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RESEARCH ARTICLE

Medical Physics

Determination of safe zone of the mandible for implant and bone harvesting (using CBCT) of mandible in a group of Sri Lankan subjects

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Abstract: Bone grafting procedures are required for patients with insufficient bone volumes for dental implants. The incisive mandibular nerve is more prone to iatrogenic injury during bone graft harvesting. This study aimed at examining the relative position of the mandibular canal (MC), gender Variation and to observe a safe zone for the implant and bone harvesting. Cone beam computed tomography (CBCT) scans of 200 patients (males 56 %) with age ranging from 16 to 70 years (mean age, 34.1 ± 14.5 years) were selected from the database of the Dental Imaging Unit of the National Dental Teaching Hospital of Sri Lanka. The MC length, mental foramen (MF) diameter, and location and the safe zone distance for bone graft harvesting were recorded for each hemi-mandible. The mean length of left and right MC of males were 6.99 ± 0.21 cm and 6.98 ± 0.22 cm, respectively while for females the mean length was equal for both sides (6.88 cm). The mean MF horizontal length of males was 0.32 ± 0.03 cm on the left and right sides while for females it was 0.31 ± 0.03 cm on either side. The vertical length of MF was 0.25 cm for both left and right (for both genders). The mean safe zone distance of the left and right mandibles for males were 0.27 ± 0.07 cm and 0.30 ± 0.06 cm, respectively while for females the values were 0.26 ± 0.06 cm and 0.27 ± 0.06 cm, respectively. The most frequent position of the MF among males was below the second premolar on each side of the mandible. The MF of females were frequently located below and between the first and second premolar on each side of the mandible. MC and other measurements showed a high sexual dimorphism. Therefore, gender variation in MC length, diameter and location of MF should be considered during surgical interventions such as implant and bone harvesting.

Keywords: CBCT, cone beam computed, tomography, mandibular canal, mental foramen.

INTRODUCTION

The mandible or inferior maxillary bone is the largest, strongest, and lowest bone in the human face (Breeland *et al*., 2020). It acts as the lower jaw and consists of the body and ramus. Ramus divides into a coronoid process and head, which articulates with the mandibular fossa (Lev & Artzi, 2020). The inferior alveolar nerve (IAN), which is a branch of the mandibular nerve transmits through the mandibular canal (MC) towards the mental foramen (MF) (Drake *et al*., 2014; Jena *et al*., 2021). The IAN gives off the mental nerve at the MF, which supplies to the skin of the lower lip and the mucus membranes. Due to the high density of neurovascular structures, dental implantation in the mandibular region is risky with several complications (Kämmerer & Al-Nawas, 2020). The most common and severe complication is the neurosensory disturbance of the IAN (incidence of approximately 7 % of surgeries) (Goodacre *et al*., 2003). The surgical procedures performed close to the mental foramen of the mandible present a minor risk of injury to the neurovascular structures. Therefore, the mental foramen is identified as a safe zone for surgical procedures such as bone graft removal, mentoplasty surgery, and fixation of fractures by placing plates (Mraiwa *et al*., 2003). Knowledge of anatomical structures located in this region is important in pre-operative planning for dental surgeries (Imada *et al*., 2014). The position and the dimension of the MC are critical as the IAN, which

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travels through it, is susceptible to injury during surgical interventions of the mandible. Also, the relative position of the MC, mental and mandibular foramina in adults are age-dependent and show sexual dimorphism (Angel *et al*., 2011). Moreover, anatomical variations such as deviated MC trajectory, bifid MC and anterior loops of the mental nerve are common in the mandibular region (Guimaraes *et al*., 2014; Okumus & Dumlu, 2019).

