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A new classification system of trifid mandibular canal derived from Malaysian population

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Background: The purpose of this study was to identify and classify the anatomic variation of mandibular canal among Malaysians of three ethnicities.
Materials and methods: The courses of the mandibular canal in 202 cone-beam computed tomography scanned images of healthy Malaysians were evaluated, and trifid mandibular canal (TMC) when present, were recorded and studied in detail by categorizing them to a new classification (comprising of 12 types). The diameter and length of canals were also measured, and their shape determined.
Results: Trifid mandibular canals were observed in 12 (5.9%) subjects or 16 (4.0%) hemi-mandibles. There were 10 obvious categories out the 12 types of TMCs listed. All TMCs (except one) were observed in patients older than 30 years. The prevalence according to ethnicity was 6 in Malays, 5 in Chinese and 1 in Indian. Four (33.3%) patients had bilateral TMCs, which was not seen in the Indian subject. More than half (56.3%) of the accessory canals were located above the main mandibular canal. Their mean diameter was 1.32 mm and 1.26 mm for the first and second accessory canal, and the corresponding lengths were 20.42 mm and 21.60 mm, respectively. Most (62.5%) canals had irregularly shaped lumen; there were more irregularly shaped canals in the second accessory canal than the first branch. None of the second accessory canal was oval (in shape).
Conclusions: This new classification can be applied for the variations in the branching pattern, length and shape of TMCs for better clinical description. (Folia Morphol 2023; 82, 2: 315–324)

Key words: accessory canal, mandibular canal, trifid mandibular canal, cone-beam computed tomography, Malaysians

INTRODUCTION

The mandibular canal is nowadays acknowledged as a main canal with multiple smaller canals running roughly parallel to it [16]. These canals are termed accessory, bifid or trifid canals depending on the size, configuration, and number of canals present. The term "accessory canal" has been used by Kaufmann et al. [12] to denote multiple branches that are

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short, i.e. less than 15 mm in length. The accessory canals are usually detected as incidental findings by means of radiography as they do not have any clinical landmark [16].

The presence of accessory canals has been attributed to the embryonic development of the three branches of the inferior alveolar nerve that innervate three groups of mandibular teeth, namely the incisors, deciduous molars (and their permanent successors) and permanent molars [9]. During this development process, one single main trunk is expected to form. Accessory branching with various patterns however, forms as a result of incomplete fusion of any of these nerve branches [9]. In accordance to this branching, ossification around the nerves results in the formation of accessory canals. Specific variants of these accessory canals, namely the bifid canals have been reported since the 1970s [13, 26]; while the trifid canals, since 2005 [4].

The trifid mandibular canals (TMC) are considered as the second most reported mandibular canal variant in the literature after bifid canals [20]. The first case of TMC was reported in 2005 as an incidental finding adjacent to an impacted lower left third molar, noticed during a pre-orthodontic screening [4]. Computed tomography (CT) scan was used to confirm the initial finding. Most other cases reported since then were case reports [1, 5, 6, 17, 18, 29]. Recently, Aljunid et al. [3] reported a unique case where one of the accessory canals in a patient with TMC became impinged following implant insertion. This case illustrated how injury to a branch of the accessory canals can inflict injury as severe as if the main mandibular canal is affected.

Currently, there are multiple studies that reported on the presence/prevalence of TMC [1, 3–6, 17, 18, 29]. However, the objectives of these studies were not to solely study TMC; instead, all researchers were studying the presence of various types of accessory canals in the mandible. Bogdán et al. [7] in studying dry mandibles found 1 case of TMC out of 46 mandibles examined. This gives a prevalence of 2.2% for the presence of TMC. One other study used digital panoramic images, while the remaining five research groups conducted their study using cone-beam computed tomography (CBCT). The advantage of using CBCT is that it can provide multiplanar images without the presence of a ghost image and the false appearance of the accessory canal. Using CBCT, Okumus and Dumlu [24] reported a prevalence of 2.4% in the Turkish population, almost similar to that reported by Bogdán et al. [7]. Rashuren et al. [27] reported a prevalence of 1.4% of TMC in 500 patients studied. Yang et al. [30] reported a prevalence of 1.1% among Han Chinese residing in Shanghai. These TMC involved 2 cases of forward canal and 1 case showing a combination of forward canal and retromolar canal. In comparison, Afsa and Rahmati [2] reported observing accessory branches (canals) in 40.5% of cases with 8 of them being trifid, i.e. giving a prevalence of 6.9%. De Castro et al. [10] reportedly found 15 patients with TMC (mostly bilateral with one being unilateral) from 700 CBCT scans. This gives an estimated prevalence of 4.12%. Strangely, Fuentes et al. [11] found no evidence of TMC in 925 digital panoramic images examined. This is most probably because of the limitation of a two-dimensional imaging modality.

