The location of the mental foramen in relation to the biometrics of the lower dentition and mandibular arch: A cross-sectional study

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Abstract
Purpose: To evaluate the position of the mental foramen among Malaysian Malays and Chinese based on the biometrics of the lower dentition and mandibular arch dimensions.
Materials and methods: The horizontal and vertical position of mental foramen in relation to the midline, roots of teeth, mesiodistal dimension of the anterior and posterior teeth, and the mandibular arch length and width were measured and evaluated in 65 Cone-Beam Computed Tomography scans.
Results: The location of mental foramen was predominantly located either between 1st and 2nd premolar or below 2nd premolar. There were no significant differences for all measurements of the mandible in relation to gender and ethnicities. There was a positive correlation of the mesiodistal diameter of the teeth with the mandibular arch length and width. However, mandibular arch length and width did not affect the location of the mental foramen.
Conclusions: As the size of the teeth increases, the mandibular arch length and the width increase concurrently. However, regardless of the changes in the biometrics of the mandibular dentition and the arch dimensions, the anatomical position of the mental foramen remains the same. The mental foramen was located at the ratio of 0.5 vertically and 0.27 horizontally in the mandible. The inter-foramina distance of 51.36 mm suggests that Malaysian Mongoloids had sufficient space to receive five implants rigidly joined with a bar.

Introduction

In clinical dentistry, arch width and shape of the jaws are of particular interest to the orthodontists and prosthodontists. For the orthodontists, dental arch expansion is one of the methods used to solve dental crowding as extraction of teeth may not be required. However, stability has always been controversial in the dental arch expansion.[1] As a result, different formulae, indices and methods using tooth size has been suggested to predict the ideal inter-premolar and inter-molar width for the purpose of arch expansion. Because of this, several publications have investigated the maxillary and mandibular arch length and interdental width to develop baseline data.[2, 3]

In the mandible, identification of actual position of mental foramen (MF) is of

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substantial clinical significance in dentistry especially during surgical interventions and anaesthetic procedures. Pre-operative imaging examinations are necessary to aid in developing a comprehensive treatment plan for patients who requires dental implant, flap surgery or anaesthetic procedures in the mental region.[4] Traditionally, panoramic imaging is used as a preoperative diagnostic tool in treatment planning of implant placement in inter-foramina region. However, the drawback of panoramic imaging includes the distortion and magnification of anatomic structures which often results in either over- or underestimation of the real size. On the other hand, CBCT has clearly proven its reliability of negligible distortion, superimposition, and magnification of the images. Hence, high accuracy can be achieved by using CBCT scans.

Population-specific 3D database is needed to determine the location of mental foramen in relation to the biometrics of lower dentition and mandibular arch dimension. These findings are essential to maximise the best mechanic and function of implants where its shape and size must meet both technical and clinical requirements.[5] The two most common location of the MF is between the first and second premolar or apical the second premolar, but variations have been reported. Green (1987) reported that the most common location of the mental foramen in Caucasians and Middle Eastern was between the first and second premolars, but was more distally placed in the Mongoloids, Melanesian and Negroids.[6]

Knowing that the position of mental foramen can vary according to different populations, the purpose of this research is to determine the biometrics of lower dentition and mandibular arch dimensions in the ethnic Malay and Chinese Malaysians of Mongoloid ancestry. The results obtained can be used as baseline to plan the number and position of implants for edentulous case.

Materials and methods

Ethical approval

The study was approved by the Faculty of Dentistry, University of Malaya and MAHSA University Ethics Committee (RMC/EC13/2019).

Sample collection

Sample size was estimated based on two means formula. A standard deviation (SD) of 2.3 mm was estimated. A minimum of 58 adult subjects was needed to be recruited, considering level of significance at 0.05 and 80% of the power of the study. In our study, 65 CBCT scans of patients who underwent treatment at Faculties of Dentistry at University of Malaya and MAHSA University for diagnostic purposes were carefully selected. This was a retrospective cohort study using convenient sampling method.
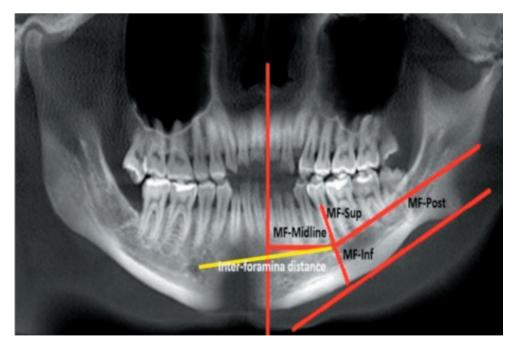
The following are the inclusion criteria for CBCT:
- High quality CBCT scans with respect to sharpness and contrast of images
- Images of mandible without any radiolucent/radiopaque lesions.
- Images with identifiable mental foramen.
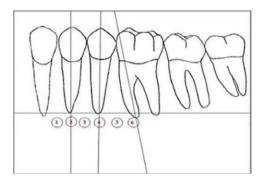- Healthy periodontal structures.

