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Bifid variations of the mandibular canal: cone beam computed tomography evaluation of 1000 Northern Chinese patients

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Objectives. The aim of this study was to evaluate and quantify variations of bifid mandibular canals (BMCs) in a population of Northern China by using cone beam computed tomography (CBCT).

Study Design. CBCT images of 1000 consecutive patients were analyzed by using the NewTom proprietary software. BMCs were identified and classified on the basis of the Naitoh classification. Linear and angular measurements of BMCs were performed. Statistical analyses were conducted by using χ^2 and Wilcoxon tests.

Results. BMCs were observed in 13.2% of 1000 patients and 8.4% of 2000 sides. The prevalence of BMCs was significantly lower in patients in the first 2 decades and in cases with a class II molar relationship. The retromolar canal (68.4%) was the most common type of BMC observed. No buccolingual canals were identified; however, 2 special canals were detected. A classification system of 3 subtypes of retromolar canals was suggested. On average, the beginning site of the branches from the opening of the main canal was at a distance of 8.1 mm. The mean diameter and length of BMCs were 2.1 mm and 12.6 mm, respectively.

Conclusions. This study underlined the prevalence and characteristics of BMCs in a population of Northern China. Preoperative identification of BMCs with CBCT may help prevent postoperative complications. (Oral Surg Oral Med Oral Pathol Oral Radiol 2018;126:e271−e278)

Accurate recognition of the anatomy and variations of the mandibular canal is indispensable for clinicians during oral surgical procedures involving the mandible, such as placement of dental implants, tooth extraction and orthognathic surgery.[1] A bifid mandibular canal (BMC) is an anatomic variation found in the ramus or body of the mandible, where the mandibular canal is divided into 2 branches; each canal might contain a separate neurovascular bundle.[2] The prevalence of BMCs ranges from 0.08% to 0.95%[3-5] when evaluated by using panoramic radiographs and from 9.8% to 65%[1,6-9] when assessed by using cone beam computed tomography (CBCT). Large variations in data from previous studies regarding the prevalence, pathway, and length of BMCs may be explained by differences in ethnic backgrounds, sampling sizes, image resolutions, and interpretations of anatomic structures. In China, the prevalence of BMCs has been reported in the populations of Shanghai[10] and Taiwan.[3] No studies with a large sample size and high-resolution scans have been conducted with regard to the characteristics of BMCs in the population of the Beijing area, which represents a large and densely populated region of Northern China. The purpose of this study was to evaluate the prevalence and variations of BMCs in 1000 Northern Chinese patients by using high-quality CBCT images and to promote better understanding of the variations, as well as the safety of corresponding surgical procedures.

MATERIALS AND METHODS

Patients

CBCT images of patients who presented at our imaging center from January 2016 to December 2016 were

Statement of Clinical Relevance

Variations of bifid mandibular canals (BMCs) are observed in 13.2% of a population of Northern China. The retromolar canal is the most common type of BMC observed. Accurate recognition of the BMCs is indispensable during surgical procedures involving the mandible.

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retrospectively collected and evaluated. This study was approved by the institutional review board (PKU-SSIRB-201732010), and patients fulfilling the following criteria were enrolled:

Inclusion criteria

1. Ages 18 to 60 years
2. Complete dentition (with or without third molars)
3. Scan with a field of view (FOV) of 12 × 15 cm, with the full mandible visible
4. High-quality images without motion artifacts

Exclusion criteria

1. Presence of severe periodontal lesions or implant treatment
2. Presence of tumoral lesions, cleft lip and palate, or systemic diseases that might affect the skeletal structures of maxillofacial region
3. Presence of orthodontic or orthognathic treatment

In total, data from 1000 patients (341 men and 659 women) were acquired. These patients, ranging in age from 18 to 56 years, were divided into 4 age groups: ≤20, 21−30, 31−40, and >40 years. The incidence of BMCs was recorded relative to gender, laterality, age group, and molar relationship.

Evaluation of bifid mandibular canals at the posterior mandible using CBCT images

CBCT images were obtained by using NewTom VGi (NewTom, Verona, Italy) with the following exposure settings: 110 kV, automatic mA, and 5.5-second pulsed exposure. A voxel size of 200 μm was applied. The NNT software, version 4.00.1 (NNT, Verona, Italy) was used for data analysis according to the manufacturer's instructions. All images were displayed on an 18.7-inch monitor with screen resolution set at 1546 × 2048 pixels (Dome E3; NDS Surgical Imaging, San Jose, CA). CBCT images were separately assessed twice by 2 oral radiologists. Both of them had greater than 5 years' experience with CBCT imaging. They were initially calibrated by examination of 10% of the cases.