Currently, only Rashsuren et al. [27] have proposed classifying TMC into five subtypes, namely:
- A: two accessory canals of the retromolar type;
- B: two accessory canals of one retromolar and one dental type;
- C: two accessory canals of the dental type;
- D: two accessory canals of one dental and one forward type;
- E: two accessory canals of the retromolar type with two mandibular foramina.

This classification appears to have derived from the classification of bifid mandibular canal proposed by Naitoh et al. [19], except for the description involving two mandibular foramina. It is believed that Rashsuren et al. [27] came out with this classification to fit the seven TMC they found in their study.

The purpose of this current study was to investigate the prevalence and the types of TMC present in Malaysian population that consisted of three different ethnic groups, namely Malays, Chinese and Indians, by using CBCT scanned data. As there is currently an inadequate classification system available to define TMC, the authors would like to propose a different classification system that is believed to be more accurate for clinical and academic communication. This study also determined the diameter, shape, and length of the TMC as such information is currently limited.

MATERIALS AND METHOD

Ethical approval

This study received the Faculty Ethical Committee's approval prior to commencement (Ethical approval:

DF DP1303/0014 [P]). The committee was aware that this was a retrospective study and that it was undertaken using patients' data and scanned images. As this is a teaching institution, all patients seeking treatment from the Faculty of Dentistry are informed of the need that all forms of their records may be used for teaching and research purposes, and verbal consent is taken (for imaging purposes) with the assurance that their identity will remain anonymous.

Sample selection

Castro et al. [8] in a review of the literature regarding the classification of the mandibular canal branching reported that the sample size of three-dimensional (3D) classifications used included an average of 187 CT examinations. Therefore, the authors set out to include at least 200 CBCT scans. Following a thorough screening of 850 CBCT scans stored at the database of the Oral Radiology Division of the Faculty of Dentistry, University of Malaya, CBCT scans of 202 subjects (93 male and 109 female) were included in the study based on the inclusion and exclusion criteria. These patients attended the division to obtain scans for various other conditions affecting the upper and/or lower jaws. Each CBCT dataset of the patients that had a complete image of either the right or the left side, or a combination of both sides of the mandible were examined.

Inclusion criteria

- Subjects of both genders from the three main ethnic groups in Malaysia, namely the Malay, Chinese and Indian, were selected.
- Healthy subjects with no mandibular deformity, or medical conditions that affects skeletal growth.
- Accessory canal cortication when present, can be seen and drawn in all aspects of CBCT images.
- Accessory canal must be connected to the mandibular canal.

Exclusion criteria

- Patients with a history of having undergone surgery to the mandible due to trauma or pathology.
- Patients with existing pathological disorder in the mandible such as cyst, tumour, osteomyelitis, fibrous dysplasia, or invasion of cancer that will alter the appearance of the mandible radiographically.
- Syndromic patients and patients with congenital disorders that affect the size and shape of the jaw bones.
- Patients with severe malocclusion that affect the size and shape of the jaw bones.
- Patients with a history of surgical intervention to the body of the mandible i.e. orthognathic surgery, or reconstructive surgery.
- The reformatted CBCT images, which appear distorted or blurred due to patients' movements.

Image acquisition

These patients were subjected to I-CAT Imaging System (Imaging Sciences International, Hatfield, USA), following a standardized protocol for patient positioning and exposure parameter setting (120 kVp, 3–7 mA), with an extended field of view equal to 13 × 16 cm, 0.3 mm voxel, and 20 s of exposure time. As the main clinical reasoning for the examinations arose from the purpose of confirming the diagnosis of a lesion elsewhere in the head and neck region, the CBCTs included had a large field of view and a voxel size of 0.3 mm. The patients were placed in a vertical position and stabilized with custom made head bands and chin support.

Processing of images

The axial slices retrieved from scanning were reformatted according to the protocols advocated by Materialise Dental (Leuven, Belgium). The axial images were elaborately cleaned off from irrelevant anatomies such as the spinal cord, opposing teeth and metal scatterings, in a process called "masking". During this procedure all non-important data were meticulously removed and an exact full-colour 3D reconstruction of the jaw was prepared, as described by Nikzad et al. [21]. The reformatted and cleaned data were rendered to a special implant-planning software programme, SimPlant™ (SimPlant 3-D Pro version 13.1, Materialise Dental, Leuven, Belgium), dedicated for this purpose.

