Original Article

Anatomical Variations of Mandibular Canal Using Cone-Beam Computed Tomography- A Retrospective Study

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Abstract

Background: Precise anatomy and course of mandibular canal is important to obtain the desired outcome of different mandibular surgical procedures and circumvent various surgical complications. This study aimed to document the presence, frequency, and type of mandibular canal variations using cone-beam computed tomography (CBCT). **Materials and Methods:** CBCT images of 100 patients with a total of 200 sides (right and left) were obtained retrospectively from the database of Government Dental College and Hospital, Mumbai. The presence and type of mandibular canal variation were evaluated and classified according to Naitoh *et al.* classification (2009) along with Rashsuren *et al.* modification (2014). Prevalence rates were determined according to gender, side of the mandible, and type. Morphometric analysis of the mandibular canal variations was made. Statistical analysis with Chi-square, analysis of variance (ANOVA), and Scheffe's tests were performed. **Results:** Mandibular canal variations were found in 13% of patients and 8% of total sides. Type I dental canal (37.50%) was the most common type of accessory canal followed by Type II retromolar canal (31.25%), Type III forward canal type (25%), Type V trifid canal (6.25%), and Type IV buccolingual canal (0%). The retromolar canal had the maximum length and diameter and most of the accessory mandibular canals (60%) had a diameter of more than 50% of that of the main canal. **Conclusion:** Bifid mandibular canal was the most common anatomical variation of the mandibular canal found in this study with dental canal type being the most frequent type. To avoid iatrogenic injuries, a presurgical detailed evaluation of the mandibular canal using CBCT was suggested.

Keywords: Accessory mandibular canals, anatomical variations, bifid mandibular canal, cone-beam computed tomography, trifid mandibular canal

Introduction

Mandibular canals are intraosseous ducts that contain inferior alveolar neurovascular bundles.[1] Anthropological study detected the occurrence of mandibular canal branching in the form of bifurcations and trifurcations.[2] Occasionally, double mandibular canal from double mandibular foramen may also exist.[3] The incidence of these mandibular canal aberrations was underestimated in the panoramic imaging studies (0.08–2.3%).[4-7] Whereas cone-beam computed tomography (CBCT) provided high resolution, three-dimensional imaging, and was considered superior in identifying these variations (5.6-66.5%)[8-16] and detecting narrow diameter canals.[10]Although an infrequent anomaly, insights into the prevalence, location, and configuration of these canals are highly important as they can complicate surgical and anesthetic procedures.[1]

The literature review reveals that cone-beam computed tomography (CBCT) studies[8,9] on the Indian population to detect mandibular canal variations are exiguous and warrant further research. Hence, we conducted this study to evaluate the presence, frequency, and type of mandibular canal variation using CBCT in the mixed Indian population.

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Materials and Methods

Whole mandible CBCT images of 100 patients with a total of 200 sides (right and left) were retrieved from the archival database of Government Dental College and Hospital,

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Mumbai (registered between 2018 and 2019) and analyzed after receiving approval (IREB/2020/OMDR/03) from the Institutional Research and Ethical Board of D.Y. Patil University School of Dentistry, Navi Mumbai, dated 10.10.19.

The sample size was determined using the formula:

$n = 4\,P * q/d^2$

Where,

n: Sample size

p: Prevalence of the condition (obtained from the previous study[8][V4] done on Indian population accounting for 0.05). *P* value in decimal form.

q: Taken in decimal term (1-*p*)

d: The precision of the estimate (relative precision taken 0.05)

Image selection was done irrespective of ethnicity, gender, age, or presence/absence of teeth. They were selected according to the inclusion and exclusion criteria. Only scans showing the full extension of the mandible and with satisfactory tomographic quality were considered. Scans with evidence of fractures, pathological lesions, orthognathic surgery, or any restorative bone procedures involving the mandible were not included in the study. The study was conducted in accord with the ethical standards as per the Helsinki Declaration of 1975.

Image evaluation

CBCT images were acquired and selected using the Planmeca ProMax 3D apparatus with standard protocol— kilovoltage peak: 90 kVp, tube current: 10 mA, and voxel size ranging between 0.2 and 0.4 mm depending on the variable field of view.