- No missing teeth at the lower arch and must be caries-free from teeth 37-47.
- No history of orthodontic treatment.
  The exclusion criteria for CBCT include:
- Presence of any supernumerary teeth.
- Severe malocclusion or obvious diastema.
- Presence of tooth/teeth with abnormal anatomy.
- Has any history of dental treatment (tooth restoration, prothesis etc)

CBCT imaging measurement in panoramic, sagittal and axial views were performed using i-CAT Vision software (Imaging Sciences International, Inc. Hatfield, USA).

The panoramic image was obtained using the Implant Screen windowpane of the software. Fig 1 illustrates the various points of measurement on the panoramic view of a CBCT scan. Two reference points were drawn prior to the measurements. First reference line was straight line drawn from the nasal spine down to the symphysis menti, which divided the mandible into left and right side. The second reference line was a line drawn parallel to and in contact with the lowest margin of the body of the mandible. The distance between symphysis menti and mental foramen (MF-Midline) was recorded with a straight horizontal line drawn from the mental foramen to the first reference line. The distance between mental foramen and posterior border

Figure 1. Parameters for measurement. MF-Midline: Mental foramen to the symphysis; MF-Post: Mental foramen to the posterior border of the mandible. Yellow line denotes the inter-foramina distance. MF-Sup denotes the distance from the middle of mental foramen to the alveolar crest, and MF-Inf denotes the distance from the middle of the mental foramen to the lower border of the mandible.

Figure 2. The position of mental foramen in relation to the longitudinal axis of the lower dentition. Position 1 MF is situated anterior to the first premolar; Position 2 MF is in line with the first premolar; Position 3 MF is situated between the first and second premolar; Position 4 MF is in line with second premolar; Position 5 MF is situated between second premolar and first molar; Position 6 MF is in line with first molar.
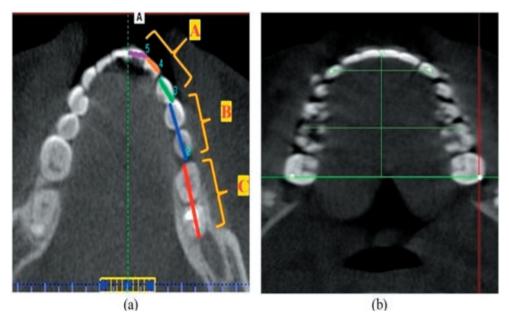
of ramus (MF-Post) was recorded with a horizontal line paralleling with the second reference line. The distances from the alveolar crest of bone to the mental foramen (MF-Sup) and the mental foramen to the lower body of mandible (MF-Inf) were measured with a vertical line drawn perpendicular to the second horizontal line. Distance between the left and right mental foramen was measured from the point of intersection (which marks the location of mental foramen) on the left to the right side.

Based the description by Ngeow & Yuzawati,[7] the location of mental foramen was classified in relation to the longitudinal axis of mandibular teeth, as shown in Fig 2.

Fig 3(a) demonstrates the tooth size measurement carried out on the axial planes of the Multiplanar Reconstruction (MPR) screen of the i-CAT Vision software. The mesiodistal width of molars, premolars and anterior were measured from interproximal anatomical contact

Figure 3. (a) The measurement of teeth size: A=Anterior tooth size, B = Premolar tooth size, C = Molar tooth size (b) the measurements of arch widths, namely the intercanine, inter-first-molar and inter-second molar.

of each tooth as seen on the occlusal view (Fig 3a). The arch length, i.e., the horizontal distance from the incisal point perpendicular to the midpoint of a line joining the distobuccal cusp tip of permanent second molars was also obtained.[8]

The arch widths were measured in the mandible as the followings (Fig 3b):
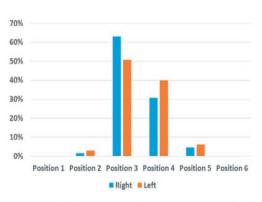
a) Inter-canine width – Measured as the distance between cusp tips of the permanent canines. If attrition is noticed, the middle of the facet on the tooth will become the measuring point.
b) Inter-first molar width – Measured as the distance between the mesiobuccal cusp tips of permanent first molars.
c) Inter-second molar width – Measured as the distance between the distobuccal cusp tips of permanent second molars.