Therefore, the variation in the anatomical position of the MC must always be taken into account to avoid iatrogenic inferior alveolar nerve damage. Dental radiological imaging plays an essential role in understanding the variations of these structures, such as intraoral periapical (IOPA) X-ray images, occlusal images, orthopantomogram (OPG) and cone-beam computed tomography (CBCT) (Shah, 2014). A cadaveric study had proven that the reproducibility and accuracy of the mandibular canal CBCT measurements were superior and even comparable to that of digital calliper measurements (Kamburoglu *et al*., 2009). In addition, high image quality and the comparatively lower radiation dose in CBCT has made it a convenient mode of assessing three-dimensional (3D) craniofacial structures in dental practice (Liang *et al*., 2009). According to the author's knowledge, an evaluation of the mandibular region's vital anatomical structures, including the safe zone for bone grafting, has not been conducted in Sri Lankan subjects. Therefore, the present study focuses on several parameters of the anatomical structures within the mandible (length of MC and diameter of MF), including the safe zone for surgical interventions exclusively for the Sri Lankan population using CBCT. While acknowledging that only a few CBCT units are available in Sri Lanka, the findings of this study would become a helpful guide in centres where CBCT is not available to take accurate measurements.

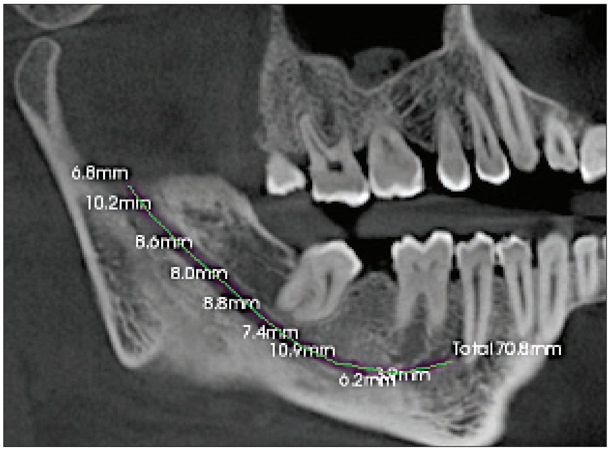
MATERIALS AND METHODS

This cross-sectional study was carried out in the Dental Imaging Department of the National Dental Teaching Hospital, Sri Lanka. Among 355 patients who were presented to the department between December 2018 to January 2020, a sample of 200 patients (16–70 years) was included for the final evaluation after excluding those having mandibular fractures, deformities, pathological conditions, and previous manipulation which could alter the position of the IAN MC canal. All the scans were acquired using field of view (FOV): 15×9 cm, tube potential: 90 kVp, tube current: 10 mA and exposure time: 11.3 s. Mandibular canal length, the diameter of the anterior loop of mental foramen and distance from the root endpoint to the opening of the inferior border of MC (safe distance) were measured for each patient. In addition, the frequent location of the mental foramen was recorded and graded according to the criteria given in Table 1.

Table 1: Assigned grade according to the location of the mental foramen

Location of the mental foramen	Grade
Below the canine	1
Below and between the canine and the first premolar	2
Below the first premolar	3
Below and between the first and second premolar	4
Below the second premolar	5
Below and between the second premolar and the first molar	6

The linear measurements were performed on the axial section of the mandible with 0.5 mm slice thickness. Point 1 was selected in the first trans-axial view immediately after the origin of MF, where the loop of mandibular canal is formed. This was selected as point 1 and interludes of 10 mm were selected for subsequent measurements along the MC (respectively, points 2, 3, 4). This point-by-point connections resulted in a 2D view of the mandible, where the mandibular canal was seen beginning to end (Figure 1). The measurements were obtained using the virtual ruler option available with Carestream (CS) imaging software version 7.0.2.8 (CS Health, Inc, 150, Verona Street, Rochester, NY 14608, USA). Each measurement was recorded in cm and repeated for both left and right sides of the mandible. Descriptive and non-parametric statistics were used to analyze the data which did not follow a normal distribution with 95 % confidence interval. Spearman's correlation was run to measure the correlation between recorded linear dimensions and age.



