J. Maxillofac. Oral Surg. (Oct–Dec 2019) 18(4):596–603
https://doi.org/10.1007/s12663-018-1168-2

CrossMark

ORIGINAL ARTICLE

Evaluation of Mandibular Incisive Canal using Cone Beam Computed Tomography in Malaysians

Jimmy Teong Sek Lim[1] · Wan Jing Kang[1] · Ranjeet Ajit Bapat[1] · Sham Kishor Kanneppady[1] · Rohit Pandurangappa[1]

Received: 14 March 2018 / Accepted: 10 October 2018 / Published online: 17 October 2018

Abstract

Objectives The risk of damaging the mandibular incisive canal (MIC) during surgery in the anterior mandible should not be overlooked. Hence, preoperative radiographic assessment is essential to avoid complications. This study was aimed to estimate the length of the MIC in the interforaminal safe zone, to analyse its course in relation to the lingual and the buccal cortical plates of the mandible using cone beam computed tomography (CBCT) scans and to relate the above findings to age, gender, dental status and Malaysian races.

Methods Retrospective analysis of 100 CBCT scans ($n = 200$) was performed on both sides of the mandible. Cross-sectional and panoramic images were reconstructed. The length of the MIC and the horizontal distances between the MIC and the buccal and the lingual cortical plates were measured at the three different points (starting, mid-, end points). Independent samples t-test and one-way ANOVA test were used to analyse the variation in the length and course of the MIC in gender, age, dental status and Malaysian races.

Results The mean length of the MIC was 11.31 ± 2.65 mm, with the Malays having the longest MIC, followed by the Chinese and the Indians ($p < 0.05$). The MIC deviated towards the lingual cortical plate, with significance seen in the Indian and the male patients ($p < 0.05$). No significant difference was noticed with respect to patient age and dental status.

Conclusions Assessment of the MIC should be performed using CBCT on a case-by-case basis as it provides essential information during preoperative planning of surgery in the anterior mandible.

Keywords Mandible · Incisive Canal · Cone Beam Computed Tomography · Malaysia · Humans · Retrospective Studies

Introduction

It is essential to understand the anatomic landmarks and their variations prior to any surgical intervention in the mandible. Anterior mandible is commonly used for harvesting of autogenous grafts [1] and implant placement [2] for replacement of missing teeth. The mental interforaminal region is generally considered as safe without major risks of damage to the vital anatomic structures [3]. The mandibular incisive canal (MIC), the mental nerve and the lingual foramen are the important anatomic landmarks in this region [4–6].

Being a mesial extension of the inferior alveolar canal [7, 8] containing the neurovascular bundle [5, 9], the MIC should be carefully looked for during the preoperative planning of surgical procedures in the anterior mandible

✉ Jimmy Teong Sek Lim
limjimmy94@gmail.com

Wan Jing Kang
kang.wanjing@student.imu.edu.my

Ranjeet Ajit Bapat
RanjeetAjit@imu.edu.my

Sham Kishor Kanneppady
ShamKishor@imu.edu.my

Rohit Pandurangappa
rohitpandurangappa@imu.edu.my

1 School of Dentistry, International Medical University, 126, Jalan Jalil Perkasa 19, 57000 Bukit Jalil, Wilayah Persekutuan Kuala Lumpur, Malaysia

[10], including implant placement [11] and harvesting of bone from the mental protuberance [1]. Despite the mental interforaminal region being known as a 'safe zone' [3], several reports have described complications following surgery in the anterior mandible such as postoperative sensory disturbances [5, 9, 12, 13], lack of osseointegration of implants [9], pulp sensitivity changes [1], oedema [13] and neuropathic pain due to perforation of the incisive canal and nerve [14]. The risk of damaging the vital anatomic structures should not be overlooked [2, 4, 10, 12, 14–16].