For each patient, the molar relationship (class I, II, or III) was analyzed initially, and the entire course of the mandibular canal was observed under free angulation of 3-dimensional slices on multiplanar reconstruction (MPR) images, together with 0.5 mm thickness and spacing of multiplanar panoramic reconstructed views. The CBCT appearance of a BMC was established as visualization of a continuous, rounded radiolucent area with intense thin cortical lines on at least 2 of the 3-dimensional planes. Initially, the 2 observers recorded their responses on a dichotomous scale (with/without BMC). Four weeks after independent examination, both observers compared their findings and discussed them until consensus was reached. At this stage, the κ coefficient was calculated to determine the reliability of image evaluations by the 2 observers.

Among patients whose BMCs were visible in CBCT images, concomitant panoramic radiographs were also observed to evaluate if these accessory canals could be visualized on these radiographs.

Evaluation of classification of bifid mandibular canals using CBCT images

After the BMCs were determined, they were consensually classified into the following types according to a modification of the Naitoh classification[8]:

1. *Retromolar canal:* Bifurcates from the main mandibular canal in the ramus region and opens at the retromolar foramen. Three subtypes were defined according to the configuration: Subtype 1, coursing directly to the surface of the bone (Figure 1A); subtype 2, reaching the retromolar region with 1 crook, giving an impression of a "V" (Figure 1B); and subtype 3, 3 segments and 2 main crooks before ending at the retromolar region, simulating a "U" (Figure 1C).
2. *Dental canal:* Reaches the root of the second or third molar (Figure 2).
3. *Forward canal:* Originates in the superior wall of the main canal and courses forward parallel to the main canal, with (Figure 3) or without confluence (see Figure 2).
4. *Buccolingual canal:* Begins from the buccal or lingual wall of the main canal.
5. *Bicanal:* The accessory canal bifurcates from the inferior wall of the main canal at the origin and courses anteroinferiorly.
6. *Trifid canal:* Two bifid canals bifurcate from one side of the mandibular canal.

Measurement of the beginning site, diameter, length, and angle of bifid mandibular canals

For each of the branches, the beginning site was recorded according to its distance from the mandibular foramen. The diameter of the accessory canal as well as that of the main canal was measured immediately after bifurcation on the cross-sectional image. Length of the accessory canal was measured from the bifurcation point to the endpoint that could be observed on the panoramic reconstructed image by using the Carestream PACS 11.0 program (Carestream Health, Rochester, NY), which allowed measurement of a curved structure. Inferior angles between each accessory canal and the main canal were measured at the beginning site with the NNT software (see Figure 1A). In addition, the main angles in the running courses of the retromolar canals were measured (see Figure 1B). All measurements were recorded twice by the same observer, and the mean of these values was used for analysis.