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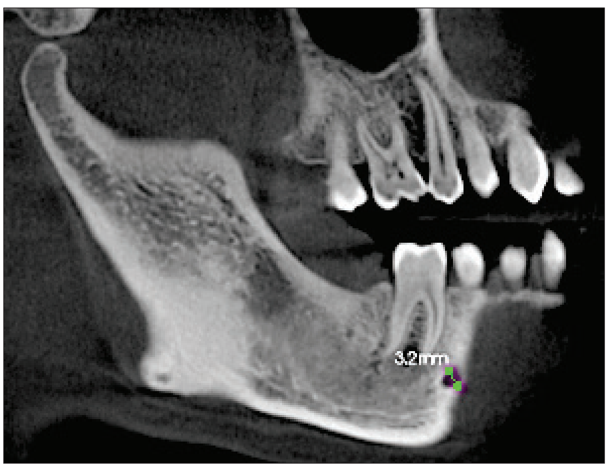

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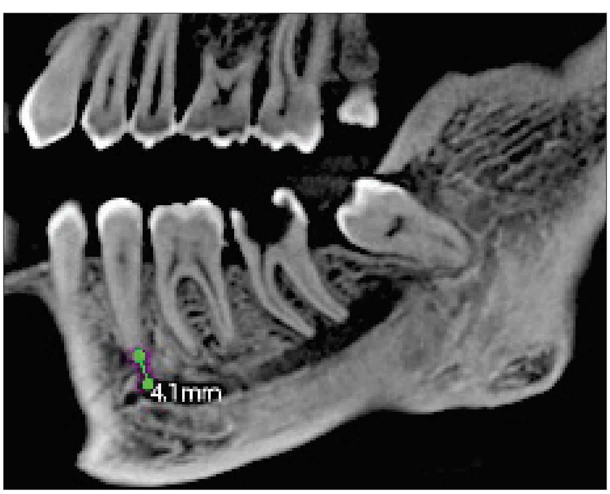


(c)

Figure 1: Illustration of (a) mandibular canal as seen in CBCT para-sagittal section of the mandible. The green path indicates the mandibular canal (b) mental foramen as seen in CBCT para-sagittal section of the mandible. The green line connecting the two dots indicates the mental foramen diameter and (c) safe zone for bone grafting as seen in CBCT para-sagittal section of the mandible. The green line indicates the safe length

RESULTS AND DISCUSSION

Table 2 illustrates the descriptive statistics of the study sample and the distribution of MC length, dimension of the MF, and safe zone length. The values are given for both sides of the mandible (left and right) for males, females and both genders (overall). The mean lengths of left and right MC of males were 6.99 ± 0.21 cm and 6.98 ± 0.22 cm, respectively, while for females the mean length was equal for both sides (6.88 cm). The mean vertical length of males' left and right MF were 0.25 ± 0.33 cm and 0.25 ± 0.02 cm, respectively. The vertical length of left and right MF of females was similar to that of males. The mean horizontal length of MF of males were similar for both sides (0.32 ± 0.03 cm), while for females, it showed a similar trend but lower mean length for both sides (0.31 ± 0.03 cm). The mean safe zone distance of the left and right mandible for males was 0.27 ± 0.07 cm and 0.30 ± 0.06 cm, respectively while for females, the values were 0.26 ± 0.06 cm and 0.27 ± 0.06 cm, respectively. The association between age and measured parameters were assessed and found that only a weak correlation exists between age and MC length for females (Figure 2).