The Planmeca Romexis Viewer software was used for the reconstruction and measurement of the scans in all the orthogonal planes. Adjustments were made using the adjustment tools for improving the visibility of the course of the mandibular canal.

All scans were evaluated by two investigators (oral radiologist) and analyzed twice within 1 week. In case of interobserver discrepancy, a third investigator was consulted to reach a final consensus.

The presence and type of mandibular canal variations were evaluated in the left and right side of the mandible and classified according to the criteria proposed by Naitoh *et al.* (2009)[14] with modification given by Rashsuren *et al.* (2014).[11]

- **Type I (The retromolar canal)**: The bifid canal which reaches the retromolar region.
- **Type II (The dental canal)**: The end of the bifid canal reaches the root apex of the second or third molar.
- **Type III (The forward canal)**: (A) Forward canal without confluence: The bifid canal, which arises from the superior wall of the mandibular canal and courses forward toward the second molar region. (B) Forward canal with confluence: The bifid canal, which arises from the superior wall of the mandibular canal courses anteriorly, and then, joins the main mandibular canal.
- **Type IV (The buccolingual canal)**: The bifid canal arising from the buccal or lingual wall of the mandibular canal.[14]
- **Type V (The trifid canal)**: (A) Two accessory canals of the retromolar canal type. (B) Two accessory canals of one retromolar and one dental canal type. (C) Two accessory canals of the dental canal type. (D) Two accessory canals of one dental and one forward canal type. (E) Two accessory canals of the retromolar canal type with two mandibular foramina[11]

Morphometric analysis

The length of the accessory mandibular canal was measured from the bifurcated point to the endpoint that is observable on the panoramic reconstructed images. The diameter of the main mandibular canal was measured just after bifurcation on the cross-sectional image and that of the accessory mandibular canal at the widest portion of the canal.

The diameter of the accessory mandibular canal was classified according to Kuribayashi *et al.*[10] into two categories. Class A: 50% or above and Class B: less than 50% of the main mandibular canal.

Statistical analysis

All data were entered into Microsoft Office Excel (version Office 365) in a spreadsheet and checked for errors and discrepancies. Statistical analysis was done using windows-based

'MedCalc Statistical Software' version 19.0.1 (MedCalc Software Bvba, Ostend, Belgium; http://www.medcalc.rorg; 2019).

Discrete data for gender, side of the mandible, and canal type was expressed as numbers with percentages, whereas measurement data for canal length and diameter was obtained by standard deviation.

Categorical data were analyzed for differences between groups based on gender, side, and canal type using the Chi-square test. The canal length and canal diameter were analyzed for differences between the different canal types (Types I through V) using one-way ANOVA. Post-hoc Scheffe's test was planned for pairwise comparisons.

All the tests were done using two-sided tests with alpha 0.05.

Results

Among 100 patients, 52% were males and 48% were females aged between 15 and 72 years with a mean age of 40.10 (±13.16) years. Mandibular canal variations were identified in 13% of the total cases and in 8% of the total sides of the mandible (200 sides) [Table 1]. These were accessory canals, identified more in females (16.7%) when compared to males (9.6%) [Table 2]. Out of 13 accessory mandibular canals, six (46.15%) canals were present unilaterally on the right side, four (30.76%) canals unilaterally on the left side, and three (23.07%) canals were present bilaterally. Thus, suggesting that accessory canals were present more unilaterally (76.92%) than bilaterally (23.07%). Pearson's Chi-square test revealed no significant difference between the presence of accessory canals on the right or left sides of the mandible when compared between genders [Table 3].

Out of the 16 accessory canals, Type II [Figure 1] was the most commonly observed canal followed by Type I [Figure 2], Type III (with confluence [Figure 3], without confluence [Figure 4], from the inferior wall of the main canal [Figure 5] and Type V [Figure 6]. Type IV canals were not identified in our study. The third variant of the forward canal, arising from the inferior wall of the main canal, has not been mentioned in the Naitoh *et al.* classification[14] and has been included in the above-mentioned classification as a forward canal subtype. There was no significant difference between the types of accessory canals when compared between genders suggesting that different types of bifid mandibular canals were distributed uniformly and no gender showed a predominance of a particular type of accessory canal [Table 4].

