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ORIGINAL ARTICLE

Study of Normal Anatomy of Mandibular Canal and its Variations in Indian Population Using CBCT

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Abstract
Introduction Identification of detailed anatomy of mandibular canal (MC) with its contents including the position, course, and morphology is extremely important for the management of various surgical procedures including dental implant placement, third molar surgery, dental anesthesia, mandibular osteotomy, bone-harvesting procedure from the ramus and body of mandible, bone plating in angle and body region of mandible, or any other surgical procedure involving the mandible.
Methods This prospective randomized study was carried out in the Department of Oral and Maxillofacial Surgery, Saraswati Dental College, Lucknow, on 100 randomly selected cone-beam computed tomography (CBCT) mandibular views displaying the entire mandible.
Results Various parameters of the canal were studied in detail and subjected to statistical analysis using SPSS 20 software. For all the observations, paired t test was applied to compare right and left sides and independent t test for the comparison of gender.
Conclusion For centuries MC has been a paramount topic of discussion, and with the contraption of CBCT, we can finally decipher the canal in great detail. CBCT acts as a guide to prevent damage to the neurovascular bundle as the canal traverses its course and sometimes with certain variations.

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Introduction

The mandibular canal (MC) is an imperative anatomical structure which has been studied in detail since ages with respect to its location and path as well as the possible variations in normal anatomy since it can have diverse configurations. The anatomy of MC comprises an extension from the mandibular foramen to the mental foramen bilaterally, carrying the inferior alveolar nerve, artery, and vein. Certain variations in the anatomy of mandibular canal and its course are not uncommon [1]. Acquaintance with the morphology and topography of the inferior alveolar neurovascular bundle is essential for various surgical procedures including dental implant placement, third molar surgery, dental anesthesia, mandibular osteotomy, bone-harvesting procedure from the ramus and body of mandible, bone plating in angle and body region of mandible, or any other surgical procedure involving the mandible [2, 3].

The presence of bifid/trifid canals, anterior loop of mental nerve, and its anterior extensions lack explicit definitions. So, a radiographic examination with superior image quality becomes essential. In oral and maxillofacial surgery, routinely IOPAs, OPG, MRI, and CT form the mainstream of diagnostic tools. CBCT machine which produces superior image quality with 1:1 measurement and 3D display has added further dimension to the diagnosis and treatment planning. If proper preoperative evaluation is not carried out, there can be failure in anesthetic techniques, and patients can also suffer from hemorrhagic complications and paresthesia [4]. Lack of clear definitions in the literature, wider availability of three-dimensional imaging, and increased demand of implant surgeries indicate that features of mandibular canal should be revisited. This holistic study focuses on diverse parameters in respect to the mandibular canal in different regions done exclusively in Indian population using CBCT. Review of the literature suggests that such studies have been not carried out earlier with this wide spectrum especially in Indian inhabitants.

Materials and Method

This prospective randomized study was carried out in the Department of Oral and Maxillofacial Surgery, Saraswati Dental College, Lucknow, on 100 randomly selected CBCT mandibular views displaying the entire mandible. i-CAT CBCT machine using i-CAT CB 500 (GENDEX) cone-beam 3D imaging system with high resolution (0.125/0.2 mm voxel), standard pulsed exposure with acquisition time of 23 s (exposure time 8–10 s) and 12.6 s (exposure time 8–9 s), tube voltage (270 kV and 10–15 mA), field of view (14 × 6 cm and 8.5 × 6 cm) and (0.125 × 0.125 × 0.125 mm^3) spherical imaging volume was used in the study, and parameters were recorded in millimeters.

Following parameters were assessed on CBCT:

(a) Diameter of the MC
(b) Length of the MC
(c) Location of the MC
Horizontal plane—(distance of the outer margin of the canal)
  (i) from buccal cortical plate
  (ii) from lingual cortical plate
  Vertical plane—(distance of the outer margin of the canal)
  (i) from crestal bone level
  (ii) from base of mandible
(d) Relationship of mandibular roots to the MC
  (i) distance
  (ii) position
(e) Length of the anterior loop of the mental nerve
(f) Bifid/trifid canals

Diameter of the MC

The inner maximum vertical and horizontal diameters were measured in coronal plane (cross section in each tooth region). In multi-rooted tooth, the diameter was measured in relation to each root, and the final value was the mean of the measurements taken (Fig. 1).