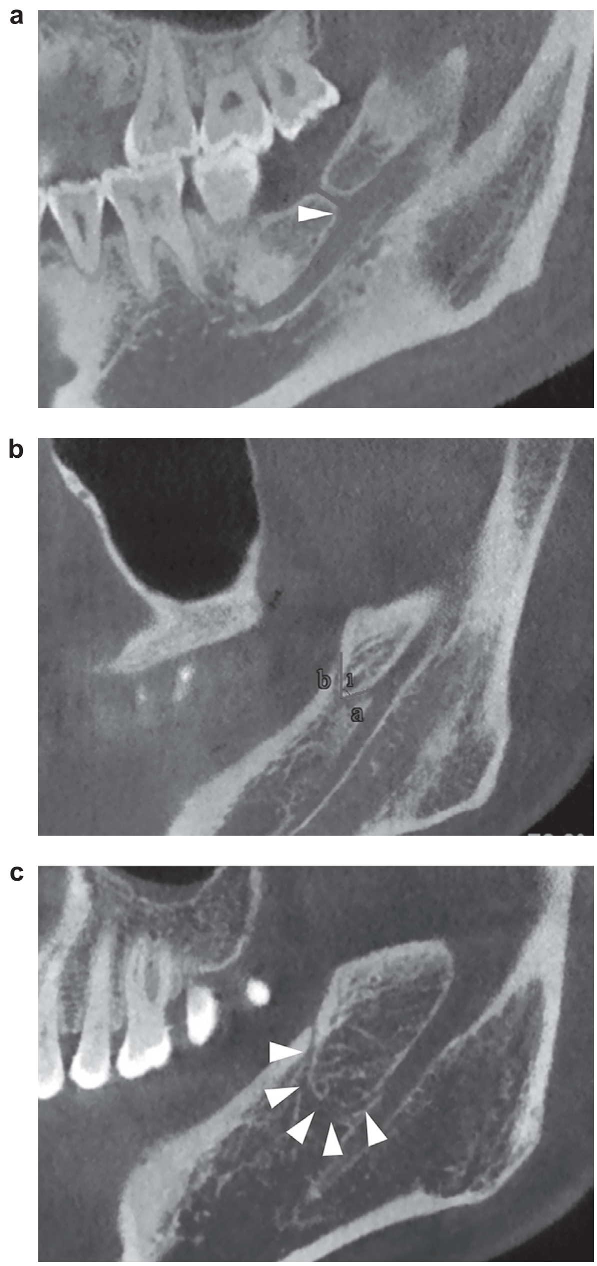

Fig. 1. Three subtypes of retromolar canal. **A,** The retromolar canal (subtype 1) courses directly to the surface of the bone. Inferior angle between the accessory canal and the main canal was measured *(white arrowhead)*. **B,** The retromolar canal (subtype 2) reaches the retromolar region with 1 crook, giving an impression of "V". Lengths of line *a* and line *b* were measured separately, and the sum of these measurements was the total length of the accessory canal. The angle (1) of the crook was measured. **C,** Sagittal view of cone beam computed tomography (CBCT) image shows a retromolar canal (subtype 3, *white arrowhead*), mimicking a "U".

Statistics

Statistical analyses were conducted by using SPSS, version 22.0 (SPSS Inc., Chicago, IL). χ^2 tests were used to investigate differences in the prevalence of BMCs relative to gender, laterality, age group, and molar relationship. The Wilcoxon test was used to compare differences in beginning site, size, length, and inferior angles among the various BMC types. When there were significant differences, post hoc analysis was conducted. Differences were considered significant for P values <.05.

RESULTS

Incidence of bifid mandibular canals

Overall, BMCs were observed in 132 (13.2%) of 1000 patients and 168 (8.4%) of 2000 sides. These accessory canals were observed in 44 (12.6%) men and 88 (13.5%) women, with 77 (7.7%) on the right side and 91 (9.1%) on the left side. In total, 36 patients had bilateral BMCs, 41 had BMCs only on the right side, and 55 patients had BMCs only on the left side. No significant differences were noted in BMCs between men and women ($P = .685$) or between right and left sides of the mandible ($P = .259$). Younger patients (≤20 years) had a lower prevalence of BMCs compared with patients in the older age groups ($P < .05$). However, no significant differences were observed in the prevalence of BMCs among the other 3 older age groups ($P > .05$) (Table I). The prevalence of BMCs was 17.5% in patients with class I molar relationship and 16.0% in those with class III; however, class II patients presented with a significantly lower prevalence (8.1%; $P < .05$) (Table II).

Of the 132 patients with BMCs, 85 had concomitant panoramic radiographs; of these, bifid canals were found only in 6 panoramic radiographs.

With respect to dichotomous evaluations, the κ coefficient between the 2 observers was 0.85.

Occurrence of each type of bifid mandibular canals

The most frequently observed type of BMC was the retromolar canal (68.4%), followed by dental canal (14.9%), forward canal (13.7%), bicanal (0.6%), and trifid canal (2.4%). No buccolingual canals were detected (Table III).

Of the 115 retromolar canals, 34 were subtype 1, 71 were subtype 2, and 10 were subtype 3.

Of the 25 dental canals, 4 extended to the root apex of the second molar and 21 to the third molar.

Of the 23 forward canals, 10 occurred with confluence and 13 occurred without confluence. In a special case with confluence, the forward canal joined the main canal at the mid-point and ended with confluence (Figure 4).

In the bicanal case, the accessory canal coursed anteroinferiorly to a foramen on the lingual cortex of the ramus (Figures 5A and 5B).