MC length

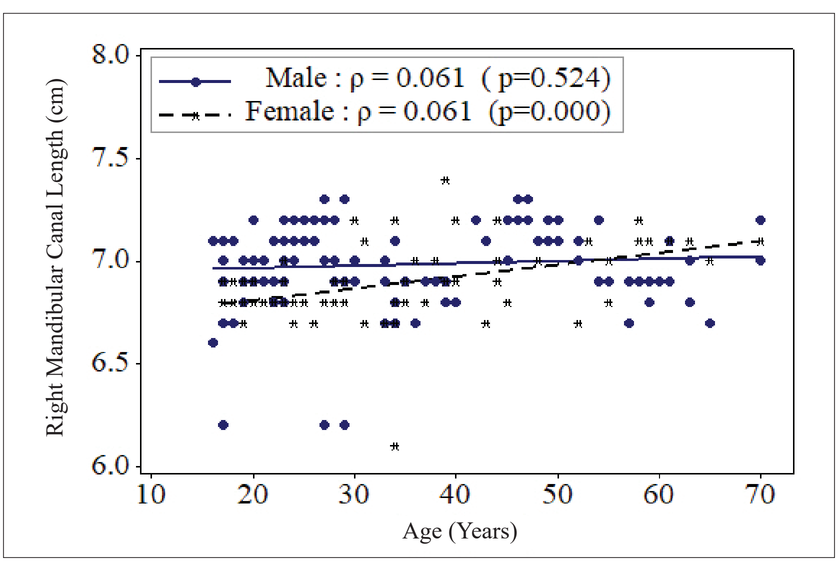
A gender-Variation in the mean length of MC was observed in the study sample (Table 2). However, the mean MC length was nearly similar for both sides of the mandible irrespective of gender. Figure 3 compares the mean MC lengths of India (Komal *et al*., 2020), Turkey (Direk *et al*., 2018) and Chile (Gonzalo *et al*., 2017) with the findings of the present study. The mean MC values of left and right mandibles for the Indian population (6.57 and 6.60 cm, respectively) as suggested by Mraiwa *et al*. (2003) was lower compared to our results (6.95 and 6.94 cm, respectively, for left and right sides). However, remarkably, the values suggested by the Chile study (7.1 and 7.08 cm for left and right sides, respectively) were comparable with the MC lengths of the present study. These individual differences may be due to the morphological variation seen among different ethnicities. A weak correlation was noted for MC length against age for females (Spearman's $\rho = 0.528$ and 0.413) for left and right sides, respectively (Figure 2).

MF Dimensions

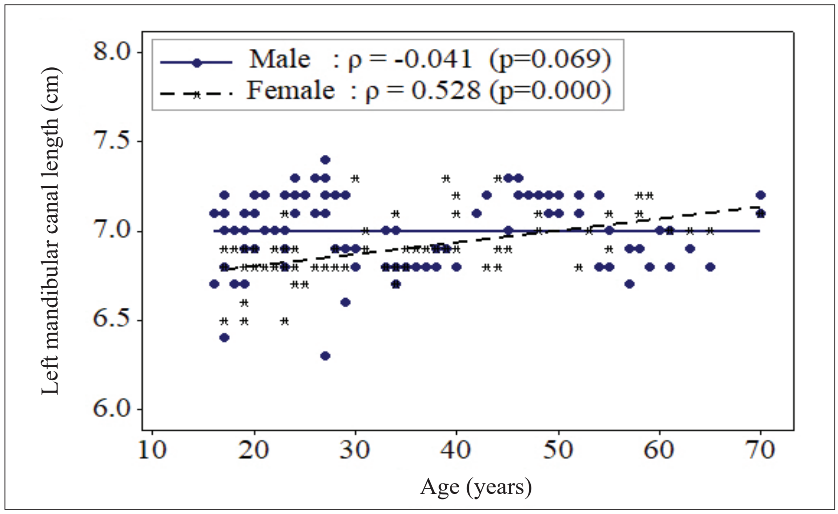
The size, shape, location, and direction of the opening of the MF can vary depending on the ethnicities and gender. Neiva *et al*. (2004) had found that the mean diameter of MF was 0.36 ± 08 cm (range 0.2 – 0.55 cm). The above measurements were done on 22 Caucasian cadaveric skulls. Also, Apinhasmit *et al*. (2006) had examined