The presence of multiple mandibular canals is documented by first opening the file using Simplant™. The visibility rating and dimensional measurements were performed by only one researcher (first author) who is trained in the interpretation of oral and maxillofacial images. Some questionable CBCT images were re-evaluated by one principle oral and maxillofacial radiologist and one oral and maxillofacial surgeon. The SimPlant™ software allows the viewing of axial, cross-sectional, panoramic and 3D visualisation of the jaw on the same screen. Changing the position of reformatted images makes it possible to trace the

Table 1. Proposed classification for trifid mandibular canal

Type	Description
1A	Retromolar canal ending in bone
1B	Retromolar canal ending in foramen
2A	Dental canal originating from one mandibular foramen
2B	Dental canal originating from multiple mandibular foramina
2C	Dental canal originating from the mandibular canal in the ramus
2D	Dental canal originating from the mandibular canal in the body
3A	Forward canal originating from one mandibular foramen
3B	Forward canal originating from multiple mandibular foramina
3C	Forward canal originating from the mandibular canal and ending in bone
3D	Forward canal originating from the mandibular canal and ending in foramina
4A	Buccolingual canal ending in bone
4B	Buccolingual canal ending in multiple foramina

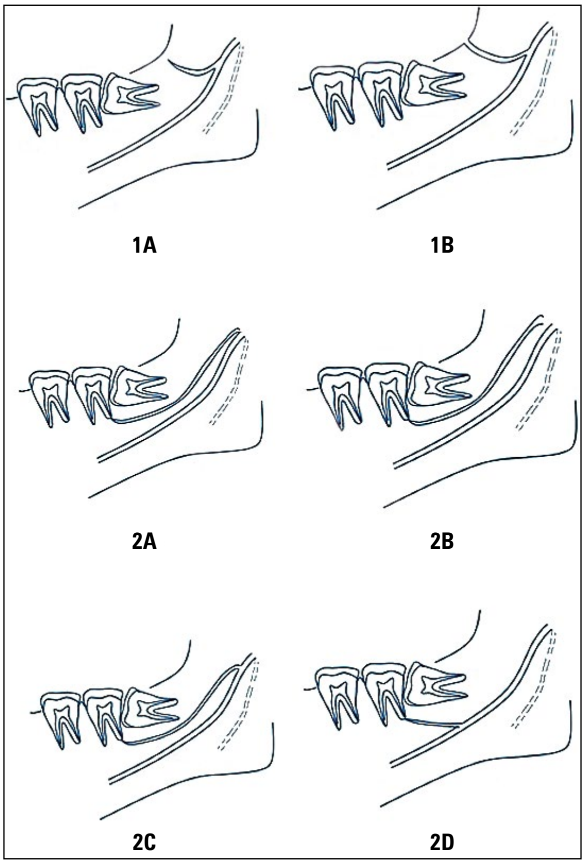

Figure 1. Diagrammatic representation of trifid mandibular canal (type 1A, 1B, 2A, 2B, 2C, 2D) according to our classification system.

course of the mandibular canal precisely and draw the exact pathway of the nerve and its branches.

The course of the mandibular canal was marked and determined by firstly identifying the mandibular foramen and mental foramen followed by outlining it by marking in orange using the Simplant™ software. The location of the mandibular foramen was recorded as being positioned at any of the nine quadrants reported by Lim et al. [15]. Then, the accessory canals/TMCs, when observed, were drawn, and marked in white to distinguish them from the main mandibular canal. The accessory canals were based on their superior-inferior relationship to the main mandibular canal and whether it terminates buccolingually in the bone/foramen or even multiple foramina. Their patterns were firstly recorded, and later they were entered into any of the following classification patterns (Table 1, Figs. 1, 2), which is an expansion of the original classification proposed by Naitoh et al. [19] for bifid mandibular canal. This proposed classification incorporates the origin and ending of the TMC.

The length of TMC was then measured either in the sagittal or panoramic reconstructed CBCT images using the SimPlant™ software as it allows one to measure straight or curved structures. The length of the accessory canals was measured from the starting point of separation of the main canal to an end point that resides in the mandible or at its ending at a foramen.