Among the 4 trifid mandibular canals, 1 on the right side showed 2 dental canals, and 3 on the left side

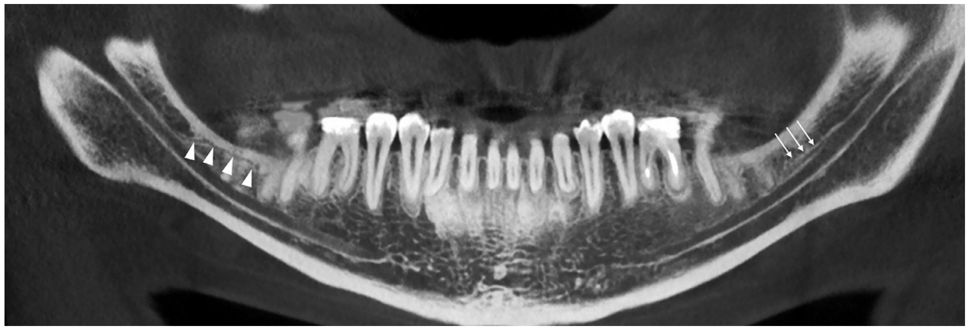

Fig. 2. A panoramic-reconstructed view of cone beam computed tomography (CBCT) images shows a dental canal on the right side *(white arrowhead)* and a forward canal without confluence on the left side *(white arrow)*.

showed 2 retromolar canals (Figure 6), 1 retromolar and 1 dental canals, and 1 dental and 1 forward canals, respectively.

Beginning site, diameter, length, and angle of bifid mandibular canals

The mean distance of the beginning site from the mandibular foramen was 8.1 ± 5.6 mm (Table IV). No significant differences were noted in the distance between the left and right side ($P = .276$) or among different BMC types ($P = .287$).

The mean diameter of the accessory canal was 2.1 ± 1.4 mm. The diameter of the accessory canal was 50% or greater of the main canal in 64 (38.1%) and less than 50% in 104 (61.9%) of the 168 sides considered in this study. The mean diameter of each BMC type was as follows: 2.28 ± 1.29 mm for retromolar canals, 1.75 ± 0.53 mm for dental canals, and 1.74 ± 0.68 mm for forward canals (see Table IV). In the bicanal case, diameters of the accessory and main canals at the bifurcation were 2.8 and 4.8 mm, respectively. However, the mean diameter of the retromolar canals was found to be significantly larger than the other two types of canals ($Z = -2.617$, $P = .009$; $Z = -2.213$, $P = .026$).

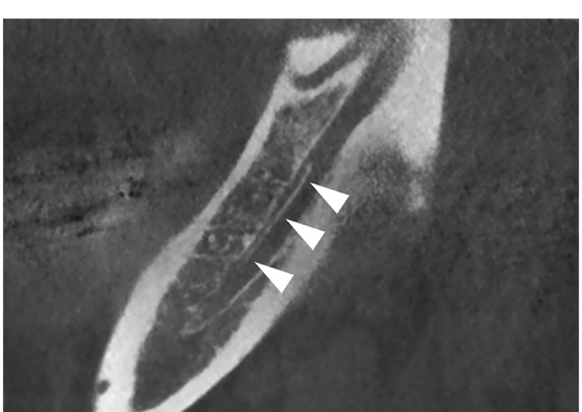

Figure 3. Sagittal view of a cone beam computed tomography (CBCT) scan shows a forward canal with confluence *(white arrowhead)*.

The mean length of BMCs was 12.6 ± 4.9 mm, and no significant differences were noted in length between the retromolar and forward canals ($Z = -1.839$, $P = .066$). However, the mean length of the dental canals was found to be significantly shorter than the other 2 types of canals ($Z = -4.051$, $P = .000$; $Z = -2.091$, $P = .037$). The length of the bicanal was 18.1 mm.

The mean inferior angle of the accessory canals from the main mandibular canal was 52.4° ± 37.5° for retromolar canals, 23.8° ± 23.3° for dental canals, 2.4° ± 6.6° for forward canals, and 0° for the bicanal. Significant differences were noted across the different BMCs types ($P = .000$) (see Table IV).

For the retromolar canals, the mean length of subtype 1 was 11.2 ± 3.9 mm. In subtype 2, the mean lengths of the 2 segments were 6.9 ± 2.8 and 7.2 ± 4.2 mm, respectively, with a mean intersection angle of 81.8° ± 20.8°. In subtype 3, the mean lengths of the 3 segments were 6.8 ± 2.8, 4.8 ± 1.5, and 5.1 ± 3.3 mm,

Table I. Prevalence of bifid mandibular canals according to age group

Age (years)	*≤20*	*21−30*	*31-40*	*>40*
Presence (n = 132)	10	87	22	13
Absence (n = 868)	237	561	145	57
Prevalence (%)	4.2[b]	15.5[a]	15.2[a]	22.8[a]

Same superscript letters indicate no statistically significant difference ($P > .05$).