Results

From 65 CBCT scans studied, 32 scans belonged to Malay (18 male & 14 female) and 33 scans were from Chinese patients (15 male & 18 female). The initial investigation revealed that the baseline characteristics of all parameters between the genders and ethnicities were found to have no significant differences (Independent *t-test*; p > 0.05).

Fig 4 shows the distribution of various positions of the mental foramen. The findings indicate that most of patients had their left mental foramen located in between the first and second premolar (Position 3) & in line with second premolar (Position 4), which accounted for 50.8% and 26.4% respectively. However, it was also noticed that there are 2 patients (3.1%) who had the left mental foramen located below first premolar (Position 2) and 4 (6.2%) who had their left mental foramen located between second premolar and first molar (Position 5). Similarly, most patients had their right mental foramen located at Position 3 and Position 4, accounting for 63.1% and 30.8% of patients respectively. However, it was also noticed that there was 1 (1.5%) patient who had his right mental foramen located at Position 2 and 3 (4.6%) patients showing the presence at Position 5.

The overall mean distance from the middle of mental foramen to the superior border of the mandible (MF-Sup) on the right side was 15.75mm (SD ± 2.20) and on the left side, it was 15.22mm (SD ± 2.46). The inter-foramina distance was 51.36 (SD ± 6.20) [95%CI = 42.61 to 61.63 mm]. The overall mean distance from the middle of mental foramen to the inferior border of the mandible (MF-Inf) on the right side was 15.23mm (SD ± 1.91) and on the left side was 15.27mm (SD ± 1.80). These results give a ratio of 0.51 on the right side, and 0.50 on the left side between the superior (MF-Sup) and the mandibular height (MF-Sup + MF-Inf). There was no statistically

Figure 4. The distribution of various positions of the mental foramen.

significant difference between side, with the overall mean ratio being 0.50 (max-minimum = 0.37-0.62). Besides, the overall mean distance from the middle of mental foramen to the midline of the mandible (MF-Midline) on the right side is 25.21mm (SD ± 3.84) and on the left side is 26.17mm (SD ± 3.90). The overall mean distance from the middle of mental foramen to the posterior border of the mandible (MF-Post) on the right side was 69.95mm (SD ± 4.56) and on the left side was 68.43mm (SD ± 4.54). The ratio of the MF-Midline distance to the mandibular length (MF-Midline + MF-Post) was 0.26 on the right side, and 0.28 on the left side. There was no statistically significant difference between side, with the overall mean ratio being 0.27 (max-minimum = 0.19-0.38).

The breakdown of measurements from various specific anatomical structures to the mental foramen in Position 3 and Position 4 is shown in Table 1. Overall, it can be observed that the MF-Sup and the MF-Midline measurements were larger in cases where the mental foramen was located in Position 4.

MF- sup is the distance from mental foramen to the superior border of the man-

Table 1 Measurements from specific anatomical structures to the mental foramen for 2 MF different positions.

Side	Location of mental foramen	No.	Mean distance (SD)			
			(MF-Sup)	**(MF-Inf)**	**(MF-midline)**	**(MF-post)**
Right	Position 3	41	15.54mm (SD ±2.06)	15.77mm (SD ±1.66)	24.35mm (SD ±3.25)	70.92mm (SD ±4.48)
	Position 4	20	16.14mm (SD ±2.45)	14.09mm (SD ±1.73)	26.32mm (SD ±4.65)	67.64mm (SD ±4.38)
Left	Position 3	33	14.61mm (SD ±2.54)	16.07mm (SD ±1.69)	25.65mm (SD ±3.89)	69.69mm (SD ±4.33)
	Position 4	26	15.81mm (SD ±2.38)	14.30mm (SD ±1.57)	26.99mm (SD ±3.64)	66.69mm (SD ±4.38)

Table 2. Correlation between mandibular arch dimensions and position of mental foramen on both sides.

Variables	*R_LOMF		P value	*L_LOMF		P value
	Position 3	Position 4		Position 3	Position 4	
Arch length	41.93mm (SD ±2.65)	40.53mm (SD ±2.40)	0.051	41.74mm (SD ±2.70)	41.25mm (SD ±2.68)	0.491
Inter-canine width	30.46mm (SD ±2.20)	30.23mm (SD ±1.81)	0.682	30.34mm (SD ±2.31)	30.40mm (SD ±1.80)	0.921
Inter-first molar width	51.55mm (SD ±3.36)	50.82mm (SD ±2.85)	0.402	51.79mm (SD ±3.25)	50.55mm (SD ±2.94)	0.134
Inter-second molar width	61.85mm (SD ±3.23)	60.71mm (SD ±2.31)	0.162	62.12mm (SD ±3.17)	60.67mm (SD ±2.70)	0.068

