European Review for Medical and Pharmacological Sciences 2024; 28: 1741-1750

Assessment of bifid mandibular canals using cone beam computed tomography in general population: a retrospective evaluation

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Abstract. – OBJECTIVE: To evaluate the prevalence of bifid mandibular canals (BMC) using cone-beam computed tomography (CBCT) in the Saudi population subset.

MATERIALS AND METHODS: In the study, three hundred and forty-three CBCT scans (661 sides) were evaluated for the presence of BMC, involving 162 males and 181 females. Tomographic acquisitions were performed on the device Planmeca®. The image analysis was performed on the Planmeca Romexis® software, aided by image filters associated with transverse, oblique, and panoramic reconstruction cuts for analysis of the BMC. Naitoh's classification (2009) was employed to classify mandibular canals. The prevalence of BMC was determined according to location, gender, and age of participants. The data were analyzed with Chi-square and one-way ANOVA tests at a significance level of 95%.

RESULTS: The BMC was observed in 37 (12.34%) out of 343 participants, of whom 20 (54.05%) were males and 17 (45.94%) were females. There was no significant difference in the proportion of bifid canals in both genders and various age groups. The most common BMC was the retromolar canal type, with 56.75% occurrence. The dental canal type was observed in 18.91% of BMC participants. The presence of a forward canal without confluence was observed in 16.21% of participants in the BMC, whereas a forward canal with confluence was noted in 8.10% of participants.

CONCLUSIONS: The prevalence of bifid mandibular canals (BMC) within a subset of the Saudi population was 12.3%. The retromolar canal was identified as the most frequently occurring type, accounting for 56.7% of cases. No significant variations in BMC prevalence were observed concerning age and gender. Consequently, it is strongly advised to conduct a thorough assessment of the mandibular canal and its potential variations using CBCT imaging before undertaking mandibular surgical procedures, in order to minimize the risk of complications.

Key Words:
Bifid mandibular canals, Inferior dental canal, CBCT, Retromolar canal, Maxillofacial.

Introduction

The mandibular canal is an anatomical internal structure located within the mandible. It runs bilaterally, originating at the mandibular foramen and ending at the mental foramen containing the inferior alveolar neurovascular bundle, which supplies the mandibular teeth and adjacent structures[1]. The mandibular canal appears radiographically as a radiolucent longitudinal strip with radiopaque borders superiorly and inferiorly due to the higher density of the cortical borders of the canal[2]. Although the mandibular canal is traditionally thought to be a single canal, several anatomic variations have been described, mainly the bifid and trifid types[3-5]. Bifid is a word derived from Latin, meaning dividing into two parts. The exact etiological factors leading to the development of bifid or trifid canals remain unclear. However, Chavez et al[6] proposed that the inferior alveolar nerve is the result of the fusion of three distinct nerves during embryonic development, and incomplete fusion can result in clefting of the nerve and canal.

The course of the inferior alveolar nerve has been classified into three types by Carter and Keen[7] where the third type corresponds to the bifid variant. Accurate identification of the location and configuration of the mandibular canal is a crucial step during planning and performing oral surgical procedures involving the mandible, including orthognathic surgeries, dental implant placement, and extraction of impacted third molars[8,9].

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Complications, such as traumatic neuroma, nerve dysfunction, paresthesia, excessive bleeding, and hematoma may result from injury to the mandibular canal and its content[1,8]. Therefore, identification of the mandibular canal and its anatomic variations is critical to avoid such complications.

The anatomical variations of the mandibular canal, including the presence of bifid mandibular canals (BMC), have gained increasing attention in dental and maxillofacial radiology. While studies have explored the prevalence of BMC in various populations, the influence of age on the occurrence of these variations remains a subject of interest and significance[1,4]. Age-related variations like changes in bone density[9], remodeling processes, and overall skeletal maturation could potentially affect the prevalence of bifid canals[10]. Therefore, understanding these associations is crucial for informed clinical decision-making.