The diameter of the first and second accessory canals was measured immediately after separation on cross-sectional image at the widest portion of the canals. The shape of the lumen of the accessory canal was recorded as either being circular, oval, or irregular.

Intra-observer reliability was performed by analysing 32 randomly selected CBCTs with 2 months intervals between each evaluation. Cohen's Kappa k was used to confirm categorical subclass agreement. Intraclass correlation coefficient (ICC), p was used to assess agreement of length and diameter of the TMC and mandibular canal. The ICC finding was confirmed using Bland-Altman analysis, by applying the following formula:

$$\text{Mean difference} = \frac{\text{Result 1} - \text{Result 2}}{(\text{Result 1} + \text{Result 2})/2} \times 100\%$$

In general, the lower the difference in percentage, the more accurate is the result.

Statistical analysis

All data were gathered, entered, and analysed using SPSS 12.1 (SPSS Inc., Chicago, USA) software programme. Descriptions of parameters were reported as mean ± standard deviation (SD), and minimum

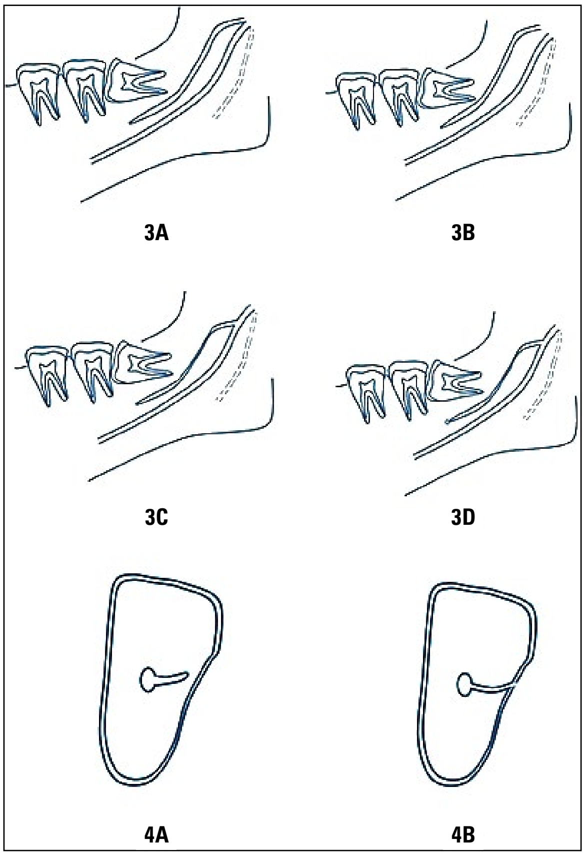

Figure 2. Diagrammatic representation of trifid mandibular canal (type 3A, 3B, 3C, 3D, 4A, 4B) according to our classification system.

and maximum values. The 95% confidence interval (CI) was also determined. Chi-square test was used to determine if any significant differences was present in the prevalence of different types of TMC with respect to ethnicity, gender, and age-group of the subjects. The significant differences in the mean length and diameter of the trifid canal among gender was investigated using independent *t*-test. One-way analysis of variance (ANOVA) with post-hoc Tukey's analysis was used to determine the significant differences between the mean length and diameter of TMC in the subjects of different ethnicity and age-groups. Differences were considered significant when the p-value < 0.05.

RESULTS

Measurement of agreement

A total number of 32 records (16% of total sample) were included in the agreement test and retest. All relevant data were measured again after 2 months by using the same methods described earlier. Regarding the assessment of intraexaminer agreement, all parameters showed optimal agreement. Cohen's Kappa k was used for the categorical subclass agreement; the reliability of observing TMC ($k = 0.84$; $p < 0.001$), vertical positioning of canal ($k = 1.00$; $p < 0.001$), lumen shape ($k = 0.73$; $p < 0.001$) and pattern of canal ($k = 0.84$; $p < 0.001$) were between good and excellent.

Intraclass correlation coefficient, p was used for the assessments of the length and diameter of the TMC and mandibular canal. The reliability in measuring the length of TMC (ICC = 0.996; $p < 0.001$), diameter of TMC (ICC = 0.763; $p = 0.009$) and diameter of mandibular canal (ICC = 0.923; $p = 0.001$) were between good and excellent. The ICC finding was confirmed using Bland-Altman analysis. The differences in measuring the length of TMC (0.21%), diameter of TMC (2.19%) and diameter of mandibular canal (0.87%) were small, resulting in an average of 0.87% difference being observed.