Length of the MC

The length of the MC was assessed in the panoramic view after locating a midpoint in the mandibular and mental foramen region and measured along the line traversing between the two points in the midline between upper and lower cortication of the canal (Fig. 2).

Location of the MC

The distance from the outermost margin of the MC to the buccal cortical plate, lingual cortical plate, crestal bone level, and inferior border of mandible was measured (Fig. 3).

Relationship of the Roots to the MC

The distance of the roots from the upper margin of the MC was measured in the cross section. In multi-rooted tooth, the distance was measured in relation to each root, and the final value was the mean of the measurements taken (Fig. 4).

Anterior Loop of the Mental Nerve

For the cross sections, the anterior loop was determined by counting the number of sequential 1-mm slices displaying two round hypodense images (corresponding to the upper and lower segments of the MC, typically ending in an "8-like" shape anteriorly), from the anterior-most image of the mental foramen and starting point of the incisive canal (Fig. 5).

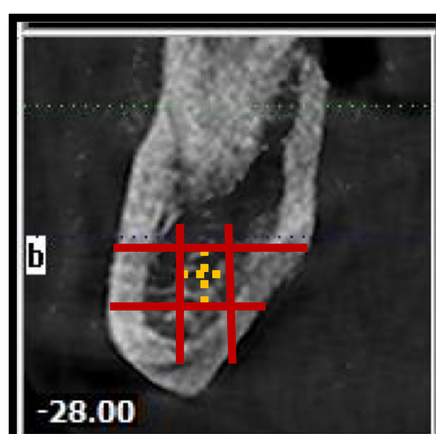
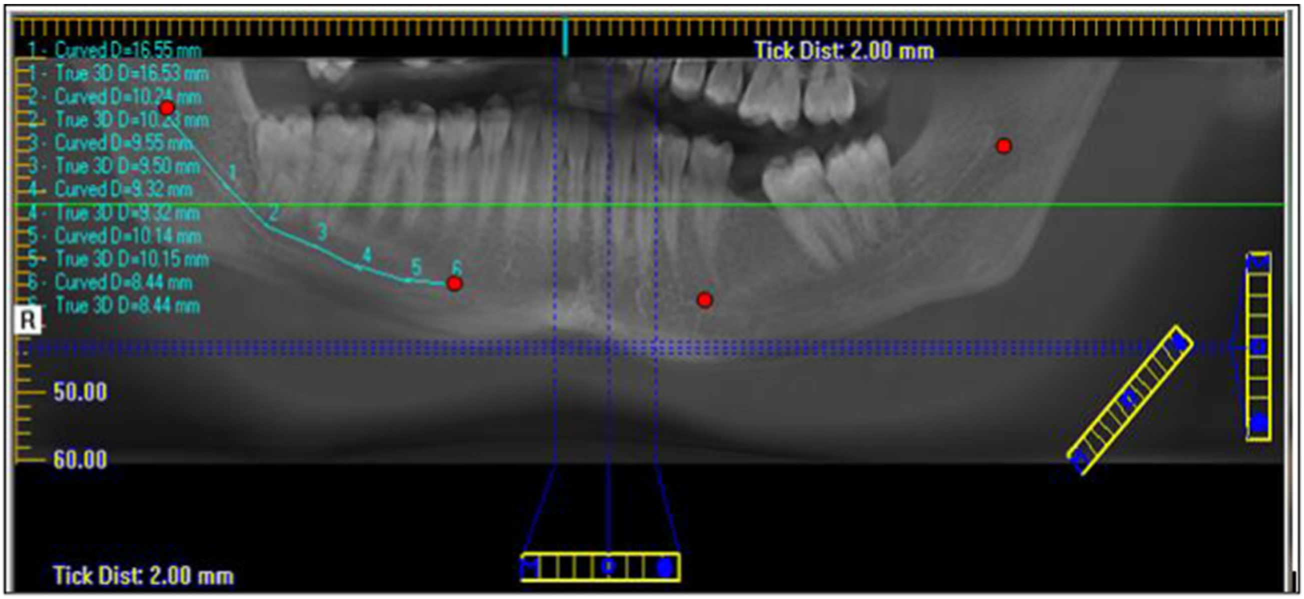