The prevalence of BMC has been previously investigated by several studies using panoramic radiographs and cone beam computed tomography (CBCT)[3-5,11-14]. Studies using panoramic radiographs reported a prevalence of 0.08-0.95%[3,4,10]. Meanwhile, CBCT studies reported a prevalence of 10.2% to 65%[5,11-15]. The panoramic radiographs may underestimate the prevalence of bifid mandibular canals due to their two-dimensional limitations. Also, ghost images and superimposition can obscure the mandibular cana[15,12]. Rouas et al[16] suggested that CBCT is the preferred radiographic imaging method in assessing the mandibular canal due to its three-dimensional view and high resolution while requiring substantially less radiation than computed tomography (CT). Bifid mandibular canals were classified by several authors according to their pattern and anatomic configuration. Langlais et al[4] and Nortje et al[3] based their classification on panoramic radiographs, while Naitoh et al[5] relied on CBCT imaging. Naitoh et al[5] classified bifid mandibular canals into four types: retromolar canal, forward canal, dental canal, and buccolingual canal. The working hypothesis of this study was that there is no significant difference in the prevalence of bifid mandibular canals among different genders, age groups, and locations in the Saudi population.

A review of current literature revealed data scarcity regarding bifid mandibular canals among the Saudi population[10]. Hence, the present study aimed to investigate the configuration and prevalence of bifid mandibular canals among the Saudi population using CBCT. The results of this study will help oral surgeons have a better understanding of bifid mandibular canals in Saudi patients and improve the safety and accuracy of surgical procedures.

Materials And Methods

The King Saud University, College of Dentistry, Institutional Review Board reviewed the protocol and approved the study (IRB-E 21-6248). This study was conducted in the Riyadh region at King Saud University, Dental University Hospital. The CBCT images of patients who underwent preoperative radiographic assessment for dental procedures were investigated to evaluate the prevalence of bifid mandibular canals in the Saudi population.

Sample Size and Subject Criteria

The CBCT images of 343 patients (661 sides), which were taken between September 2020 and September 2021, were evaluated retrospectively. Male and female participants with maxillo-mandibular CBCT investigation for planned oral surgical procedures above the age of 17 years were included. CBCT for both dentate and edentate patients was included. The excluded cases were CBCT images that had insufficient accuracy of the region of interest, those that failed to show any part of the mandible, and cases with the presence of tumors, cysts, bony malformation, or surgical procedures in the body or ramus of the mandible.

Evaluation of Images

For imaging of CBCT, the Planmeca® system was used (Promax 3D Classic, Helsinki, Finland), and Planmeca Romexis software was employed for image processing. CBCT images of the left and right hemi-mandibular regions were evaluated using Planmeca Romexis software in axial, sagittal, and coronal sections as well as a panoramic reconstructed view.

To begin with, the Mandibular canals were visualized in a panoramic reconstructed view to make sure the evaluated image was included in our criteria. For organization, the right image was evaluated, followed by the left side. The reference line for multiplanar reconstruction was set at the mandibular canal in the axial section in the right and left hemi-mandibular regions, respectively. Sections were rotated to a degree that showed a clear visualization of the canal. The mandibular canal was followed from the mandibular foramen until the mental foramen multiple times and observed from different sections. If a bifid mandibular canal was suspected, a nerve-marking tool was

used to trace the main course of the inferior alveolar nerve using thick red color marking, and a thinner line was used for the suspected bifid mandibular canal. The traced canals were then viewed in multiple sections simultaneously. In case of disagreements, a discussion between examiners was established until a consensus was reached.

Examiner Reliability Protocol

Three examiners participated in the initial assessment of CBCT images. They were experienced and qualified dental professionals with expertise in oral and maxillofacial radiology. They were selected based on their prior experience in interpreting CBCT images in dental and maxillofacial settings.

