci classification [40] was employed as a recognized standard for categorizing canal types due to its pioneering identification of intricate canal system configurations. Despite its long-standing status as a conventional classification, the majority of authors persist in employing it in their most recent scholarly investigations [3–5]. This study also utilized it to make it simpler to compare the findings with those of other studies. It was chosen in this study due to the aforementioned factors as well as to make findings comparisons simpler. Nevertheless, this study has considered other root canal architectures besides the Vertucci categorization. The categorization proposed and introduced by Ahmed et al. [6,37] was utilized in this research due to its comprehensive nature, as it establishes a connection between the number of roots and the number of root canals in each tooth, while also offering a clear elucidation of the tooth's anatomy.

The second molar demonstrates larger root number variability than the first molar, according to several studies [41]. In comparison to earlier studies on the populations of Thai, Burmese, and Indian [42,43], our data reveal a more frequent three roots in MSMs. According to the findings of the current, MSMs most frequently have three roots (93.0%), which is in line with the conclusions of studies conducted on other populations. Furthermore, the findings of our investigation are consistent with a former study performed by Alamri et al. [33] in the central part of the Saudi population. They noted that three roots (92%) are most frequently discovered in MSMs. Research by Plotino et al. [29] utilizing CBCT on a White population revealed that 88.5% of the MSMs under study had three roots. In another study that focused on the Korean population, 74.79% of participants had three roots in the MSM [44]. The incidence of the same discovery was estimated to be 66.1% in the Chinese population [31]. Our findings also revealed that 1.1% of the sample had four roots, which is regarded as a very low percentage. From 0.49% to 1.20% of cases were found in several studies to have four roots [31,45]. These variations show how ethnic heritage affects tooth root shape. The absence of distinct distinguishing fused roots could be the cause of the high proportion of second molars with three roots.

During the process of root canal therapy, dentists prioritize the quantity and location of root canals over the total number of roots. According to a study conducted on a Chinese population, the presence of a second mesiobuccal canal was observed in 18% of the individuals investigated [41]. Conversely, a separate study conducted on a Thai community revealed a higher prevalence of 55% for the presence of this canal within the population [42]. The findings of this study indicate that there were no statistically significant variations seen between the right and left sides ($p > .05$). This observation aligns with previous research studies [41,46], which have