Prevalence of TMC

Two hundred two scans of the mandibles of patients from three different ethnic groups were studied in this research. Ninety-three of them were Malays, 72 were of Chinese and the remaining 37 were Indians. Their mean age was 48.29 ± 16.9 years (range 11–80 years).

Twelve patients were found to have two accessory canals present in at least one side of the mandible, giving a prevalence of 5.9%. Additionally, the TMC were observed in 16 (4.0%) hemi-mandibles. The mean age of the patients was 53.4 ± 11.4 years (range: 22–76 years). They were observed in 5 males and 7 females and 4 patients presented with bilateral TMCs with the remaining two-third being unilateral presence TMC. Interestingly, 7 of these unilateral TMC patients showed the presence of bifid canals on the contralateral sides. An example of the TMC is shown in Figure 3.

Ethnicity appears to influence the prevalence of TMC. Only 1 Indian presented with TMC as compared to 6 Malays and 5 Chinese subjects. Bilateral TMC was seen in Malays and Chinese but not in the sole Indian subject with TMC. The gender distribution for all subjects with TMC is shown in Figure 4.

Except for one subject (who happened to be the Indian), all TMCs were observed in subjects above the age of 30 years. The average age of Malay, Chinese and Indian subjects were 51.0 years, 56.7 years, and 26 years, respectively. Amongst males, three-quarter of subjects presenting with TMC were found to fall

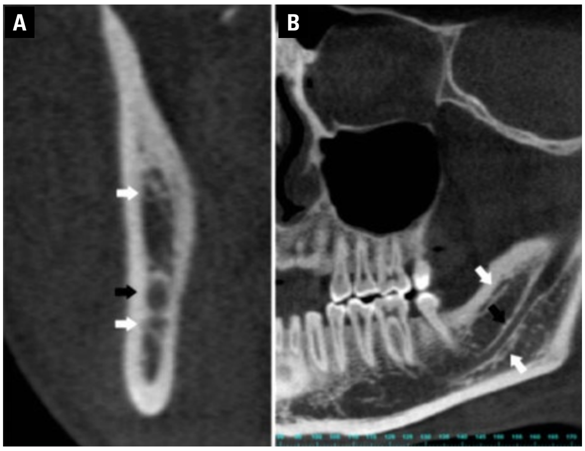

Figure 3. Trifid mandibular canal (white arrow); main mandibular canal (black arrow). Coronal view (**A**) and panoramic view (**B**) of cone-beam computed tomography image improved with SimPlant.

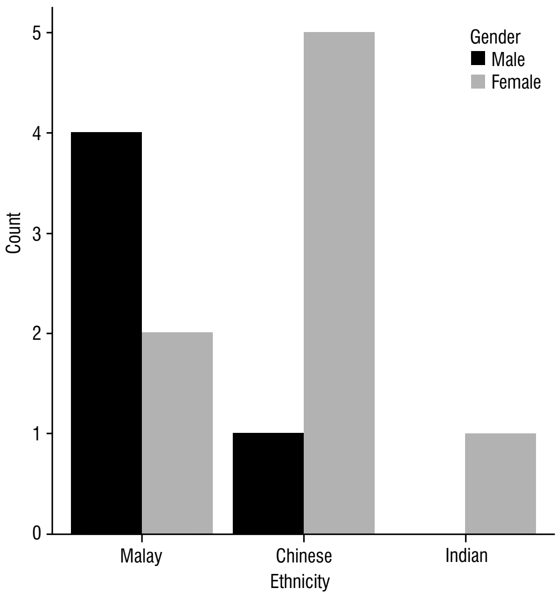

Figure 4. The distribution of trifid mandibular canal found in all subjects of both genders.

within the age of 51 and 80 years old. In females, those between the age of 41 and 50 years made up 57.1% of the subjects, and together with those between the age of 51 and 70 years, they made up of 85.7% of subjects. In summary, it appears that TMC was more commonly seen in female subjects below 50 years, but for the male subjects, the prevalence was higher among those older than 50 years old.

Types of TMCs

Table 2 shows the distribution of various types of TMC according to the classification system proposed in Materials and Methods.