Observing the relationship of the accessory mandibular canal to the main canal, we found out that most of the accessory mandibular canals (14) (87.50%) originated from the superior wall of the main canal whereas only two canals (12.50%) arose from the inferior wall of the main canal.

On morphometric analysis, the mean length and diameter of the accessory mandibular canal were 12 and 1.24 mm, respectively. Type I canal had the maximum mean length (13.43 mm) and mean diameter (1.35 mm) [Table 5]. Most of the accessory

Table 1: Prevalence of mandibular canal variations

	Patients		Sides	
	No.	**%**	**No.**	**%**
Presence	13	13	16	8
Absence	87	87	184	92
Total	100		200	100

Table 2: Prevalence of accessory mandibular canal based on gender

Gender	Present		Absent		Total		χ^2	*P*
	No.	**%**	**No.**	**%**	**No.**	**%**		
Male	5	9.6	47	90.4	52	100	1.086	0.297
Female	8	16.7	40	83.3	48	100		

Table 3: Prevalence of accessory mandibular canal based on sides of the mandible involved

	Male (n=7)		Female (n=9)		Total (n=16)		χ^2	*P*
	No.	**%**	***No.***	**%**	***No.***	**%**		
Left side	3	42.9%	4	44.4%	7	43.8%	0.0037	0.951
Right side	4	57.1%	5	55.6%	9	56.3%		

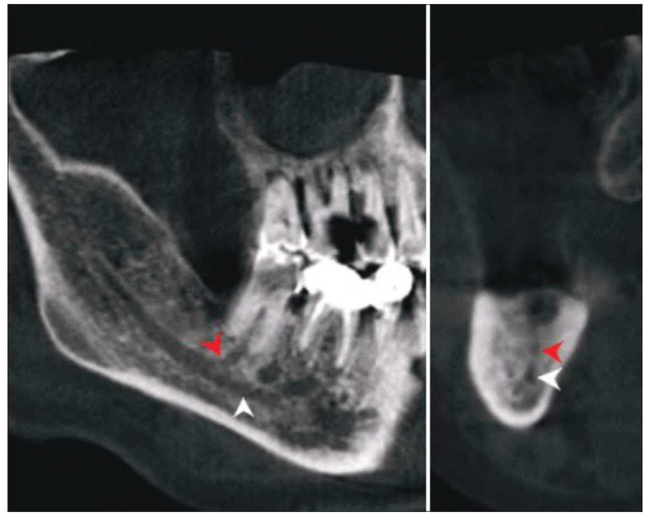

Figure 1: Type II canal (red arrow) shown on a cropped panoramic view (left) and confirmed on cross-sectional view (right); white arrow—main canal

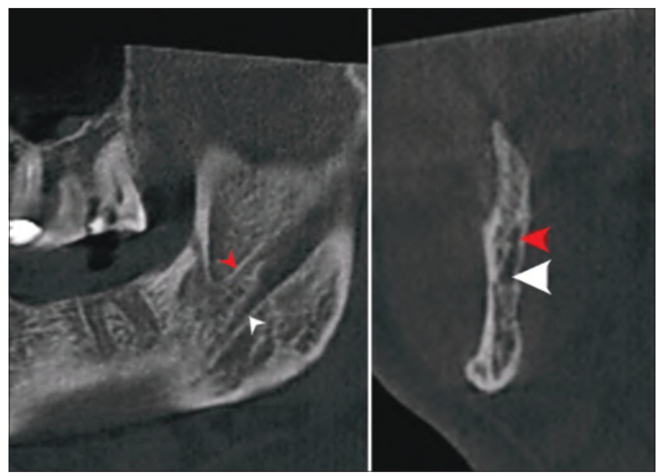

Figure 2: Type I canal (red arrow) shown on a cropped panoramic view (left) and confirmed on cross-sectional view (right); white arrow—main canal