*R_LOMF is the location of the mental foramen on the right side of mandible whereas L_LOMF is the location of mental foramen on the left side of the mandible.
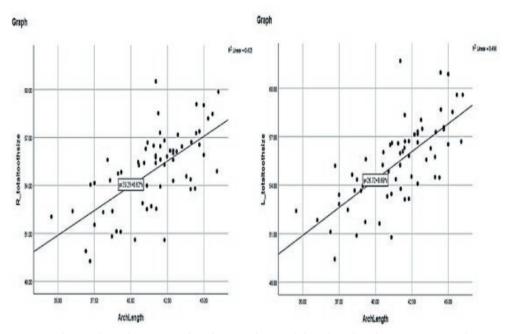
Figure 5. The correlation between total teeth size and inter-ach length. Right side (R), Pearson correlation = 0.650 (P<0.001); Left side (L), Pearson correlation = 0.704 (P<0.001).
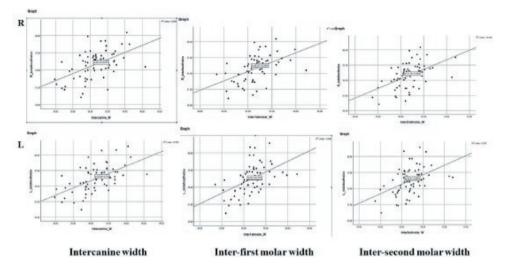
dible; MF – Inf is from the mental foramen to inferior border of the mandible, MF – Midline is from the mental foramen to midline of the mandible and lastly, MF – Post denotes the distance between mental foramen and posterior border of the mandible.

The anterior teeth sizes were 17.94 (SD ± .13) [95%CI = 16.06 to 19.62 mm]. In comparison, the premolar teeth sizes were 14.69 (SD ± 0.83) [95%CI = 13.30 to 20.39 mm] and the molar teeth sizes was 22.55 (SD ± 1.18) [95%CI = 16.03 to 24.50 mm].

The mean arch length was 41.56 (SD ± 2.60) [95%CI = 37.00 to 45.51 mm]. The mean intercanine distance was 30.53 (SD ± 2.09) [95%CI = 26.71 to 34.10 mm]. The mean inter- molar (first molar) distance was 51.67 (SD ± 3.43) [95%CI = 44.55 to 54.29 mm]. The mean inter- molar (second molar) distance was 61.78 (SD ± 3.23) [95%CI = 55.38 to 66.78 mm]. The detailed arch length and inter-arch widths are shown in Table 3. The correlation study between mandibular arch dimensions and the position of mental foramen on both sides shows no significant correlation (P > 0.001).

The results from correlations test showed that there was statistically significant correspondence between the total size of teeth and total arch length (P < 0.001 on both sides, and arch width (P < 0.001). The total tooth size is directly proportional to the increment of mandibular arch length and width (Figs 5 and 6).

Moreover, further analysis was undertaken to determine the correlation between mandibular arch dimensions and positions of mental foramen on both sides. Interestingly, statistic result showed no significant differences between the mandibular arch dimension and the position of the mental foramen as shown in Table 2.

Figure 6. Correlation between total teeth size in relation to inter-canine width, inter-first molar width and inter-second molar width. On the right side, their respective Pearson correlation are 0.576, 0.500 and 0.452 (P<0.001); on the left side, their respective Pearson correlation are 0.519, 0.493 and 0.496 (P<0.001).

Discussion

Clinical and radiographic evaluation of inferior alveolar canal, incisive canal and mental foramina of the mandible is an essential preoperative assessment for the success of many of the surgical interventions. This includes injection of local anaesthesia during routine dental procedures, implant placement, periodontal surgeries and orthognathic surgeries.[9] CBCT scanned images has been deemed as a gold standard in these and other clinical scenarios. It is widely acknowledged that the radiological information provided surpasses the risks associated with absorbed radiation doses. CBCT scans allows for the establishment of quantitative correlation between different anatomical structures, which may then minimize complications and help predict favourable treatment outcomes.[10]

The mental foramen is an important landmark to identify prior to local anaesthesia injection and for the planning dental implant placement in the anterior mandible. In addition, the mental nerve that emerges from the mental foramen is the important anatomical structures that needs to be identified, preserved and avoided during surgery. The location of the mental foramen is usually determined by relating its relationship the lower dentition. Previous study involving the Malays reported that the most common location of the mental foramen is Position 4.[7, 11, 12] The current findings suggest that there is ethnic influence on the position of the mental foramen in Mongoloids, as the addition of the Southern Chinese into the sample pool possibly skewed the most common position to be between the first and second premolar (Position 3). In the current study, the location of mental foramen was predominantly located either between 1st and 2nd premolar or below 2nd premolar regardless of gender and ethnicities on both left and right sides. Another possible explanation for the

difference with regards to the Malays is the fact that previous studies were done on dentopantomographs, while the current one is undertaken using CBCT.