In addition to the three initial examiners, a qualified maxillofacial surgeon and an oral radiologist were also involved in the study. They were responsible for evaluating images suspected to have bifid mandibular canals (BMC). These professionals were chosen based on their specialized training and expertise in diagnosing and managing complex maxillofacial anatomical variations, including BMC. Their role in the study was specifically focused on confirming the presence of BMC and characterizing these variations in the suspected images.

To detect intra-examiner errors for detection of and types of BMC, the images were re-evaluated by the same examiners, the maxillofacial surgeon, and the oral radiologist with an interval of one month.

Canal Classification

Bifid mandibular canals classification was performed following Naitoh et al[5] into one of four main groups, namely, forward, retromolar, buccolingual, or dental. Forward canals were further subdivided into those with and without confluence. Dental canals were subdivided into first-, second-, and third-molar canals. The buccolingual canals were subdivided into either buccal or lingual canals separately, Figure 1.

Statistical Analysis

Descriptive and inferential statistics were calculated using SPSS 24 Software, (IBM Corp., Armonk, NY, USA) and Microsoft Excel spreadsheet (Microsoft Corporation, Washington, DC, USA). Data such as image number, age group, gender, presence of bifid mandibular canal (right or left), and type of bifid mandibular canal were evaluated with descriptive analysis. The differences in the prevalence rate of the bifid mandibular canal according to parameters such as age group, gender, location (right or left), and type were analyzed using Pearson's Chi-square and one-way ANOVA. A significance level was set at $p \leq 0.05$.

Table I. Prevalence of BMCs according to gender.

Gender	Present (%)	Absent (%)
Male	20 (12.34%)	142 (87.65%)
Female	17 (9.39%)	164 (90.60%)

Bifid mandibular canals (BMC).

Results

In the present study, BMCs were observed in 37 (12.34%) out of 343 participants. These BMCs were observed in 20 men (54.05 %) and 17 women (45.94%). The majority of the BMCs were recorded from the right side of the mandible, 16 (33.33%), whereas 9 (18.75%) BMCs were found bilaterally (Table I).

The patterns of the 37 BMCs found were as follows: the retromolar canal type was the most common with 21 (56.75%) cases, followed by the dental canal type in 7 (18.91%), forward canal without confluence in 6 (16.21%), and forward canal with confluence in 3 (8.10%) cases. Lingual and buccal canal types were absent in all participants (Table II). According to the age group comparison, the BMC recorded from different locations showed no significant difference (p=0.565) in distribution. Out of the total 37 BMCs, ten were noticed in the 20 to 30 years age group, while eleven of them were found in the 40 to 50 years of age (Table III).

The data in Table IV represents the distribution of participants with a bifid canal based on gender. The Chi-square value was calculated as 2.446, with 2 degrees of freedom. The corresponding p-value was 0.294, with no significant effect. Further categorization showed that eight

Table II. Frequency of different types of BMCs according to Naitoh's 2009 classification.

Classification	Frequency	(%)
Type I – Retro molar canal	21	56.75
Type II – Dental canal	7	18.91
Type III – Forward canal		
With confluence	3	8.10
Without confluence	6	16.21
Type IV – Buccolingual canal		
Buccal canal	0	0.00
Lingual canal	0	0.00

Bifid mandibular canals (BMC).