Fig. 1 Measurement of maximum vertical and horizontal diameters



Midpoint of mandibular foramen and mental foramen is marked in red. Curved distance between the two points is measured where the line traverses between the upper and lower cortication of the canal.

Length of mandibular canal in this image: 64.24mm

Fig. 2 Measurement of length of mandibular canal

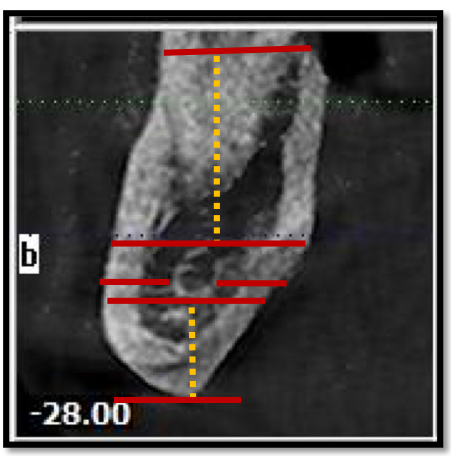


Fig. 3 Measurement of the distance of mandibular canal from the crestal bone level, inferior border of mandible, buccal, and lingual cortical plate

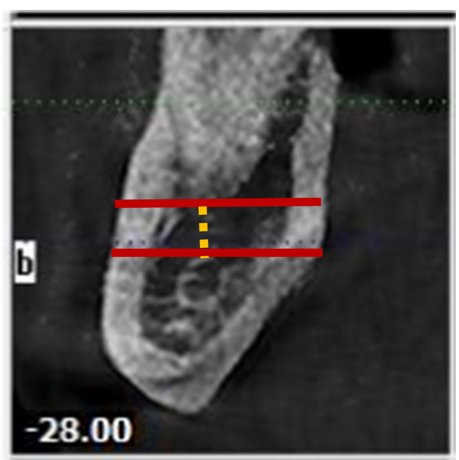


Fig. 4 Measurement of the distance between the root tip and upper border of the mandibular canal