The current results shown here were in accordance with previous studies in other populations such as the Australoids and Caucasian (American, Anglo-Saxon, central European and South African Caucasian) showing that the commonest location of the mental foramen was positioned between the first and second premolar tooth, followed by a position below the second premolar.[6, 13, 14] However, in others like the Mongoloids (Chinese, Japanese, Thai, Korean, Malay), Melanesian and Negroids, the mental foramen was most commonly located below the second premolar.[7, 14-17]

The MF is usually located in the body of the mandible at an equal distance from the superior and inferior border below.[18, 19] In this current study, the distance from upper border of mandible or alveolar crest to MF was at a range of 11.03 – 20.12mm (Mean: 15.75±2.20mm) on the right side, and at a range of 9.83-20.58mm (Mean: 15.22±2.46mm) on the left side. The mean distance between the MF to the inferior border of mandible was 15.23±1.91mm on the right side, and 15.27±1.80mm on the left side. An average ratio of 0.5 is obtained by dividing the MF-Sup against the height of mandible at the mental foramen (Table 3). This finding concurs with the same ratio reported by Apinhasmit et al. (2006), Wang et al. (1986) and Tebo and Telford (1950).[18, 20, 21]

The MF-Sup range is within the means reported by various studies (Table 3). The reason for this wide variation maybe due to resorption and deposition (remodelling) causing the changes in the size of the mandible. In addition, the location of the mental foramen appears to be affecting this measurement. The fact that these figures were between 10-20 mm of height suggests that short or standard implants can be placed above the mental nerve, while avoiding the mental foramen/nerve if done early before gross resorption sets in. The MF-Sup measurements were larger in cases where the mental foramen in located in Position 4 than those in Position 3. Such finding has not been reported before and shall be kept in mind during treatment planning.

Besides that, the mean distance between the MF to the inferior border of mandible was 15.23±1.91mm on the right side, and 15.27±1.80 mm on the left side. This finding concurs with those reported for 2 other group of Mongoloid ethnicities. Chung et al. (1995) found that the average distance from the inferior border of the MM to the centre of the MF was 15.5 mm for Korean men and 14.0 mm for Korean women.[22] Guo et al. (2009) found that MFs were located 15.56 mm above the inferior border of the mandible.[15] These findings are important as there are clinical applications associated with locating the MF by relating it to the symphysis and lower border of mandible, as suggested by Delgadillo-Ávila et al. 2015.[23]

However, Currie et al.'s study showed only fair agreement between examiners when scoring the MF position in relation to the premolar crowns, and moderate agreement when scoring the position in relation to the premolar apices in dentopantomographs.[24] Their results casted doubt on the reliance to conventional radiography alone, although the MF is more commonly visible on dentopantomographs than periapical radiographs.[25] In addition, although the MF is reported to be visible in the majority of dentopantomographs, it is only clearly identifiable in 49% of cases.[26] Ngeow et al. (2010) attributed this to ageing, where they reported that the visibility reduced tremendously in patients aged >50 years.[12]

Because of these inconsistencies, the authors resorted to turn back to the most fundamental approach to determine the location of the mental foramen, namely by

Table 3. The vertical measurements related to the apicobasal morphometric of the mental foramen in the mandible.