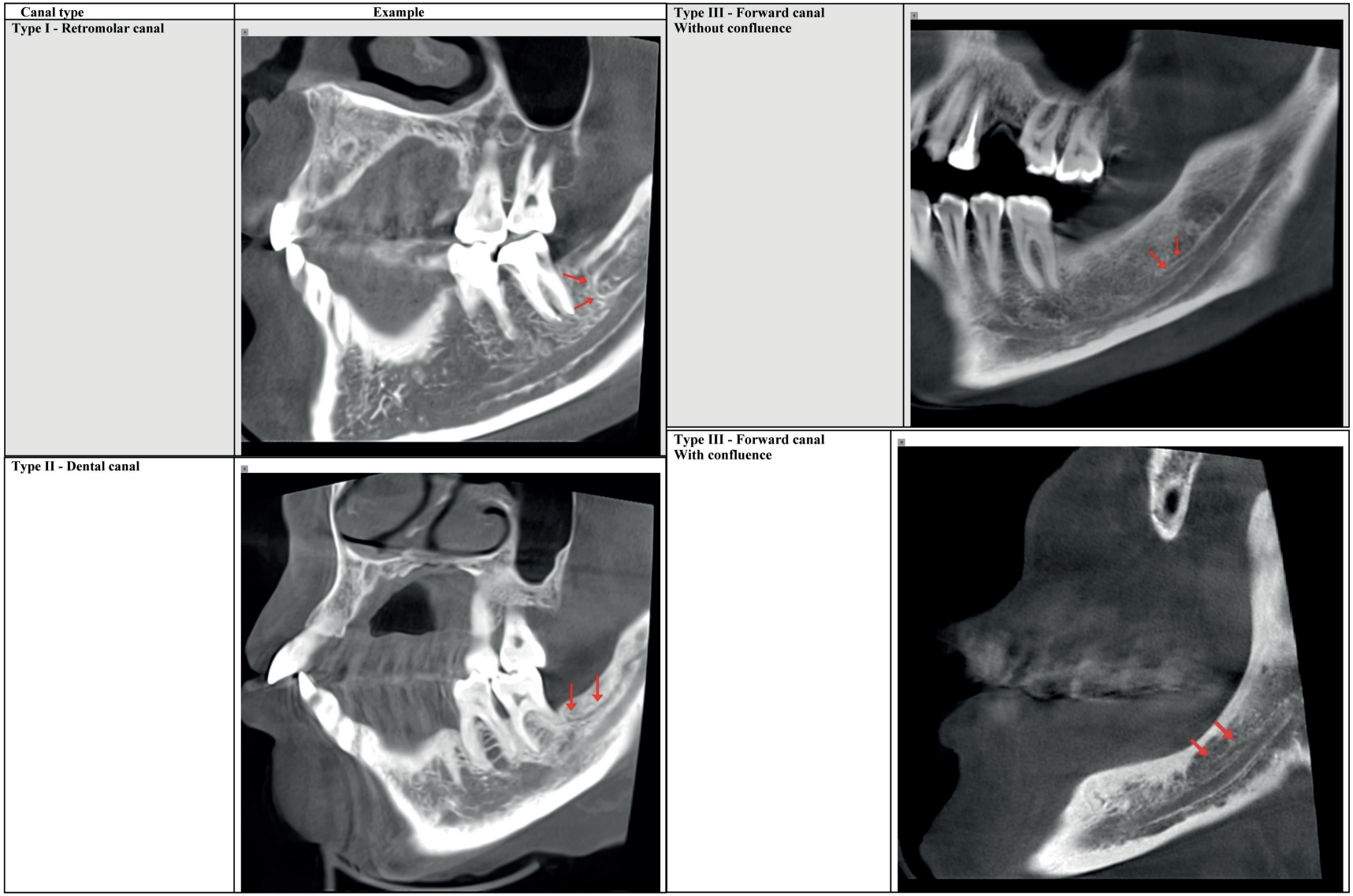

Figure 1. Naitoh's 2009 BMCs classification.

Table III. Differences in the prevalence rate of the bifid mandibular canal from various locations with age groups (n=37).

Variables		Age						Total	Chi-square value	df	p
		11-20	21-30	31-40	41-50	51-60	61-70				
Bifid canal	**Bilateral**	1	1	2	4	1	2	11	8.653	10	565
	Left	0	2	1	4	1	2	10			
	Right	0	7	4	3	1	1	16			
Total		1	10	7	11	3	5	37			

df; difference, p=0.05 was considered significant.