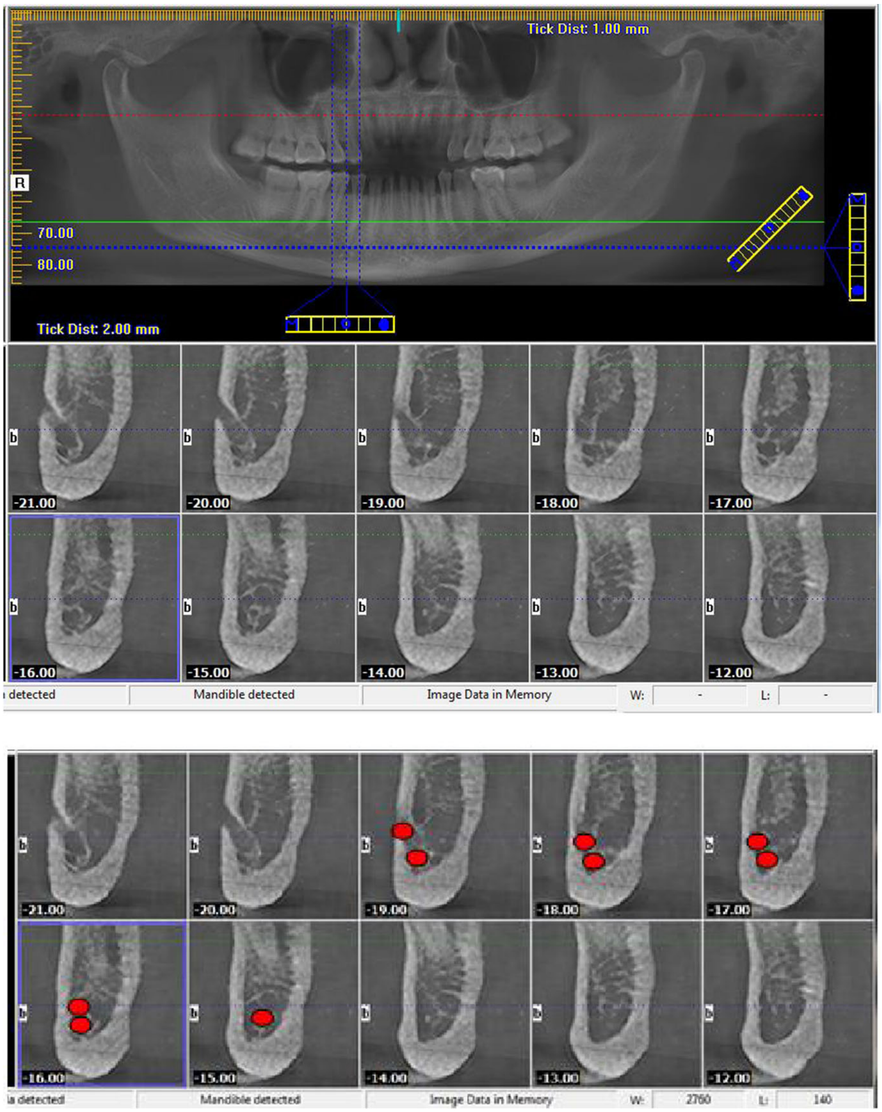
Bifid/trifid Canal

Axial, coronal, sagittal, cross sections, and volume rendering were viewed to assess bifid MC (Fig. 6).

The results were subjected to statistical analysis using SPSS 20 software. For all the observations, paired t test was applied to compare right and left sides, and independent t test was used for the comparison of the gender.

Results

A total of 100 patients comprising 47 female patients with the mean age of 41.85 ± 14.363 and 53 male patients with the mean age of 40.96 ± 14.771 were included in the study. Comparing the mean age between two genders (independent *t* test), no statistical significance was found with a p value of 0.762, the level of significance being p value < 0.05.



Section 19 shows anterior most image of the mental foramen and section 15 shows starting point of the incisive canal. In cross section, number of 1mm sections showing two hypodense image of the anterior loop is counted till it ends in incisive canal.

Length of anterior loop in this image: 5mm.

Fig. 5 Measurement of the anterior loop

The inner vertical diameter of the MC on right and left side was found to be maximum in third molar region which gradually decreased till first premolar region. The inner vertical diameter in each tooth region was found to be more than the inner horizontal diameter, suggestive of oval to round shape of the MC (Table 1).

The length of the MC on right side was in the range of (50.63–78.55 mm) with mean value being 65.175 ± 5.578 mm, while on left side it was in the range of (49.84–78.73 mm) with mean value being 66.039 ± 5.753 mm (Table 2).

The location of the MC was found to be close to lingual cortical plate in third molar, second molar, and first molar region, while it was close to the buccal cortical plate in second premolar and first premolar region, suggesting S-shaped topography of the canal in horizontal plane. Also, the distance of the MC from the crestal bone level and inferior border of mandible in various regions was suggestive of catenary course of the canal meaning "curled as hanging between two points" as mentioned by Ozturk et al. [5] (Table 3).