Table II. Prevalence of bifid mandibular canals according to molar relationship

	Class I	*Class II*	*Class III*
Presence	51	28	53
Absence	250	328	290
Prevalence (%)	17.5[a]	8.1[b]	16[a]

Same superscript letters indicate no statistically significant difference ($P > .05$).

Table III. Occurrence of each type of bifid mandibular canal

Classification	*Number of BMCs*	*Percentage*
Retromolar canal	115	68.4
Subtype 1	34	20.2
Subtype 2	71	42.2
Subtype 3	10	6.0
Dental canal	25	14.9
Second molar	4	2.4
Third molar	21	12.5
Forward canal	23	13.7
With confluence	10	6.0
Without confluence	13	7.7
Buccolingual canal	0	0
Bicanal	1	0.6
Trifid canal	4	2.4
Total	168	100%

BMC, bifid mandibular canal.

respectively, and the mean angles was 119.3° ± 19.5° at the first crook and 105.2° ± 19.5° at the second one.

DISCUSSION

BMC is one of the most common variations of the mandibular canal. CBCT provides high-resolution, 3-dimensional images and is considered a suitable modality for detailed evaluation of the presence of BMCs.[2,6,11-13]

Previous studies have reported wide variations in the prevalence rates of BMCs: 15.6% to 65% in Japan,[8,11] 26.7% to 46.5% in Turkey,[14,15] 30.6% in Taiwan,[3] 26.67% in Brazil,[16] 10.2% to 22.6% in Korea,[6,17] and 31.1% in the Shanghai area of China.[10] After meta-analysis of 15 studies, identified by using CT or CBCT assessments, Haas[1] reported that the overall prevalence of BMC was 16.25%. In our study, BMCs were found in 13.2% of 1000 patients; this finding was comparable

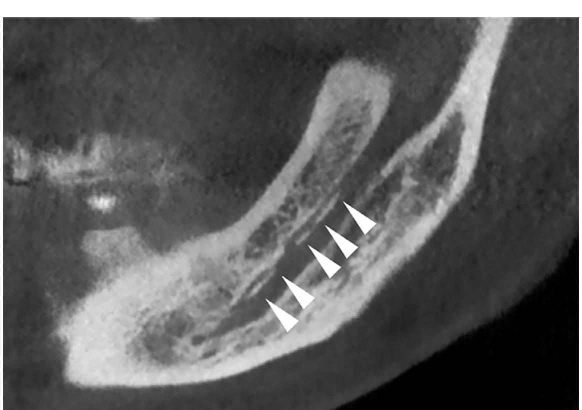

Fig. 4. Sagittal view of a cone beam computed tomography (CBCT) scan shows a specific forward canal *(white arrowhead)*, in which the canal joins the main canal at the mid-point and ends with confluence.