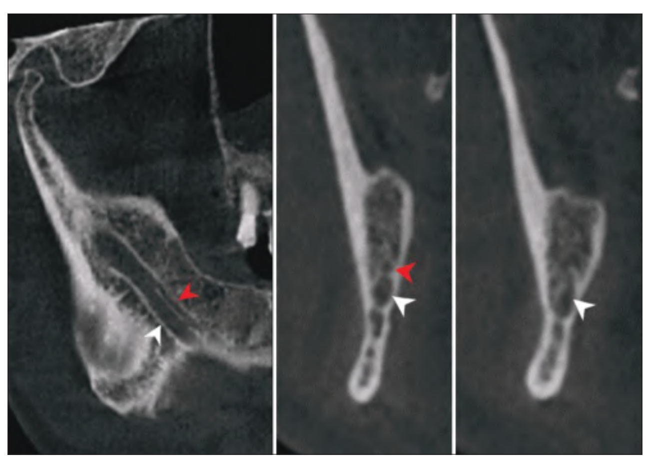

Figure 3: Type III A canal (red arrow) shown on a cropped panoramic view (left) and confirmed on cross-sectional views (middle, right). The last cross-sectional image (right) shows the merging with the main canal (white arrow) to form a single canal

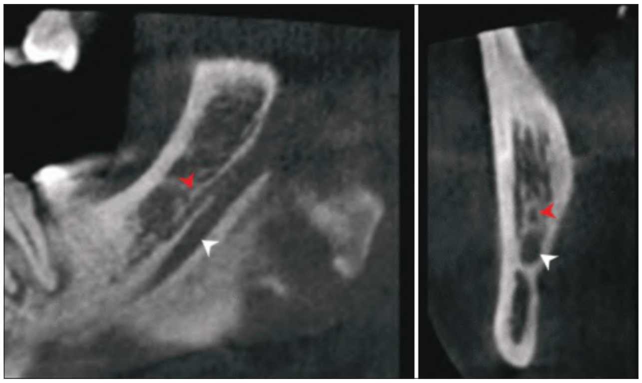

Figure 4: Type III B canal (red arrow) shown on cropped panoramic view (left) and confirmed on cross-sectional view (right); white arrow—main canal

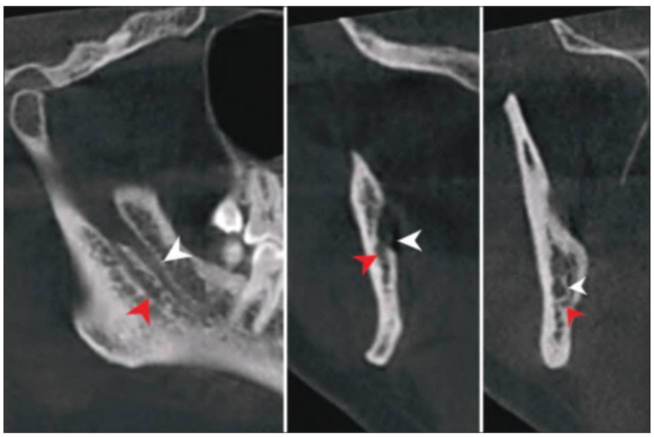

Figure 5: Type III C canal (red arrow) shown bifurcating from the inferior wall of the main canal (white arrow) and coursing forward in the mandibular body on the cropped panoramic (left) and cross-sectional images (middle, right)

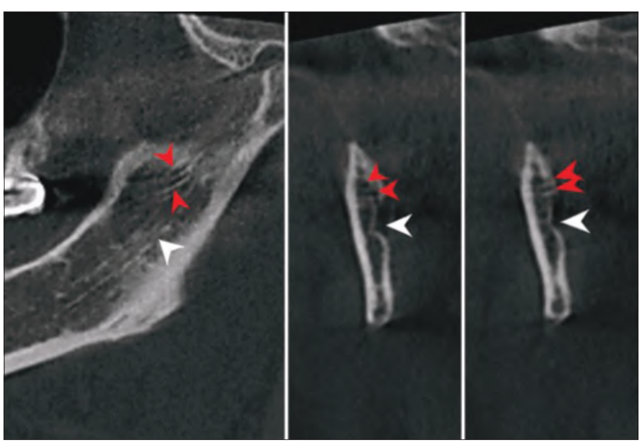

Figure 6: Type VE canal from two mandibular foramina shown on cropped panoramic view (left) and confirmed on cross-sectional images (middle, right); white arrow—main canal

canals (60%) showed a diameter of more than or equal to 50% of the main canal (Class A) whereas only 40% of the accessory canals had less than 50% diameter (Class B).