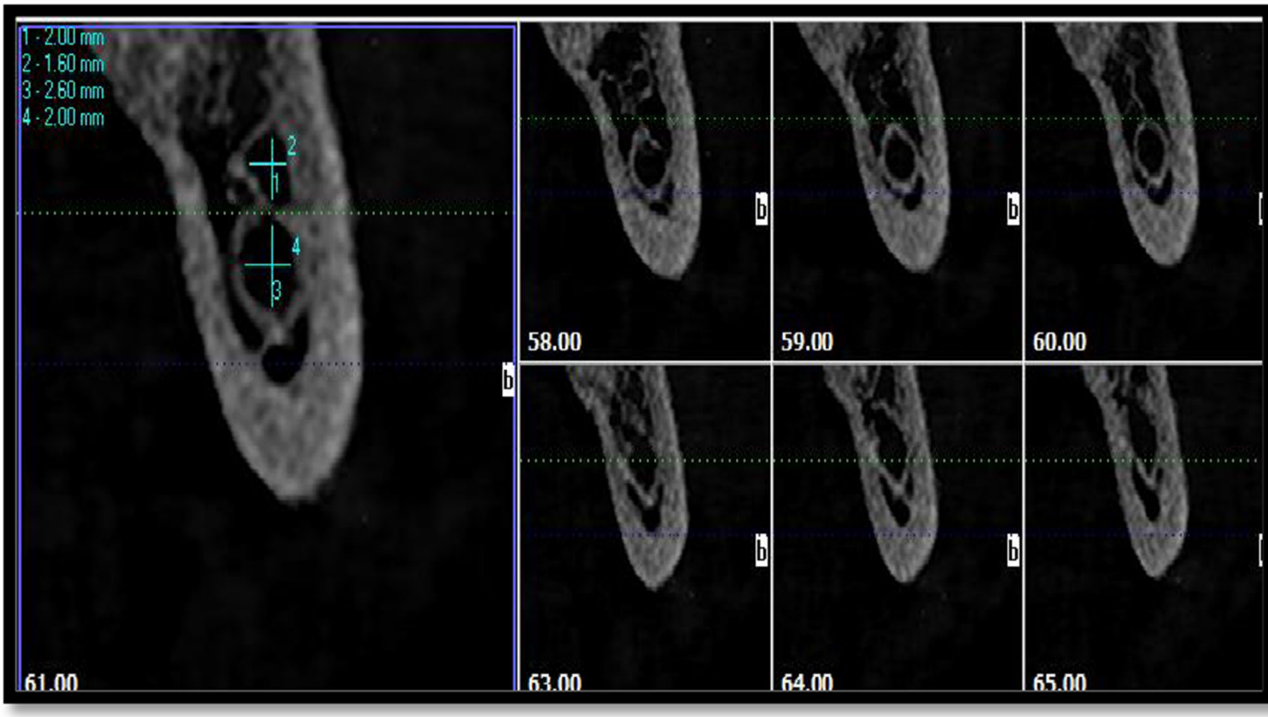


Fig. 6 Assessment of bifid canal

Table 1 Inner diameter of the mandibular canal in different regions (in mm)

	Third molar	Second molar	First molar	Second premolar	First premolar
Right vertical (RV)	2.5927	2.4877	2.4362	2.2189	1.931
Right horizontal (RH)	2.259	2.2435	2.3204	2.0875	1.7462
Left vertical (LV)	2.7167	2.5269	2.3718	2.1369	1.746
Left horizontal (LH)	2.304	2.2622	2.2972	2.065	1.675

Table 2 Length of the mandibular canal (in mm)

	Mean	SD	Maximum	Minimum
Length right (R)	65.7155	5.5783	78.5500	50.6300
Length left (L)	66.0395	5.7536	78.7300	49.8400

The roots of the mandibular third molar on right and left side was found in closest relationship to the MC, while the distance gradually increased till first molar region where it was found to be maximum on both sides (Table 4).

Anterior loop was found in 20% of the cases on both sides. A total of 18 cases (18%) of bilateral anterior loop and four cases (4%) (2 each on right and left side) of unilateral anterior loop were found (Tables 5, 6).

Out of 100 CBCT, one case (1%) of bilateral bifid canal was found which was type 2 bifid (bifid within body of mandible) according to Langlais' classification of bifid MC [21]. The canal divided supero-inferiorly in the first molar region bilaterally and rejoined in the first premolar region, terminating at single mental foramen.