Table 2: Descriptive statistics of the study sample and results summary

Gender		Male	Female	Overall
Sample size (n)		112	88	200
Mean age (± SD) in years	(range)	35.3 ± 15.3 (16 – 70)	32.5 ± 13.2 (17 – 70)	34.1 ± 14.5 (16 – 70)
Mean length (± SD) of mandibular canal (cm)	Left (range)	6.99 ± 0.21 (6.30 – 7.90)	6.88 ± 0.16 (6.50 – 7.30)	6.95 ± 0.20 (6.30 – 7.90)
	Right (range)	6.98 ± 0.22 (6.20 – 7.80)	6.88 ± 0.17 (6.70 – 7.40)	6.94 ± 0.20 (6.10 – 7.80)
Mean (± SD) vertical length of mental foramen (cm)	Left (range)	0.25 ± 0.03 (0.21 – 0.36)	0.25 ± 0.27 (0.22 – 0.34)	0.25 ± 0.02 (0.21 – 0.36)
	Right (range)	0.25 ± 0.02 (0.21 – 0.34)	0.25 ± 0.02 (0.22 – 0.34)	0.25 ± 0.02 (0.21–0.34)
Mean (± SD) horizontal length of mental foramen (cm)	Left (range)	0.32 ± 0.03 (0.26 – 0.41)	0.31 ± 0.03 (0.27 – 0.41)	0.32 ± 0.03 (0.20 – 0.40)
	Right (range)	0.32 ± 0.03 (0.27 – 0.41)	0.31 ± 0.03 (0.27 – 41)	0.31 ± 0.03 (0.27 – 0.41)
Mean (± SD) of safe zone distance (cm)	Left (range)	0.27 ± 0.07 (0.20 – 0.40)	0.26 ± 0.06 (0.20 – 0.40)	0.27 ± 0.07 (0.20 – 0.40)
	Right (range)	0.30 ± 0.06 (0.20 – 0.40)	0.27 ± 0.06 (0.20 – 0.40)	0.29 ± 0.07 (0.20 – 0.40)



(a)



(b)

Figure 1: Correlations plots of (a) left mandibular canal length (cm) against age (years) and (b) right mandibular canal length (cm) against age (years). Spearman's correlation coefficient (ρ), level of significance (p)

106 Thai adult skulls and found that the mean MF width was 0.28 ± 0.07 cm. In addition to these cadaveric studies, many authors have determined the MF size using radiographic imaging techniques such as OPG and CBCT. Sheikhi *et al*. (2015) had assessed 180 CBCTs and found that the mean MF diameter for the Iran cohort was 0.36 cm. The resultant mean MF diameters (horizontal length) for Sri Lankan males were 0.32 ± 0.03 cm for both sides, while for females, it was 0.31 ± 0.03 cm on either side. In addition to the horizontal dimension, the vertical length of MF was assessed to determine the shape of MF. It was found that the overall vertical length of MF was 0.25 ± 0.02 cm for both left and right, and it is the same for both genders. This suggests that the shape of the MF is oval for both genders.

MF location

Except for these size variations, MF also varies in location and direction of the opening (Neiva *et al*.,

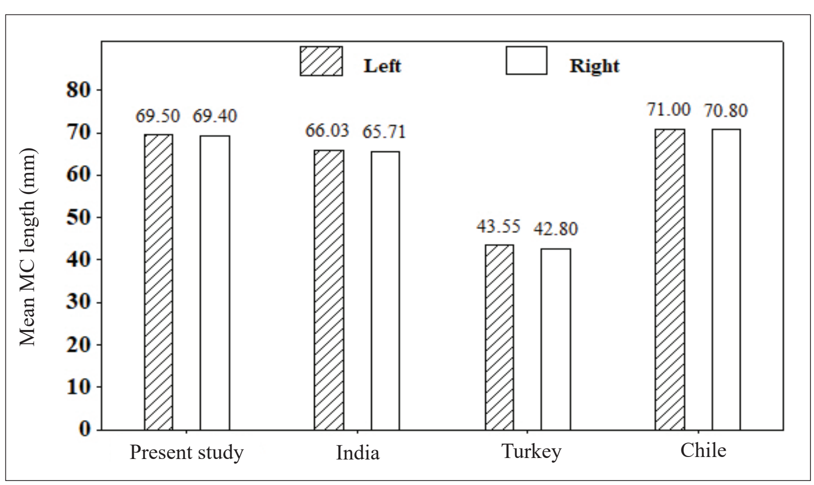


Figure 3: Comparison of present study data (mandibular canal mean length) with similar studies found in literature. India, Turkey and Chile

2004; Apinhasmit *et al*., 2006). Due to variations in the location, injuries to MF are common during achieving anaesthesia or surgery. Therefore, precise identification of the MF location is clinically essential to avoid chances of iatrogenic injuries (Juodzbalys *et al*., 2010). According to Srivastava *et al*. (2017) the frequent position of MF was below the second premolar in the Indian population. However, in the present study findings, the location of MF is observed to be different between genders (Figure 4). The MF is frequently located below the second premolar in males, while it is below and between the first and second premolar for females.