Discussion

The mandibular canal is one of the most crucial structures present within the mandible. It is mostly present as a single entity though anatomical variations in the form of accessory canals may be present. According to Chavez *et al.*[2], during the embryonic development of the mandibular canal, it is present as three different inferior dental nerve canals innervating three different groups of mandibular teeth. During rapid prenatal growth and remodeling, failure to fuse or partial fusion may give rise to bifurcation or trifurcations of the mandibular canal. Bifurcated canals are considered the most common anatomical variations of the mandibular canal but unfortunately are often neglected and missed out in clinical practice.[13]

The analysis of mandibular canal variations improved with the usage of CBCT imaging. Naitoh *et al.*[14] first observed a bifid mandibular canal using CBCT in 2009. Neves *et al.*[17] compared panoramic radiograph with CBCT for the assessment of mandibular canal variations and suggested a higher prevalence rate of 2.4% using CBCT. A meta-analysis by Hass *et al.*[18] suggested that CBCT showed a higher prevalence of mandibular canal variations (16.25%) when compared to panoramic radiography (6.46%).

Most of the research studies done to assess mandibular canal variations using CBCT were in the non-Indian population[10-16,19,20] which showed varied results ranging from 10.3 to 65%. This difference could be due to the difference in sample size, methodology, and ethnicity. Two research studies[8,9] conducted in the Indian population have, however, reported a lower prevalence rate of 5.63 and 10.6%, respectively. We also found a lower prevalence rate of mandibular canal variations of 13%.

In the present study, females showed a higher incidence of accessory canals when compared to males which was not statistically significant. This is corroborated with the study done by Okumus *et al.*[13] However, some authors[9,14] have suggested a higher prevalence of men having bifid mandibular canal. There was a slightly higher incidence of accessory canals on the right side which was similar to the other studies conducted.[12,15]

Various classifications have been suggested in the literature to determine the type of mandibular canals variations using dry mandibles, panoramic radiographs, and CBCT.[1] Naitoh *et al.*[14] first reviewed the bifid mandibular canal using CBCT imaging and proposed criteria for different types of bifid mandibular canal which was also used in the present study along with the Rashsuren *et al.*[11] modification. The most frequently observed type of accessory mandibular canal was found to be Type II dental canal (37.5%). However, there was a dilemma regarding Type II canals where a few mimic a normal branch of IAN, bifurcating from the body of the mandible close to the molar roots and terminating at the root apex; the authors considered those cases as Type II dental canal cases.

Table 4: Prevalence of accessory mandibular canal based on types

	Male (*n*=7)		Female (*n*=9)		Total (*n*=16)		χ^2	*P*
	No.	%	No.	%	No.	%		
Canal type								
Type I	2	28.6	3	33.3	5	31.30	1.814	0.612
Type II	2	28.6	4	44.4	6	37.5		
Third molar	0	0.0	2	22.2	2	12.5		
Second Molar	2	28.6	2	22.2	4	25.0		
Type III	3	42.9	1	11.1	4	25.0		
With confluence	1	14.28	0	0.0	1	6.25		
Without confluence	1	14.28	0	0.0	1	6.25		
Arising from inferior wall of main canal	1	14.28	1	11.1	2	12.50		
Type IV	0	0.0	0	0.0	0	0.0		
Type V	0	0.0	1	11.1	1	6.25		

Table 5: Mean length and mean diameter of accessory branches according to type

Canal type	*n*	Length (mm)		Diameter (mm)	
		Mean	SD	Mean	SD
Type I	5	13.43	5.59	1.35	0.43
Type II	6	9.92	7.41	1.25	0.34
Type III	4	13.19	2.60	1.17	0.31
Type IV	0	-	-	-	-
Type V	1	12.33	3.53	1.09	0.25
Total	16	12.00	5.44	1.24	0.33
One-way ANOVA	*F*	0.421		0.340	
	P	0.741*		0.797*	