Discussion

Diameter of the MC

In our study, the mean vertical and horizontal diameter of the MC was found to be 2.326 mm and 2.131 mm, respectively, on right side and 2.289 mm and 2.120 mm, respectively, on left side. The difference in the dimensions between two sides was not statistically significant. Our findings co-relate with that of other authors as well [6–9].

Length of the MC

On comparison of the mean values of length on both sides, the mean value on left side was higher with a difference of

Table 3 Location of the mandibular canal (in mm)

	Third molar	Second molar	First molar	Second premolar	First premolar
Right horizontal distance from buccal cortical plate (RHB)	4.2514	5.0238	4.5526	2.0954	1.8846
Right horizontal distance from lingual cortical plate (RHL)	1.8277	1.8314	2.1834	4.6632	4.7769
Right vertical distance from crestal bone level (RVC)	13.9243	14.3786	14.5946	14.3166	14.3092
Right vertical distance from inferior border of mandible (RVIB)	6.793	6.3579	6.0643	7.0266	8.0077
Left horizontal distance from buccal cortical plate (LHB)	4.4112	5.3317	4.6192	2.1262	2.523
Left horizontal distance from lingual cortical plate (LHL)	1.8118	1.798	2.1064	4.7722	4.7063
Left vertical distance from crestal bone level (LVC)	13.9955	14.1443	14.6273	14.1852	15.0812
Left vertical distance from inferior border of mandible (LVIB)	7.0688	6.1974	6.1331	7.7139	8.3625

Table 4 Relationship of roots to the mandibular canal (in mm)

	Third molar	Second molar	First molar	Second premolar	First premolar
Relationship of roots to canal R	1.7449	3.4568	4.2354	2.7691	2.422
Relationship of roots to canal L	1.5173	3.0274	3.7115	2.762	2.8693

Table 5 Anterior loop of mandibular canal—right side (in mm)

Length of the anterior loop	Number of cases	Valid percent
2	4	20
3	6	30
4	5	25
5	3	15
6	1	5
9	1	5
Total	20	100

Table 6 Anterior loop of mandibular canal—left side (in mm)

Length of the anterior loop	Number of cases	Valid percent
2	6	30
3	4	20
4	8	40
5	2	10
Total	20	100

0.324 mm which was statistically not significant with a *p* value of 0.223.

Location of the MC

The anatomic features of the ascent of the canal as well as its buccolingual relationships have been studied extensively [10, 11]. It has been reported by various authors that MC might have different anatomic configurations in the horizontal plane also. Buccolingual orientation is an important parameter which should be analyzed prior to surgical procedures. In our study, the location of the MC was found to be close to lingual cortical plate in third molar, second molar, first molar region, while it was close to the buccal cortical plate in second premolar and first premolar region. Usually, the MC crosses from the lingual to the buccal side of the mandible, and in most cases, midway between the buccal and lingual cortical plates of bone is in the region of first molar [12–14]. Also, the canal was found to be at a mean distance of 4.331 mm from the lateral aspect of the buccal cortical plate and 1.819 mm from medial aspect of the lingual cortical plate in the third molar region. Our findings co-relate with other authors as well [7, 15, 16]. The clinical implication of the location of the MC is that the orientation of the neurovascular bundle should be ascertained pre-operatively in order to avoid inadvertent injury to the neurovascular bundle in case of anatomical variation buccolingually.

Relationship of the Roots to the MC

In our study, the MC was found to be in closest relationship with the roots of third molar followed by second premolar, second molar, and first molar with a mean distance of 1.630 mm, 2.765 mm, 3.241 mm, and 3.973 mm, respectively. Similar findings were observed by other authors [17].

Anterior Loop

In our study, the anterior loop was found in 20% (20 of 100) cases with length ranging between 2 and 9 mm and mean value of 3.55 mm. Similar findings have been reported by other authors [18–20].