Table IV. Differences in the prevalence rate of the bifid mandibular canal from various locations in both sexes (male n=20; female n=17).

Variables		Male	Female	Total	Chi-square value	df	p
Bifid canal	**Bilateral**	8	3	11	2.446	2	294
	Left	4	6	10			
	Right	8	8	16			
Total		20	17	37			

df; degrees of freedom, p=0.05 was considered significant.

males and three females had BMC on both sides, four males and six females had BMC on the left, and eight males and eight females had it on the right. In total, there were twenty males and seventeen females with a bifid canal, resulting in a total of thirty-seven participants.

Table V presents the analysis of variance conducted on the dependent variable (BMC), and the independent variables (gender and age). The degrees of freedom (df) for gender comparison were 2, while within-gender comparison yielded a value of 34. The sum of squares (SS) for gender comparison was 0.607, whereas within-gender analysis resulted in 8.582. The lower SS value of 0.607 between genders suggests no significant difference, variability, or dispersion in the data between both sexes. The *f*-value of 1.203 for gender and 1.742 for age indicates that the ratio of variability between and within the mentioned independent variables exhibited minimal disparity.

The ANOVA test concluded that the *p*-value for significance was greater than 0.05 in all cases, indicating no variation in BMC between and within sexes and age groups. To further analyze the evidence and substantiate the findings, Tukey's post-hoc test was applied. This test allowed for a comparison of BMC prevalence based on the location. The mean difference analysis revealed values for pairwise comparisons of group means. When comparing gender and BMC on both sides, the mean difference values were observed as -0.327 and -0.227. On the left side, the values were 0.327 and 0.100, while on the right side, the values were 0.227 and -0.100. These mean difference values indicate that there were no significant differences between gender and BMC in terms of location. Similarly, when comparing BMC with age, values of -0.182 and 0.756 were recorded on both sides. On the left side, the mean difference values were 0.182 and 0.938, while on the right side, the values were -0.756 and -0.938. These results suggested that there were no significant differences in BMC prevalence based on age and location.

Table V. Comparison of bifid mandibular canal occurrence within age groups and sex.

Variables	Sum of squares	df	Mean squares	f	p
Gender	Between the group	607	2	304	1.203
	Within group	8.582	34	252	
Age	Between the group	6.615	2	3.308	1.742
	Within group	64.574	34	1.899	

df; degrees of freedom, p=0.05 was considered significant.

Standard error values were considered to assess the precision and reliability of the mean difference estimates. The standard error values were as low as 0.220 and 0.197 on both sides when comparing BMC prevalence with gender. On the left side, the values were 0.220 and 0.203, while on the right side, they were 0.197 and 0.203. Similarly, the standard error values between age and BMC were also found to be the lowest when compared with the location of BMC. These low standard error values indicate that there was minimal uncertainty or variability in the mean difference estimates between BMC location and gender or age. The precision and reliability of the mean difference estimates, as indicated by the low standard error values, further supported the consistent results (Table VI).

Discussion

The identification of BMC is of critical importance during mandibular surgical procedures, and the prevalence of BMC is reported in the range of 0.08 to 64.8%, yet there is a lack of consensus in the scientific literature regarding its prevalence[7,9,13,15,17]. The aim of this study was to assess the occurrence of BMC among a specific subset of the Saudi population using CBCT. In this study, the null hypothesis was accepted since there were no significant variations observed in the BMC configuration, as well as in the analysis considering age and gender among the Saudi population.

The mandibular canal is commonly known and often found to be a singular canal until Patterson and Funke reported the first case of BMC in 1973[18]. The presence and configuration of BMC have been investigated using several imaging modalities, including: panoramic radiographs[3,10,19-21], CT[20,22,23], and CBCT[5,11,13,16,23,24]. The prevalence of BMC in panoramic radiographs is reported to be under 1%[4,10,13,19]; however, this is thought to be an underestimation of the actual BMC prevalence due to the superimposition and ghost images created by soft and hard tissues, which complicate their identification[25]. Additionally, the insertion of the mylohyoid muscle at the mylohyoid groove can produce a false image resembling a BMC[26].