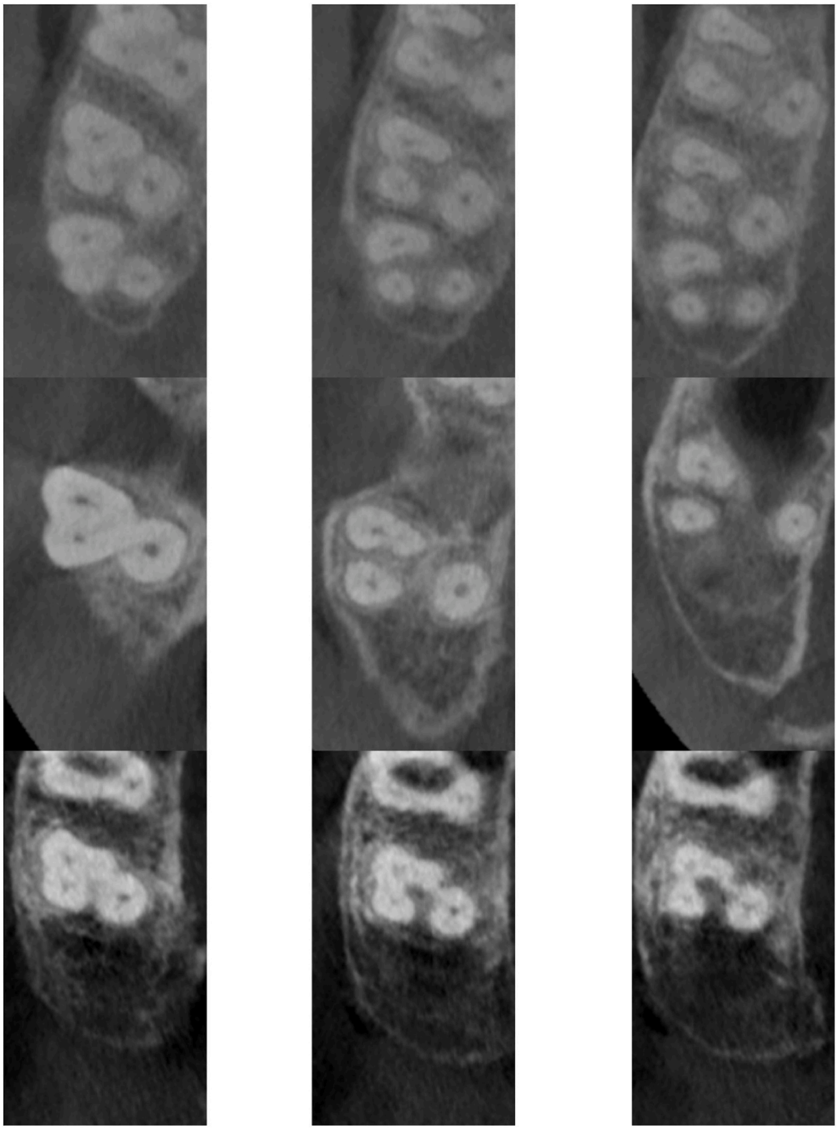

Fig. 3. Some root canal types that found in this study.

similarly highlighted the presence of morphological symmetry. The current investigation revealed a statistically significant variation in the number of root canals between genders when considering the gender variable. The present study reveals a strong correlation between the number of root canals in MSMs and gender. The findings presented here align with the research carried out by Alamri et al. [33] on the population of Saudi Arabia in the eastern region.

Based on the findings of CBCT investigations, it was observed that a range of 22%–48% of MSMs displayed the presence of MB2 [44, 47,48]. The present study's results align with previous studies, indicating that the root canal morphology of the mesiobuccal roots of maxillary second molar teeth exhibited greater variability compared to the distobuccal and palatal roots, which typically displayed a single root canal. The majority of the four Vertucci classifications were observed in the mesiobuccal root, with type I being the most prevalent, accounting for 50% of the cases. The results of our study align with the findings of Abarca et al. [49], which reported a prevalence rate of 42.8% for MB2 in the MSMs of a community in Chile. In juxtaposition to the present investigation, an examination conducted on a community in Saudi Arabia unveiled a relatively low prevalence of MB2 in second molars, amounting to 19.7%. Tanavi et al. [50] previously reported a rather low incidence rate of MB2 (17.39%) in MSMs.

The effectiveness of endodontic therapy is significantly impacted by the requirement to locate and address the MB2 canal [51,52]. This root canal can induce inflammatory disorders in the periapical tissues because it is frequently ignored [52]. As per the findings of Shetty et al. (52), a significant proportion of MSMs, specifically 90%, were seen to possess an unfilled MB2 canal. Periapical radiolucencies were observed in 88.8% of MSMs within empty MB2 canals, as reported by a previous study [52].

Studies utilizing CBCT scans have yielded diverse findings regarding the prevalence of MB2 root canals in relation to the gender of

Table 4
Root canal configurations according to the Ahmed et al. classification.

Configuration	Number (n =)	Total percentage (%)
^{1}MSM^{1}	2	0.4
^{1}MSM$^{2\text{-}3}$	3	0.6
^{2}MSM B^{1} P^{1}	15	3
^{2}MSM B$^{2\text{-}1}$ P^{1}	5	1
^{3}MSM MB^{1} DB^{1} P^{1}	226	45.32
^{3}MSM MB$^{2\text{-}1}$ DB^{1} P^{1}	65	13
^{3}MSM MB$^{2\text{-}1}$ DB$^{1\text{-}2}$ P^{1}	1	0.2
^{3}MSM MB$^{2\text{-}1}$ DB^{1} P$^{1\text{-}2}$	6	1.2
^{3}MSM MB$^{1\text{-}2-1}$ DB^{1} P^{1}	34	6.82
^{3}MSM MB$^{1\text{-}2-1}$ DB$^{1\text{-}2-1}$ P^{1}	2	0.4
^{3}MSM MB$^{1\text{-}2-1}$ DB^{1} P$^{1\text{-}2-1}$	2	0.4
^{3}MSM MB^{2} DB^{1} P^{1}	61	12.23
^{3}MSM MB$^{2\text{-}1}$ DB^{1} P^{1}	60	12.03
^{3}MSM MB$^{2\text{-}1-2}$ DB^{1} P^{1}	9	1.8
^{4}MSM MB^{1} MDB^{1} DDB^{1} P^{1}	7	1.4
^{4}MSM MB^{2} MDB^{1} DDB^{1} P^{1}	1	0.2
Total	**499**	**100**

patients [49,50]. Sert and Bayirli [22] conducted a study on a population in Turkey and found that gender significantly influenced the prevalence of the MB2 canal. Specifically, they observed that only 3% of males and 10% of females exhibited a singular canal in the mesiobuccal root. The present study demonstrates a significant correlation between the gender variable and the prevalence of the MB2 canal in MSMs. According to a study conducted by Lee et al. [44], it was shown that males exhibit a higher prevalence of MB2 in their MSMs compared to females, with a rate of 48.7% for males and 30.8% for females. According to a study conducted by Betancourt et al. [53], there was a notable disparity between men and women in terms of the presence of the MB2 canal in their MSMs. On the other hand, the occurrence of extra MB2 in other research investigations exhibited no significant variation in relation to the gender of the individual [41,49].