Authors	Apicobasal morphometric measurements			
	Upper (MF-Sup)	Lower (MF-Inf)	Mandible Height	Ratio
Matsuda Y (1927) / Multiple races	R = 13.5 – 14.0 mm L = 14.5 – 15.0 mm	R = 13.5 – 14.0 mm L = 14.5 – 15.0 mm	--	~ 0.5
Tebo & Telford (1950) / Unknown	--	R = 15.2 ± 1.54 mm L = 15.0 ± 1.57 mm	--	
Wang TM et al. (1986) / Chinese	--	R = 14.68 ± 1.78 mm L = 14.71 ± 1.77 mm Mean = 14.70 mm	R = 30.30 ± 3.03 mm L = 30.26 ± 2.83 mm Mean = 30.29 mm	0.426
Neiva et al. (2004) / Caucasian	Mean to CEJ = 15.52 ± 2.37 mm	Mean = 12.0 ± 1.67 mm		0.56
Apinhasmit et al. (2006) / Thai	--	M = 15.40 ± 1.73 mm F = 13.89 ± 1.40 mm Mean = 14.88 ± 1.77 mm	M = 31.13 ± 2.45 mm F = 27.80 ± 2.3 mm Mean = 29.97 ± 2.9 mm	0.496
Yeşilyurt et al. (2008) / Turkish	--	R = 9.44 ± 5.84 L = 9.46 ± 5.88	R = 19.44 ± 11.94 L = 20.10 ± 12.09	0.45-0.47
Guo et al. (2009) / Chinese	Mean = 16.56 ± 2.53 mm	Mean = 15.56 ± 1.74 mm	--	0.52
Sankar et al. (2011) / Indian	R = 13.7 ± 2.8 mm L = 16.4 ± 2.9 mm	R = 16.5 ± 2.1 mm L = 14.3 ± 2 .1 mm	--	R:0.45 L:0.53
Mishra & Mittal (2015) / North Indian	R = 14.86 mm L = 15.36 mm	R = 14.53 mm L = 14.01 mm	--	R:0.51 L:0.52
Rehman et al. (2015) / Pakistani	R = 13.0 mm L = 12.0 mm	R = 14.0 mm L = 15.0 mm		R:0.48 L:0.44
Chandramohan et al. (2016) / South Indian	R = 12.54 ± 3.1 mm L = 12.1 ± 2.8 mm	R = 12.9 ± 2.16 L = 12.5 ± 1.9	R = 26.7 ± 4.1 L = 26.5 ± 4.1	R:0.49 L:0.49
Subramanian et al. (2019) / Zambian	R = 15.9 ± 2.9 mm L = 12.5 ± 2.9 mm	R = 13.9 ± 1.7 mm L = 13.7 ± 1.5 mm		R:0.53 L:0.48
Present study / Malay & Chinese	R = 15.75 ± 2.20 mm L = 15.22 ± 2.46 mm	R = 15.23 ± 1.91 mm L = 15.27 ± 1.80 mm		R:0.51 L:0.50

adopting morphometric study. This approach has been used as early as 1950 by Tebo & Telford (1950) and have been adopted by several authors in determining the location of the mental foramen in some major populations of the world.[20] Table 4 shows a summary of the distance for the mental foramen from the symphysis and posterior border of the mandible in selected studies. As can be observed the mental foramen is located between ~ 19.0 mm and ~ 29.0 mm. This distance is the lowest in the Turkish[27] and highest in the Pakistani.[28] In all ethnic groups listed, the mental fora-

Table 4. The horizontal measurements related to the anteroposterior morphometric of the mental foramen in the mandible.

Authors	Anteroposterior morphometric measurements		
	MF-Midline	MF-Post	Ratio
Tebo & Telford (1950) Unknown	R = 26.8 ± 2.33 mm L = 26.6 ± 2.32 mm	R = 74.6 ± 6.09 mm L = 74.9 ± 5.90 mm	0.22
Wang et al. (1986) Chinese	R = 28.12 ± 1.86 mm L = 27.99 ± 1.86 mm Mean = 28.06 mm	R = 74.11 ± 3.79 mm L = 74.17 ± 3.75 mm Mean = 74.14 mm.	0.28
Santini A, Land M. (1990) Chinese British	Mean = 27.6 ± 1.6 mm Mean = 25.9 ± 2.0 mm	--	0.27
Chung et al. (1995) Korean	MR = 24.4 ± 1.5 mm ML = 24.9 ± 1.8 mm FR = 23.9 ± 1.9 mm FL = 24.0 ± 2.3 mm Mean = 24.4 mm	--	NA
Curtright et al. (2003) American White American African	WM: 22.5 ± 0.4 mm BM: 22.9 ± 0.6 mm WF: 20.5 ± 0.4 mm BF: 21.9 ± 0.4 mm Mean = 22.0 mm	--	NA
Apinhasmit et al. (2006) Thai	M = 29.30 ± 3.42 mm F = 27.94 ± 1.87 mm Mean = 28.83 ± 3.05 mm	M = 70.92 ± 4.39 mm F = 64.95 ± 3.49 Mean = 68.85 ± 4.98 mm	0.30
Yeşilyurt et al. (2008) Turkish	R = 19.18 ± 11.19 mm L = 19.37 ± 11.33 mm	R = 48.58 ± 29.03 mm L = 48.27 ± 28.86 mm	~ 0.28
Ilayperuma et al. (2009)[33] Sri Lankan	R = 24.87± 6.07 mm L = 24.77± 6.07 mm M = 26.02 ± 5.12 mm F = 25.62 ± 4.20 mm	--	NA
Sankar et al. (2011) South Indian	R = 27.2 ± 2.4 mm L= 27.7 ± 2.4 mm	R = 70.7 ± 4.2 mm L = 70.7 ± 4.2 mm	0.28
Santini & Alayan (2012) Hokien-Hylam Chinese European - Anglo- Saxon (English) or Dark Ages (Scottish) Indian	27.97 ± 1.66 mm 25.89 ± 2.04 mm 26.35 ± 1.81 mm	70.68 ± 3.95 mm 71.80 ± 4.35 mm 67.97 ± 4.85 mm	0.28 0.26 0.28
Moogala et al. (2014) Indian	R = 28.24 ± 5.09 mm L = 27.45 ± 3.7 mm	R = 69.61 ± 6.03 mm L = 69.17 ± 6.0 mm	~ 0.29 ~ 0.28
Mishra & Mittal (2015) Indian	R = 25.28 mm L = 23.04 mm	R = 65.47 mm L = 76.11 mm	~ 0.28 ~ 0.24
Rehman et al. (2015) Pakistani	R = 29.0 L = 30.0	R = 72.0 L = 73.0	~ 0.29