*Not significant at alpha 0.05

Nithya *et al.*[9] also found the dental canal (38.1%) to be the most frequent type but Rashsuren *et al.*[11] found the retromolar canal to be the most frequent type which was the second most prevalent type in our study. However, Okumus *et al.*[13] and Naitoh *et al.*[14] found the forward canal to be the most frequent type. We did not find any buccolingual canal (0.0%) which was also the least frequently occurring type in some of the studies.[9,11,14] This suggested that the reported prevalence rates of each type of supplemental mandibular canal were not consistent between various authors which could be due to the variation in the study sample size, methodological difference, and different genetic pool of patients participating in the study.

All Type III canals that Naitoh *et al.*[14] mentioned arose from the superior wall of the mandibular canal. However, we found two forward canals arising from the inferior wall of the mandibular canal (12.5%). This type of variation has been reported by Rothe *et al.* (2018)[7] and Kuczynski *et al.* (2014)[6] on panoramic imaging but not by any other author conducting studies on CBCT. Hence, we recommend this variation be included as a modification to the Naitoh *et al.* classification. A single Type V canal was found in the present study which has also been mentioned by other authors using CBCT[11,13,21]. According to the Rashsuren classification,[11] we found Type VE subtype of trifid canal.

Many researchers have also conducted a morphometric analysis of the bifid mandibular canal.[9-11,21,22] According to Naitoh *et al.*,[14] the maximum longitudinal measurements were found in Type I canal (14.88 mm) whereas J Muinelo-Lorenzo[22] found Type IV canal with the maximum length (10.1 mm) and Rashsuren *et al.*[11] found Type V canal (20.1 mm). However, we found Type I canal (13.4 mm) to have the maximum length. Rashsuren *et al.*[11] reported the mean diameter of the accessory mandibular canal to be 2.2 mm. Kuribayashi *et al.*[10] reported the mean diameter of the bifid mandibular canal to be 1.68 mm with 49% being Class A canal. In the present study, Type I canal had the maximum mean diameter of 1.35 mm and 60% of accessory canals were Class A canal.

Although the rate of occurrence of these mandibular canal variations was low, they are not a rare entity. Hence, awareness regarding the variations is important to avoid any injury to these canals during surgical procedures of the mandible such as during extraction of the impacted third molar, dental implant placement, orthognathic surgeries, enucleation of pathologies, and fixation of mandibular fractures. The most common complications associated with such injuries are excessive bleeding, traumatic neuroma, paresthesia, or prolonged anesthesia.[9] Inadequate anesthesia during inferior alveolar nerve block is another major problem encountered in patients with a bifid mandibular nerve canal which may be overcome using the Gow-Gates technique or Akinosi technique.[13] Further, in cases of mandibular fracture, alignment of the fracture fragments may become difficult due to the presence of a possible supplemental mandibular canal which may be damaged because of the impinging of the fracture fragments.[9] Among the different types of accessories of the mandibular canal, the retromolar canal and dental canal are clinically most crucial. During extraction of the third molar, the retromolar canal is at high risk of injury due to its proximity to the tooth. Sometimes, the retromolar region may be considered as a donor site for harvesting bone block which again increases the risk of injury to the retromolar canal. Dental canals, on the other hand, are at high risk during extraction of molars, endodontic treatment, and implant placement.[13] Shen *et al.*[3] reported that 32.4% of the bifid mandibular canals were located in the possible position for dental implant placement.

Limitations and future prospects

As very few studies with CBCT conducted on Indian population, further studies with larger sample size must be considered.

Conclusion

The bifid mandibular canal was the most common anatomical variation of the mandibular canal found in this study with dental canal type being the most frequent type. To avoid iatrogenic injuries, a presurgical detailed evaluation of the mandibular canal using CBCT is suggested.

As there is a paucity in the studies conducted in the Indian population, we reiterate future research to be addressed on a larger sample size. Furthermore, it is worth mentioning that the present study showed a forward canal variant, from the inferior wall of the main canal, and should be considered as a modification to the existing classification.

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Conflicts of interest

There are no conflicts of interest.

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