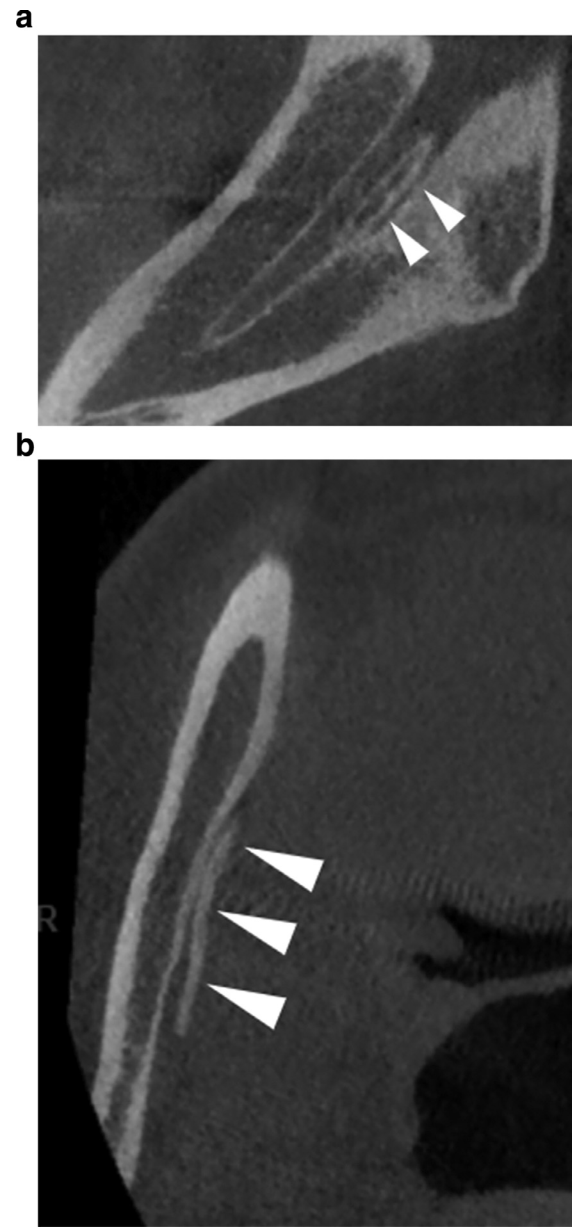

Fig. 5. Bicanal type of bifid mandibular canal (BMC). **A,** Sagittal view. **B,** Axial view. The accessory canal bifurcates from the inferior wall of the main canal and courses anteroinferiorly to a foramen on the lingual surface of the ramus.

with that of Haas[1] but lower than those of other reports, in particular, the results from studies on Chinese in Shanghai and Taiwan; this could be attributed to regional or ethnic differences. Moreover, several other factors might have influenced the results. First, 1000 patients with an FOV of 15 × 12 cm in the CBCT images provided possibly the largest sample size and most comprehensive observation of bilateral mandibles. Second, a continuous, rounded, radiolucent area with intense, thin cortical lines was considered a BMC. Some

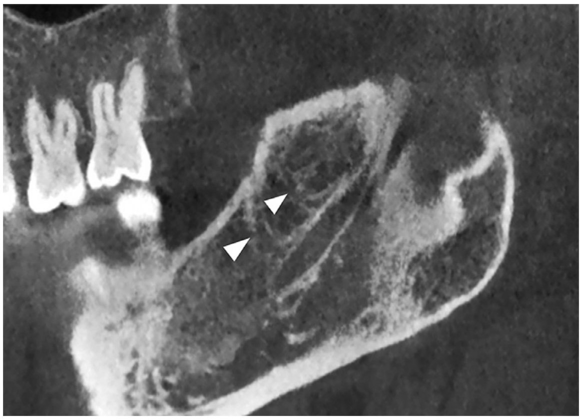

Fig. 6. Trifid mandibular canal: Sagittal view of cone beam computed tomography (CBCT) shows two retromolar canals.

ambiguous or noncorticated radiolucent lines were not classified as BMCs. Third, it should be stressed that the voxel size was an important factor that affected the results. The 200-μm voxel size used in our study was indispensable for accurate evaluation of BMCs.

In the present study, no significant differences were found in the prevalence of BMCs between men and women or between the right and left sides of the mandible; these were similar to findings from most previous studies.[6,8,10,14,16-19] Differences among age groups have been evaluated by Kang et al.[6] and Rashsuren et al.,[17] who found no differences in the prevalence of BMCs across different age groups. In our study, the age group 20 years or younger was found to have a lower prevalence of BMCs. Although the exact reason is still unknown, insufficiency of ossification in young people may play an important role in explaining this difference; that is, the smaller degree of cortication of the canal borders in people age less than 20 years makes the BMCs more difficult to distinguish. Of note, our observational study was the first to evaluate differences in prevalence of BMCs among 3 occlusal types and revealed a lower incidence of BMCs in patients with class II molar relationship.

Among patients with BMCs, concomitant panoramic radiographs were reviewed, and bifid canals were found in only 6 of 85 panoramic radiographs, giving a visible rate of 7.1% (6 of 85), which was comparable with findings reported by Sisman[15] (7.4%); this indicates that conventional radiography may be unreliable in detecting these tiny anatomic structures.

Several classifications of BMCs according to the anatomic site and configuration have been used in previous studies.[11,17,20-22] In 2009, Naitoh[8] classified these variations into 4 types by using CBCT images: retromolar, dental, forward, and buccolingual canals. Thereafter, the Naitoh classification[8] has been implemented by other researchers.[6,10,14,17] In the present study based on a modification of the classification by Naitoh,[8] retromolar canals were found to be the most common (68.4%), as in the studies by Kang et al.[6] (52.5%) and Rashsuren et al.[17] (71.3%) in Korean populations. In the retromolar canal group, 3 subtypes were defined according to configuration. Subtype 2 (V type) represented a typical course. Subtype 1, which directly reached the retromolar region, accounted for 29.6% of retromolar canals. Subtype 3 (U type) reached the retromolar foramen after 2 bends and was found in only 10 cases. To date, no cases similar to subtypes 1 and 3 have been described.