In order to get a satisfactory outcome in root canal therapy, it is imperative to possess a comprehensive understanding of the accurate quantity of roots and the canal system involved. In order to ensure the success of root canal therapy on maxillary molars with a high prevalence of variation, endodontists must diligently and precisely detect any possible differences in the root canal systems prior to commencing the treatment. Maxillary molars have been shown to have the greatest ratios of clinical failure following endodontic treatment, most likely as a result of the difficulty of the architecture of the root canal and the difficulty in detecting problems with the procedure [54–56]. In a 5-year study of 3578 root canal-treated molars, Wolcott et al. [57] discovered that 60% of cases had second mesiobuccal canals, indicating that failing to identify and deal with second canals will affect the prognosis. Thus, these anatomic variances should be taken into account when treating maxillary molars with root canals [56]. The clinician's awareness of the canal's presence, consistent allotment of enough time, and application of advanced equipment to find these canals are crucial components in the routine practice of treating second mesiobuccal canals. The mesiobuccal root of the MSM has been shown to create a technical barrier for the clinician due to significant variability in root canal morphology.

The analysis conducted in the present study focused on the root and canal anatomy of MSMs and aimed to compare these characteristics with those observed in other populations. The findings of this study indicate the presence of morphological variances that should be taken into account in clinical practice. Hence, it is imperative to conduct thorough clinical investigation and meticulous radiographic assessment in the context of endodontic therapy. This is essential for accurately diagnosing the quantity of roots and their respective canals, thereby preventing the inadvertent omission of any root canal and the subsequent risk of treatment failure. Additionally, this process aids in determining the shape of each canal at various levels, thereby facilitating effective planning for canal debridement and subsequent obturation.

The present study has a few limitations that must be considered. The fact that only one center provided the data for the current study's analysis could be seen as a methodological constraint. The results of upcoming multicenter research can so better represent the general population. To instruct doctors more accurately on the anatomy of the MSM in the Saudi population, it would also be more accurate to examine more CBCT images given the complexity of the MSM morphology. Furthermore, the influence of the age of the patients on the root canal anatomy should be considered in the new research. Moreover, as this method may produce more conclusive results, we advise conducting this anatomical investigation throughout a broad geographic range with ethnic characteristics. Comprehensive details on root and canal anatomy in the Saudi population are provided by this study. A useful tool for getting precise anatomical information is CBCT. The high price and radiation dose, however, restrict its clinical applicability. Hence, to enhance the effectiveness of endodontic therapy, the physician is supposed to be knowledgeable about various root and canal morphological variances.

5. Conclusions

The patient's race unquestionably influences the root canal system. Significant disparities among the Saudi population's root canal anatomy were found. The majority of the Saudi participants in this study had MSMs with three roots. The majority of the extra fourth canal was situated in the mesiobuccal root of the MSMs under study. The presence of two canals in the mesiobuccal root should be considered by the endodontist when performing therapy. More thought should be given to the identification of additional canals during root canal therapy, especially when treating upper second molars or treating male patients. While treating maxillary molar root canals, these anatomical variables should be taken into account as they could affect endodontic therapy. For that, magnification instruments are very useful.

Funding information

This research has been funded by Deputy for Research & Innovation, Ministry of Education through Initiative of Institutional Funding at University of Ha'il – Saudi Arabia through project number IFP-22 011.

Ethics approval

The research protocol received approval from the Medical Ethics Committee of the College of Dentistry at the University of Hail, Saudi Arabia (No: H-2021-025).

Author contribution statement

Ahmed A. Madfa: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Moazzy I. Almansour: Conceived and designed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Saad M. Al-Zubaidi: Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Albandari H. Alghurayes; Safanah D. AlDAkhayel; Fatemah I. Alzoori; Taif F. Alshammari; Abrar M. Aldakhil: Performed the experiments; Wrote the paper.

Data availability statement

The data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

This research has been funded by Deputy for Research & Innovation, Ministry of Education through Initiative of Institutional Funding at University of Ha'il – Saudi Arabia through project number IFP-22 011.

Abbreviations

DVR	Dental Volumetric Reconstruction
ALARA	As Low as Reasonably Achievable
FOV	fields of view
3D	three dimensions
MB	mesiobuccal
MSMs	maxillary second molars
CBCT	Cone beam computed tomography

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