Table 2. Types of trifid mandibular canal according to our classification system

Classification	Number (%)		
	1st Accessory canal	2nd Accessory canal	Total
Type 1A	2 (12.5%)	2 (12.5%)	4 (12.5%)
Type 1B	8 (50%)	2 (12.5%)	10 (31.25%)
Type 2A	–	4 (25%)	4 (12.5%)
Type 2B	1 (6.25%)	3 (18.75%)	4 (12.5%)
Type 2C	2 (12.5%)	3 (18.75%)	5 (15.6%)
Type 2D	–	–	–
Type 3A	–	1 (6.25%)	1 (3.12%)
Type 3B	1 (6.25%)	–	1 (3.12%)
Type 3C	–	1 (6.25%)	1 (3.12%)
Type 3D	1 (6.25%)	–	1 (3.12%)
Type 4A	–	–	–
Type 4B	1 (6.25%)	–	1 (3.12%)
Total	16 (100%)	16 (100%)	32 (100%)

The retromolar canal type (type 1) was observed to be the most common type, dominating 43.8% of TMC observed. The majority (71.4%) of them ended at multiple foramina (type 1B). The dental canal was the second most common type of TMC, making up of 40.6% of TMC. They were almost equally distributed between those originating from one mandibular foramen (type 2A), multiple mandibular foramina (type 2B), and the mandibular canal in the ramus (type 2C). No type 2D dental canal was observed. Four sites presented with each subtype of type 3 canal. Type 4 canal was only present at one site, and it was a buccolingual canal ending in multiple foramina (type 4B). In summary Types 2D and 4A were not observed in our samples.

The vertical position of the accessory canals was classified into three types: above, same or below the main mandibular canal. The majority of the TMC (n = 18) were located above the main mandibular canal. Only one canal was located at the same level with main mandibular canal while the remaining 13 canals were located below the main mandibular canal (Table 3). It appears that most of the first accessory canals were located above the main mandibular canal while the majority of the second accessory canals were most often located below the main mandibular canal.

Figure 5 shows the distribution of four different types of accessory canal according to the three superior-inferior locations. As can be seen, all type 1 canals were located above the main mandibular canal. For type 2 canals, they were equally distributed between

Table 3. Location of trifid mandibular canal (MC) in relation to the main MC

Location	Number (%)	
	1st Accessory canal	2nd Accessory canal
Above main MC	14 (87.5%)	4 (25%)
Same level with MC	1 (6.25%)	–
Below main MC	1 (6.25%)	12 (75%)
Total	16 (100%)	16 (100%)

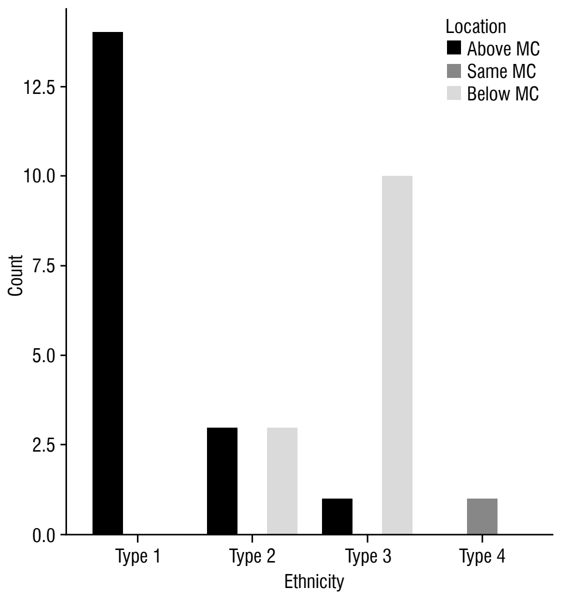

Figure 5. The distribution of four different types of accessory branch according to three different locations; MC — mandibular canal.

being located above and below the main mandibular canal. In contrast, most type 3 canals (90.9%) were located below the main mandibular canal. The only type 4 canal present was located at the same level with the main mandibular canal.

Morphometrics of TMC

Diameter of the TMC

One subject had two accessory canals that were larger than the main mandibular canal. Otherwise, all accessory canals were significantly smaller than the main mandibular canal (Table 4). The diameter of the accessory canal was greater than or equal to 50% size of the main canal in 18 (50%) of the cases and lesser than 50% in the remaining 18 (50%) canals.

The overall mean diameter of the accessory canals was 1.29 ± 0.24 mm. The mean diameter of the first accessory canal was 1.32 ± 0.24 mm (range: 0.94–1.89 mm; 95% CI: 1.19 to 1.45 mm) and that of the second accessory canal was slightly smaller at 1.26 ± 0.24 mm (range: 0.93–1.67 mm; 95% CI: 1.14 to 1.39 mm) (Table 3). In comparison, the diameter of the main mandibular canal was 2.40 ± 0.39 mm (range: 1.46–2.89 mm; 95% CI: 2.20 to 2.61 mm). Table 3 outlines the diameter of the main and two accessory mandibular canals in the three ethnic groups, according to their gender.