Dental canals accounted for 14.9% of BMCs, which was similar to findings of Rashsuren et al.[17] but higher than those of other reports.[6,8,10,14] In fact, dental canals can occasionally be confused with retromolar or forward canals in that they all bifurcate from the main canal at the ramus region. The essentials of differentiation are as follows: Retromolar canals open at the foramen in the retromolar region, forward canals run parallel to the main canal, and dental canals end at the surrounding region of the molar roots.

Previous studies[8,10,14,22] have found that the most common type of canals detected are forward canals. However, the occurrence rate of forward canals was 13.7% in the present study, which was lower than those of retromolar and dental canals. Interestingly, we found a special forward canal that converged at the mid-point of the bifid canal.

In the present study, no buccolingual branches were detected, which was similar to the findings of Rashsuren et al.[17] One patient had a special type of canal, which

Table IV. The beginning site (mm), diameter (mm), length (mm), and inferior angle (°) of bifid mandibular canals (BMCs)

Classification	*Number (sides)*	*Beginning site of the BMCs*	*Diameter of the BMCs*	*Length of the BMCs*	*Inferior angle of the BMCs*
Retromolar canal	118	8.35 ± 5.42^a	2.28 ± 1.29^b	13.32 ± 4.44^a	52.4 ± 37.5^a
Dental canal	29	8.77 ± 6.42^a	1.75 ± 0.53^a	10.26 ± 5.34^b	23.8 ± 23.3^b
Forward canal	24	6.68 ± 5.66^a	1.74 ± 0.68^a	12.17 ± 5.90^a	2.4 ± 6.6^c

Four trifid canals were calculated and summed into the fundamental types of accessory canals (3 retromolar canals, 4 dental canals, and 1 forward canal). The measurements of the bicanal case are not listed in this table. Same superscript letters indicate no statistically significant difference in vertical columns ($P > .05$).
BMC, bifid mandibular canal.

we named "bicanal." This type of branch was not included in any of Naitoh's 4 types.

The presence of BMCs has clinical implications that are of particular importance in surgical procedures.[14] Failure to accurately localize a BMC may result in damage to the canal and other complications, such as traumatic neuroma, paresthesia, anesthesia, and bleeding during surgery.[20,23,24] With regard to different types of BMCs, retromolar canals may be particularly at risk of damage during bone block harvesting, extraction of third molars, or sagittal split ramus osteotomy; dental canals and forward canals may be at risk of damage during dental implant and tooth extraction.

In the present study, the beginning site, diameter, length, and inferior angle of BMCs were measured as well. The mean distance of the beginning site from the mandibular foramen was 8.1 ± 5.6 mm, indicating that bifid canals mainly bifurcated from the initial 1.0 cm segment of the main canal. The mean diameter and length of the accessory canals were 2.1 mm and 12.6 mm respectively; this was comparable with the results of previous studies.[3,6,8,17,22] Interestingly, the mean diameter of retromolar canals was found to be larger than those of dental and forward canals; this was different from the results obtained by Rashsuren et al. and Kang et al.,[6,17] who reported no significant differences among the 4 types. The present research found that dental canals were significantly shorter than other types of BMCs, which was similar to the results obtained by Kang et al.[6]

CONCLUSIONS

In summary, this CBCT study showed that the prevalence of BMCs in the population of Northern China was 13.2%. No significant differences were found in the prevalence with respect to gender and laterality. Younger patients age 20 years or younger had a lower prevalence compared with older patients. The prevalence of BMCs was lower in cases with a class II molar relationship. The retromolar canal was the most common type of bifid canal, followed by dental and forward canals. In addition, certain novel and special types of canals were detected as well. A classification of 3 subtypes of retromolar canals was suggested. Linear and angular measurements with respect to beginning site, size, length, and angulation further depicted configurations of these accessory canals. Despite the relatively low prevalence, the occurrence of a bifid or trifid canal should not be ignored during the treatment planning for dental implants and dentoalveolar or orthognathic surgery.

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