A safe guideline of 4 mm, from the most anterior point of the MF, is recommended for implant treatment planning based upon the anatomical findings. There is a wide variation in the incidence and length of the anterior loop, and these studies indicate that sufficient data are not available to draw a definitive conclusion. Studies on larger sample size in diverse population need to be done to characterize this parameter.

Bifid Canal

There can be variation in the number of canals as well. In our study, the canal divided in the first molar region bilaterally and rejoined in the first premolar region, terminating at the mental foramen. The incidence (1%) correlates with findings of other authors as well [21–23]. The clinical significance of this lies in the fact that diagnostic errors in interpreting a bifid MC on OPG may be attributed to superimposition of structures, inadequate positioning of the patient, and bone condensation produced by the mylohyoid muscle in the floor of the mouth. It is interesting to emphasize that MC bifurcates in the infero-superior or medio-lateral plane in about 1% of patients.

The mechanism of development of bifid/trifid MC has been hypothesized by the explanation that during embryonic development a rapid prenatal growth and remodeling in the ramus region lead to intramembranous ossification that forms MC. The occurrence of bifid/trifid MC is thought to be secondary to the incomplete fusion of these three nerves. Once the multiple canals are identified, the local anesthetic injection technique and surgical procedures can be modified to prevent pain, discomfort, or even numbness during treatment.

Our study collectively incorporates various parameters pertaining to the morphology and dimensions of the mandibular canal using CBCT as compared to previous studies on diverse population which focuses on single or few related parameters using conventional techniques. Earlier studies on the course of the canal were mainly restricted to the third molar region, whereas we have traced the canal throughout its course. Also, the length of the canal has been measured which was not taken into consideration in previous studies. Significant limitations have been found in earlier studies describing the intra-bony anatomy of MC. For example, dry skull reports may have variable diseases and lack relevant data such as age, gender, or include edentulous mandibles, or use inconsistent and anatomically irrelevant landmarks. Differences in the value may be related to morphological, geographical, ethnical differences, and variable methodology and landmarks used in different studies. Studies on larger sample size in diverse population needs to be done to draw a definite conclusion.

Conclusions

From our study, following conclusions can be drawn:

1. Inferior alveolar neurovascular bundle exists in different locations and presents many variations. Individual deviation, gender, age, race, and assessing technique used largely influence these variations.
2. The inner vertical diameter in each tooth region on the right and left side was found to be more than the inner horizontal diameter, suggestive of oval to round shape of the MC.
3. The length of the MC should be ascertained prior to the neurectomy procedure in cases of trigeminal neuralgia.
4. In order to plan a proper dental implant insertion method and select the implants of a relevant type, it is important to be aware of the position of the MC in connection with the cortical plates and crest of alveolar ridge. Osteotomies in BSSO procedure should not be performed in the posterior mandible until the position of the MC is established. Also, the parameters obtained acts as guide in bone-harvesting procedures from the ramus and body of mandible and bone plating in angle and body region of mandible.
5. The distance of the MC from the crestal bone level and inferior border of mandible in various regions was suggestive of catenary course of the canal. These criteria should be considered in surgeries involving posterior mandible especially in third molar region.
6. CBCT provides a clear dimension of the anterior loop. Based upon the anatomical findings, a safe guideline of 4 mm from the most anterior point of the MF is recommended for implant treatment planning.
7. The bifid MC is of rare occurrence. The detection of these anatomical variations is important because of its clinical implications such as the ineffective mandibular

block or numbness, injury to the nerve causing paresthesia, or injury to vessels resulting in inadvertent bleeding in surgeries involving the lower jaw.

It is clear that with the advances in technology and the improvement in images as diagnostic tools, the number of anatomical variations of the MC is likely to increase considerably. So, to comment on anatomic variations, there is a requirement for a large multicentric study with defined anatomical landmarks to quantify and precisely predict these parameters and confirm the trends observed.

Compliance with Ethical Standards

Conflict of interest Authors declare that they have no conflict of interest.

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