Although the diameter of the accessory canal appeared different between gender, the average diameter at 1.36 ± 0.24 mm in male was not significantly larger than those observed for female, which averaged at 1.25 ± 0.23 mm (Independent t-test; $p = 0.216$). Malay subjects appeared to have a slightly larger accessory canal (1.31 mm) when compared to Chinese (1.28 mm) and Indian (1.24 mm) subjects although this difference was not statistically significant (ANOVA; $p = 0.888$).

There was no difference in the canal diameter between all four types of canals (ANOVA; $p > 0.05$). Their diameters were 1.35 ± 0.25 mm for type 1, 1.28 ± 0.16 mm for type 2, 1.24 ± 0.23 mm for type 3 and 0.94 for type 4.

Shape of the lumen of the TMC

Three types of lumen shape were identified in this study. The majority of the accessory canals had irregular lumen shape, as observed in 20 (62.5%) hemimandibles. The next most common shape was the circular lumen, accounting for 31.3% (n = 10) of cases. Oval shaped lumen was seen in only two (6.3%) cases. Irregularly shaped canal also made up the majority of the first accessory canal (50%) and second accessory canal (75%). All three types of canals can be observed in subjects of both genders, again with the irregularly shaped canal being the most common (male: 66.7%; female: 60.0%).

Length of the TMC

The overall mean length of the accessory canals was 21.01 ± 14.23 mm. The mean length of the first accessory canal was 20.42 ± 13.11 mm (95% CI: 13.44 to 27.41mm) and that of the second accessory canal was slightly longer at 21.60 ± 15.69 mm (95% CI: 13.23 to 30.00 mm). However, it was observed that there was a wide range in the length of both accessory canals. The first accessory canal ranged from as low 5.00 mm to as high as 52.00 mm. The second accessory canal ranged from as low 7.46 mm

Table 4. The diameter of the main and accessory mandibular canals in the three ethnicities

Ethnic/Gender	Diameter of anatomy structures [mm]			
	Accessory canal 1	Accessory canal 2	Both accessory canals	Main mandibular canal
Malay				
Male	1.48 ± 0.27 mm	1.20 ± 0.18 mm	1.34 ± 0.36 mm	2.45 ± 0.37 mm
Female	1.09 ± 0.18 mm	1.43 ± 0.41 mm	1.26 ± 0.26 mm	2.52 ± 0.45 mm
Both	1.33 ± 0.31 mm	1.29 ± 0.21 mm	1.31 ± 0.25 mm	2.48 ± 0.37 mm
Chinese				
Male	1.45 mm	1.45 mm	1.45 mm	2.60 mm
Female	1.26 ± 0.20 mm	1.23 ± 0.30 mm	1.25 ± 0.24 mm	2.31 ± 0.47 mm
Both	1.29 ± 0.19 mm	1.26 ± 0.28 mm	1.28 ± 0.23 mm	2.35 ± 0.44 mm
Indian				
Female	1.42 mm	1.06 mm	1.24 mm	2.19 mm

Table 5. The length of the main and accessory mandibular canals in the three ethnicities

Ethnic/Gender	Diameter of anatomy structures [mm]		
	Accessory canal 1	Accessory canal 2	Both accessory canals
Malay			
Male	23.51 ± 13.98 mm	13.61 ± 8.47 mm	18.56 ± 12.08 mm
Female	12.34 ± 1.59 mm	15.79 ± 10.58 mm	14.06 ± 7.02 mm
Both	19.32 ± 12.07 mm	14.43 ± 8.61 mm	16.87 ± 10.44 mm
Chinese			
Male	50.00 mm	50.00 mm	27.50 ± 31.82 mm
Female	14.09 ± 5.18 mm	35.05 ± 16.45 mm	24.57 ± 15.97 mm
Both	19.22 ± 14.37 mm	30.76 ± 18.83 mm	24.99 ± 17.17 mm
Indian			
Female	37.68 mm	14.79 mm	26.24 mm

to as high as 50.00 mm. Table 5 outlines the length of both accessory mandibular canals in 3 ethnic stocks, according to their gender.