Safe zone dimensions

Moreover, to prevent IAN damage during bone graft harvesting, a safe zone had been recommended by Al-Ani *et al*. (2013). The most preferred site is between the root apex to the open of mental foramen. The present study results indicate that the safe zone distance for males are 0.27 ± 0.07 cm and 0.30 ± 0.06 cm on left and right sides, respectively. For females, the measured lengths on the left and right sides were 0.26 ± 0.06 cm and 0.27 ± 0.06 cm, respectively. Yang *et al*. (2017) suggests that the area of 4 mm anterior and 8 mm inferior to the mental foramen is adequate, and if operated by a safe hand. Also, Pommer *et al*. (2008) suggest that the bone should be harvested at 8 mm below the tooth apices with a maximum harvest depth of 4 mm. However, the present findings suggest that the safe zone is much narrower than what is suggested in the literature. Therefore, a different reference mark should be applied during such interventions. The present study evaluated the variations of a wide range of dimensions related to mandibular anatomy using CBCT. However, to gain insight into the Sri Lankan population, a more significant sample representative of the whole country should be evaluated. This was a significant limitation in our study and should be considered to ensure a definite conclusion in future studies.

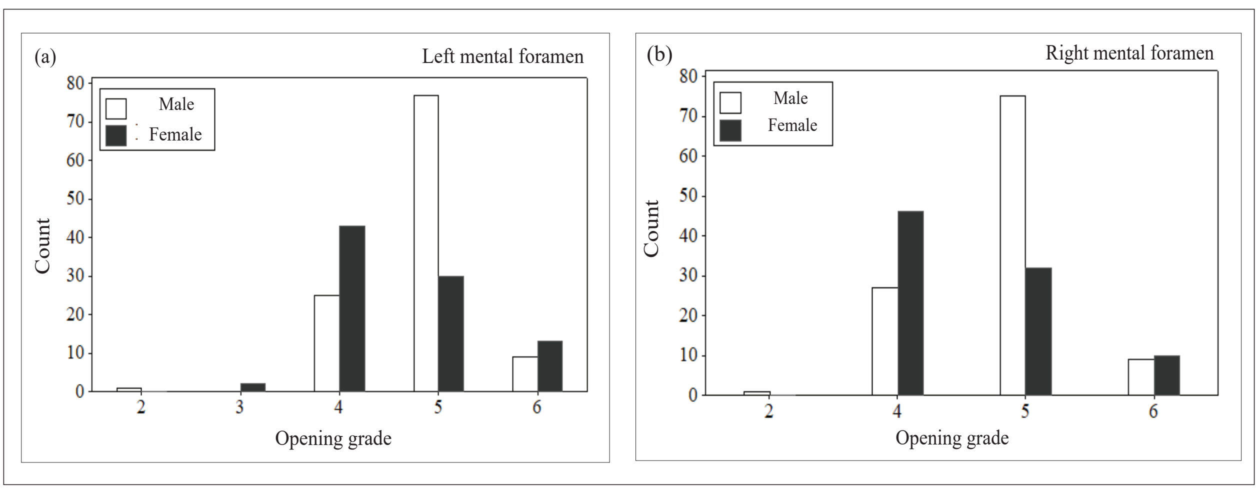


Figure 4: Gender wise variation in the opening grade of (a) left and (b) right mental foramen based on the grading given in Table 1

CONCLUSION

Mandibular canal length, safe zone distance and the horizontal length of mental foramen showed sexual dimorphism. Almost all the measurements were higher in males compared to females. Also, the frequent location of the MF varied between genders (MF located below the second premolar in males and between the first and second premolar in females). These variations in the resultant values may be attributed to morphological and ethnic diversity seen among the different populations. Therefore, gender-wise variation in MC length, diameter and location of MF should be considered during surgical interventions such as implant and bone harvesting. This will positively influence the surgical results and reduce the potential of iatrogenic injuries. The large deviation in the length and the spatial pathway of intra-bony nerve canals suggest that the exposure of anterior loop and mandibular canal using CBCT is fundamental for preoperative evaluation in the mandibular region. Finally, the authors recommend studies with a larger population to determine the precise relative position of the mandibular canal and associated structures using CBCT.

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