Naitoh et al[22] compared the ability to detect BMC between panoramic and CT images and found that panoramic radiographs were only able to detect two out of five BMC, whereas CT images detected all five. Lindh et al[27] compared different radiographic techniques and found that the mandibular canal can be visualized in only 25% of panoramic radiographs. In a study of dry mandibles, Klinge et al[24] reported that panoramic radiographs failed to detect mandibular canals in 36.1% of specimens. Moreover, in a comparative study of panoramic radiographs and dry mandibles, Bogdan et al[28] reported that only 0.2% of BMC were visible in panoramic radiographs, while 19.6% of BMC were visible in the dry mandibles. Furthermore, Tantanapornkul et al[29] compared the diagnostic accuracy of panoramic images and CBCT in visualizing

Table VI. Comparison of bifid mandibular canal prevalence between both sexes and age groups (Post-hoc; Tukey's test).

Dependent variable		Multiple comparisons			
		Bifid canal	Mean difference	St. error	*p*
Gender	Bilateral	2	-327	220	308
		3	-227	197	488
	Left	1	327	220	308
		3	100	203	875
	Right	1	227	197	488
		2	-100	203	875
Age	Bilateral	2	-182	602	951
		3	756	540	352
	Left	1	182	602	951
		3	938	556	225
	Right	1	-756	540	352
		2	-938	556	225

p=0.05 was considered significant.

the mandibular canal and found that CBCT has higher sensitivity and specificity than panoramic radiographs. Therefore, he concluded that CBCT is superior in detecting the mandibular canal. Neves et al[25] evaluated the prevalence of BMC in panoramic radiographs and CBCT and reported a higher presence of BMC observed in CBCT.

CBCT is a multiplanar, three-dimensional imaging modality, free of superimpositions or ghost images, which makes it suitable for visualizing the mandibular canal[14,15]. Studies investigating the presence of BMC in CBCT reported a prevalence range of 10.2% to 65%[5,11-15]. In a meta-analysis of 15 studies, Haas et al[9] reported a prevalence of 4.20% in panoramic images and 16.2% in CT or CBCT images. A literature review recommended CBCT as an effective and low-cost radiographic method to assess the presence of BMC[23]. In a study of cadavers, the mandibular canal was classified into three types: single, inferiorly placed, and bifid cana[17]. Using panoramic and CBCT images, several classifications for BMC have been proposed[3,5,21]. Based on CBCT images, BMCs have been classified into four types[5]. In the present study, we used CBCT imaging to detect the configuration of BMC due to its high accuracy using this classification. The prevalence of BMC in the present study was 12.3%, which is comparable to studies in Korea (10.2%)[15], India (10.3%)[30], and Beijing, China (13.2%)[31]. Conversely, the prevalence rate in our study was lower than studies in Belgium (19%)[14], Cheonan, South Korea (22.6%)[32], Tianjin, China (26.1%)[33], Brazil (26.6%)[34], Egypt (30.7%)[35], Taiwan (30.6-41.2%)[36,37], Shanghai (31.1%)[38], Turkey (27.71-46.5%)[12,39,40] and Japan (15.6-65%)[5,13].

Interestingly, in the study, retromolar canal (type 1) was the most frequent type (56.7%) observed, as also reported by others[31,15,32,40]. The prevalence of the dental canal (type 2) in BMCs was 18.9% in the current study, whereas other studies reported rates of 8.3%[12], 14.9%[31], 18.8%[32], and 18.6%[40]. The prevalence of the forward type (type 3) varied, with rates of 4.1%[32], 13.7%[31], 29.8%[12], and 30%[40] in previous studies. In our study, the prevalence of forward canals was 24.3%, and no buccolingual canals (type 4) were observed. Similarly, other studies reported no buccolingual canals[31,32], while one reported a rate of 2.7%[15].