Authors	Anteroposterior morphometric measurements		
	MF-Midline	MF-Post	Ratio
Chandramohan et al. (2016) South Indian	R = 25 ± 3.1 L = 25.7 ± 2.4	R = 64.5 ± 5.9 L = 65.6 ± 5.3	~ 0.28
Subramanian et al. (2019) Zambian	R = 28.5 ± 2.7 mm L = 28.6 ± 2.2 mm	R = 73.4 ± 5.5 mm L = 73.5 ± 5.1 mm	~ 0.28
Present study Malay Chinese	R = 26.17 ± 3.90 mm L = 25.21 ± 3.84 mm	R = 68.43 ± 4.54 mm L = 69.95 ± 4.56 mm	L = 0.28 R=0.26 Mean = 0.27

men was commonly located apical to the second premolar, except for the British,[14, 29] American White and African American.[4] For these groups of ethnic, the mental foramen, the distance between the mental foramen ranged between 22.0 and 25.9 mm.

The results of the present study were close to that observed on the British and Indian skulls and in skulls of unknown ethnicity of a number of studies.[14, 20, 29, 32] It is smaller than that reported in Thai subjects, Chinese, Pakistani, Zambian, Caucasian and some Indian subpopulations.[13, 14, 18, 19, 21, 28-30, 34] The current finding is bigger than that reported for the Turkish, Korean, Sri Lankan, American White and African American, and at least one Indian subpopulation.[4, 22, 27, 31] In addition, the current MF-Midline distance is within the length reported among Mongoloids examined.[14, 18, 21, 22]

According to Apihamsmit et al. (2006), these measurements were also not usually clinically relevant due to the wide range of values in dimensions. However, they suggested that a ratio could be clinically useful in locating the MF. The overall horizontal position of the MF, i.e., the ratio of MF-Midline (MF-Midline + MF-Post) was 0.27 in the current study. Table 4 provides a comparison of the mean distances of the MF to the posterior mandibles in different populations, summarised as the proportion ratio. In summary, it can be observed that the anterior-posterior relative position of MF on mandibles were significantly different among different ethnic groups from different geographic locations. The relative position of the MF ranged from 0.26 to 0.29 on the right side of mandibles and from 0.23 to 0.29 on the left side of mandibles, which is within the range reported for different populations. The current finding is close to the finding in other Mongoloids,[14, 21] except for the Thais.[18] Such a proportion is useful to predict the location of the mental foramen in our populations.

In this study, the Malays and Chinese (who have Mongoloid ancestry) presented with mean intercanine and inter-first molar distances which are higher than that reported in the Chinese[2] and the Malay from another study.[35] The difference with the Malays may be attributed to the low sample size in Rozali et al.'s study, while the Chinese study had younger subjects.[35] One interesting finding that has not been reported elsewhere is the positive correlation between right and left total tooth size and mandibular arch dimensions. As shown in the graphs, as the total teeth size increases, the mandibular arch width and length increases concurrently. However, the anatomical

Table 5. The inter-foramina distances of various selected ethnic groups.