The average length of accessory canal in the male was 20.05 ± 14.95 mm. This was slightly less than the 21.59 ± 14.15 mm seen in female and this difference was however not statistically significant (Independent *t*-test; p = 0.772). There was also no significant difference in the average length of both accessory canals between subjects of three ethnic groups. Malay subjects appeared to have the shortest average length for accessory canals at 16.87 mm, when compared to Chinese and the Indian subject whose TMC measured at 24.99 mm and 26.23 mm respectively (ANOVA; p = 0.265).

Trifid mandibular canal type 3 had the longest canal at 36.80 ± 11.64 mm while type 4 was the shortest at 5.85 mm. The mean lengths of type 1 and type 2 canals were 11.56 ± 4.09 mm and 15.26 ± ± 9.66 mm, respectively.

DISCUSSION

The prevalence of TMC reported in the current study (5.9%) is within those reported by other studies which ranged from 0% to 6.9% [2, 7, 10, 11, 24, 27, 30]. Ethnic-wise, the Malays presented with the highest percentage of subjects with TMC, followed by the Chinese while the Indians had the lowest prevalence. The prevalence for the Malaysian Chinese group was recorded at 6.9% and this is almost 7× higher than those observed in Shanghainese Chinese (1.1%) [30]. More important is the fact that bilateral TMC was seen in 40.0% of Chinese, 33.3% of Malays but was not observed in the sole Indian subject. This finding has not been reported elsewhere. It must be stated here that the Indian presentation of a single finding might not be correct as the sample size was only 37 Indians. The authors had difficulty finding CBCT of Indian subjects as they make up only about 7% of the 32 million populations in Malaysia.

Studies in bifid mandibular canal have shown that the length of this accessory canal ranges from 1.6 mm to 35.2 mm [19, 25], while its diameter measured between 0.91 and 2.2 mm [27]. Afsa and Rahmati [2] recently studied the accessory branches of the mandibular canal and reported their length and diameter as 13.61 mm (range: 3.90 to 48.50 mm) and 1.12 mm (range: 0.40 to 3.60 mm), respectively, without distinguishing the types of branching. Rashsuren et al. [27] also reported an average of 16.9 mm in length and 2.2 mm in diameter in 113 subjects with multiple accessory branches. A recalculation of their results provided an average length of 20.1 mm and the diameter of 2.07 mm. Hence, the finding of an average length of 21.01 mm and diameter of 1.29 mm in our TMC cases fit well into the description of accessory canals observed in cases of bifid canals and TMC.

Studies in bifid mandibular canal reported of the difficulty to fit bifid accessory canals into several classification systems even though they are established systems and one of them has even been used for more than four decades [16, 28]. They are the ones proposed by Nortje et al. [22, 23] and Langlais et al. [14] based on panoramic radiographs and the one proposed by Naitoh et al. [19] based on CT/CBCT examinations. Current reports on the prevalence of TMC by several authors did not attempt to categorize the TMC observed [2, 7, 10, 11, 24, 27, 30]. Because of this short coming, the authors had decided to come up with a classification system for TMC from the outset of this study. This current proposed classification system took into consideration the features observed by Nortje et al. [22, 23], Langlais et al. [14] and Naitoh et al. [19], hence retaining some features such as the origin and end of the canal (mandibular foramen, mandibular canal and mental foramina) and the location and orientation of the canal (retromolar, dental, forward and buccolingual canal). It is hope that this classification system will make it easier to communicate the different types of TMC seen in future studies or clinical practice.

This is indeed a significant study done on the scanned images of life patients with CBCT and 3D simulation and it clearly showed accessory canals related with mandibular canal. As the sample size is limited, efforts must be taken to increase the number of subjects, especially the Indians. In addition, As CBCT uses ionizing radiation and is considered invasive, future research with high resolution magnetic resonance imaging must be encouraged. These imaging modalities do not use ionizing radiation and are considered non-invasive.

CONCLUSIONS

In summary, there are great variations in the pattern, size, and shape of TMC which can be classified into four main types with 12 subtypes. Ten subtypes of TMC were observed in this study.

Trifid mandibular canals were observed in 5.9% of subjects or 4.0% of hemi-mandibles. One-third of these patients had bilateral TMC with more than half (56.3%) of the accessory canals being located above the main mandibular canal. The majority (62.5%) of canals had irregularly shaped lumen; there were more irregularly shaped lumen in the second accessory canal (75%) than the first one (50.0%). None of the second accessory canal was oval (in shape).

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