The present study showed no statistically significant difference in the prevalence of BMCs between males and females. This finding is consistent with other studies in the literature[5,31,32,41]. In addition, no difference among the age groups and BMC presence was found. This is similar to the findings of Rashsuren et al[32] and Kang et al[15]. The differences between studies can be attributed to ethnic, geographic, or methodological variations. The direct relation of BMC with aging is not observable, age was considered a variable in this study because of the potential impact of developmental and anatomical changes associated with aging on the detection and prevalence of BMC.

The knowledge of the BMC and its types and configuration is of great importance to oral surgeons. The retromolar canal carries nerves and blood vessels to supply the retromolar mucosa. Injury to this canal can lead to excessive bleeding or paresthesia[42]. The retromolar canal must be accurately identified before any surgical procedure in the retromolar area, including implant placement, bone harvesting, sagittal split osteotomy, or open reduction with internal fixation of mandibular fractures[1,5,43,44]. Additionally, BMCs are associated with failure of the mandibular nerve block anesthesia[45]. The addition of local anesthetic techniques like local infiltration, Gow-Gates, or Akinosi-Vazirani can be helpful[8,46,47]. Patients using dentures may complain of pain in the retromolar area due to pressure retromolar nerve[1,48]. Furthermore, BMCs should be included in tumor resection as they are shown to be a channel for tumor spreading[49,50].

Strenght and Limitations

The observation of the study suggested a 12.3% prevalence of BMC in the Saudi population subset. It also presented the implementation of CBCT investigation as an effective measure to determine anomalies, including the presence of BMC. However, the present study included a small sample size, which could affect the generalizability of the findings. In addition, the identification and interpretation of bifid mandibular canals on CBCT scans can be subjective and rely on the expertise of the operator. Moreover, the quality of the CBCT scans can vary, which may affect the accuracy of identifying and delineating the bifid mandibular canals. Poor image resolution, artifacts, or patient movement during image acquisition can hinder the visualization of anatomical structures. The findings of the study may be limited to the specific CBCT scanning protocol and software used. Different CBCT machines or settings may yield different results, potentially limiting the validity of the findings. Interestingly the present study observed the prevalence rate of BMC without investigating other characteristics, such as length

or angle. Further research with larger sample sizes and comprehensive evaluations of BMC characteristics is warranted for a more comprehensive understanding of the research findings.

Conclusions

Considering the constraints of this study, the prevalence of bifid mandibular canals (BMC) within a subset of the Saudi population was 12.3%. Among BMCs, the retromolar canal was identified as the most frequently occurring type, accounting for 56.7% of cases. No significant variations in BMC prevalence concerning age and gender were observed. Consequently, it is strongly advised to conduct a thorough assessment of the mandibular canal and its potential variations using CBCT imaging before undertaking mandibular surgical procedures in order to minimize the risk of complications.

Informed Consent
Patients consented to their data being used for research.

Acknowledgments
The authors acknowledge the support by the College of Dentistry Research Center and Deanship of scientific research at King Saud University.

Authors' Contributions
YA, WAM, MA and AA: Data collection, study design, manuscript writing, final manuscript approval. MA, AA and AAL: Data collection, study design, manuscript drafting, data analysis, and manuscript approval. WAM, MA and AA: Data collection, data interpretation, writing, revise, and editing and final manuscript approval.

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Ethics Approval
The King Saud University, College of Dentistry, Institutional Review Board reviewed the protocol and approved the study (IRB-E 21-6248).

Data Availability
The study data can be requested by contacting the corresponding author.

Conflict of Interest
The authors declare that they have no conflict of interest and all authors have read and approved the final draft.

Funding
None.

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