Study	Ethnicity	Inter-foramina distance
Morant & Adyanthâya, (1936)	Predynastic Egyptians: Badari	44.3 mm
	Dynastic Egyptians: Sedment	44.0 mm
	Dynastic Egyptians: Kerma	44.3 mm
	Dynastic Egyptians: Qau	43.9 mm
	Tamils	45.1 mm
	Nepalese	46.2 mm
	Tibetans A	45.7 mm
	Hylam Chinese	46.7 mm
	Fukien Chinese	46.8 mm
	Tibetans B	47.0 mm
	English: Dunstable	45.4 mm
	Anglo-Saxons	45.3 mm
Cleaver, 1937 [39]	Anglo-Saxons – Spitafields	
	Male	45.1 ± 0.21 mm
	Female	43.4 ± 0.27 mm
	Anglo-Saxons – Farringdon Street	
	Male	43.9 ± 0.24 mm
	Female	42.9 ± 0.25 mm
	Punjabi male	43.9 ± 0.21 mm
	Australian	
	Male	47.4 ± 0.21 mm
	Female	45.8 ± 0.32 mm
Neiva et al. (2004)	Caucasian	55.23 ± 0.32 mm
Guo et al. (2009)	Chinese	49.25 ± 5.34 mm
Bhargava et al. (2016)	Indian	
	Class I	41.81 ± 4.87 mm
	Class II	34.99 ±2.34 mm
	Class III	40.06 ±3.24 mm
	Overall	38.95 ±4.58 mm
Marieiro et al. (2017)	Brazilian	
	Male	41.93 ± 3.98 mm
	Female	39.99 ± 3.80mm
	Overall	40.52 ± 3.92mm
Vane Swetah & Jayanth Kumar (2019)	South Indian	
	Male	50.62 ± 3.63 mm
	Female	50.02 ± 3.72 mm
Present study	Malaysian Mongoloids	51.36 ± 6.20 mm

position of the mental foramen remains the same despite changes in the mandibular arch dimension. This finding can be adopted when determining the teeth size and inter-arch alignment when planning to restore the dentition of edentulous cases.

The inter-foramina distance was studied in morphometric studies of the mandible in the 1930s.[36] However, there have been a pause in such study until the revisits

by several authors in the millennium.[5, 13, 15, 37, 38] Table 5 illustrates the current finding against all available information relating to these studies. In general, it can be seen that the inter-foramina distance of the current study samples is larger than most difference races, including the Chinese who are of Mongoloid origin. However, Neiva et al. (2004) reported the largest inter-foramina distance (55.23 ± 534) in 22 Caucasian skulls examined.[13] The current finding is closer to the measurement reported by Guo et al. (2009) and is in agreement with the measurement reported by Vane Swetah & Jayanth Kumar (2019).[15, 37] Difference in measurements in the studies performed after the millennium against those reported in the 1930s may be related to the technique used, or difference in the population whereby the current samples may have benefitted from better living condition and nutrition. In the case of Bhargava et al. (2016) and Bastião Marieiro et al. (2017)'s findings, their subjects were fully edentulous.[5, 38] In addition, the method of obtaining linear measurement used by appear to cause shorter inter-foramina distance.[38]

In edentulous mandible, the mandibular arch form, arch size, and the inter-foramina distance are factors that influence the selection of size and position of implants and the prosthetic design (fixed or removable).[5] Bhargava et al. (2016) proposed a classification system that incorporated the inter-foramina distance in addition to the generally accepted classification system based on the vertical restorative space.[5] They reported that the space requirement for five implants needs to be approximately 44.5–48.5 mm to accommodate the placement of five implants with a minimum diameter of 3.3 mm in the mandibular inter-foramina region. They found that a universal treatment plan cannot be followed in their Indian subjects due to the short inter-foramina distance of 38.9 mm in their subjects. In agreement with them, Marieiro et al. (2017) reported most of their subjects could be rehabilitated using a protocol with 4 implants of 3.3mm diameters. In contrast, the finding of current study suggests that Malaysian Mongoloids had sufficient space to receive the so-called OD-5 prosthesis, i.e., five implants rigidly joined with a bar.[38]

Lastly, while this study did provide useful metrical and morphological parameters of the mandible of Mongoloid Malaysians, there were some limitations due to insufficient CBCT scans to undertake any age-related changes in different age groups. This study does present some limitations, including the insufficient CBCT scans recruited for the different age groups of adult Malaysians to recognize any age-related changes, and the facts that all subjects were dentate. However, this limitation shall be mitigated in the future when we embark on a larger sample size for a similar study.

Conclusion

Regardless of the changes in the biometrics of the mandibular dentition and the arch dimensions, the anatomical position of the mental foramen remains the same, i.e., located either between 1st and 2nd premolar or below 2nd premolar. The anteroposterior and apicobasal morphometric measurements of the mental foramen yielded a 0.5 and 0.27 ratio respectively. The inter-foramina distance of 51.36 mm suggests that Malaysian Mongoloids had sufficient space to receive five implants rigidly joined with a bar.

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Availability of data and material

The data that support the findings of this study are available from the authors upon reasonable request.

Disclosure statement

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List of abbreviations

CBCT   Cone beam computed tomography
MF   Mental foramen
MPR   Multiplanar Reconstruction

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