Radiographic assessment of the MIC is essential prior to surgical procedures in the anterior mandible to avoid complications [9, 13]. Cone beam computed tomography (CBCT) imaging has been proven by several studies for its excellence in locating and measuring the dimensions of the MIC [1, 9, 10, 16–21]. Measurements made with CBCT imaging were comparable with the results obtained through cadaveric dissection studies [5, 7, 8, 17, 18, 22]. Limitations have been found with the conventional panoramic radiography due to superimposition of cervical vertebrae and other anatomic structures [3, 16].

Al-Ani et al. [23] found a significant anatomic variation of the MIC in different races in Malaysia. Sixty subjects were included in the study. The authors believed that dental status, dentate or edentulous did not influence the measurements obtained due to less resorption of the basal bone [23]. Nevertheless, literature had reported variation in some anatomic parameters in relation to dental status [16]. Therefore, we planned to conduct a study with a larger sample size with an attempt to verify these findings.

In this study, we aimed to measure the length of the MIC and analyse its buccolingual course in relation to the buccal and lingual borders of the mandible by means of CBCT imaging. It was then determined if there was any significant difference in the measurements with respect to age, gender, dental status and Malaysian races.

Materials and Methods

Study Design and Study Population

A total of 100 CBCT scans done in year 2016 were selected randomly and evaluated retrospectively. Patients aged from 18 to 80 years old were included and classified into three age groups (18–38, 39–59, 60–80). They were either fully dentate (all lower premolars, canines and incisors were present), partially dentate (some lower premolars, canines or incisors were absent) or edentulous (all lower premolars, canines and incisors were absent). Only CBCT scans in which the MIC was visible were included in this study. Patients with congenital or syndromic disorders, history of injuries, pathology of the anterior mandible, surgeries done in the anterior mandible were not selected. Besides, blurred images with poorly defined bony borders were excluded. This study was approved by the Joint-Committee of the Research and Ethics Committee. Informed consent was obtained from the patients prior to the research for analysis of their scans as per the objectives and data interpretation.

CBCT Imaging

CBCT scans were obtained using the KaVo 3D eXam with a strict and standardised protocol. The scanning parameters were 120 kVp, 26.9 s, 5 mA, a voxel size of 0.25 mm and a field of view of 16 cm × 13 cm. Stabilised with customised headbands and chin supports, the patients were monitored so that they remained stationary throughout the duration of scanning.

Image Analysis

CBCT images were evaluated using the eXamVision software. After reconstruction of axial, sagittal, cross-sectional and panoramic images for all mandibles, the MIC was colour-marked, and its length was measured on the panoramic reconstructed CBCT images from the starting point (*p1*) up to the endpoint (*p2*), as shown in Figs. 1 and 2. The starting point (*p1*) was defined as the point where the mental nerve exited the mental foramen, while the endpoint (*p2*) was defined as the most mesial point where the canal could be located. The middle point (*p3*) was defined as the midpoint between the starting point (*p1*) and the endpoint (*p2*). The course of the MIC in the buccolingual direction was assessed on the cross-sectional reconstructed CBCT images, as shown in Figs. 3 and 4. The following measurements were performed at the starting point (*p1*), the middle point (*p3*) and the endpoint (*p2*) on both sides of the mandibles:

i. The distance (horizontal) from the centre of the MIC to the buccal cortical plate, *s1*

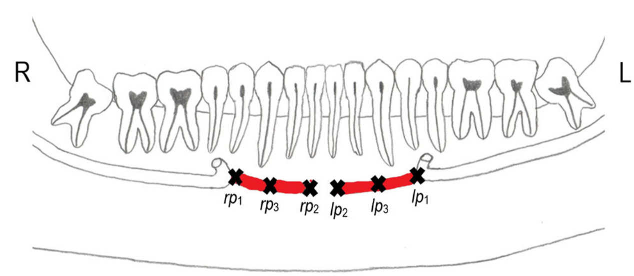

Fig. 1 Illustrated panoramic view of the mandible showing the MIC (red). *lp1*, left starting point; *lp2*, left endpoint; *lp3*, left middle point; *rp1*, right starting point; *rp2*, right endpoint; *rp3*, right middle point; R, patient right side; L, patient left side

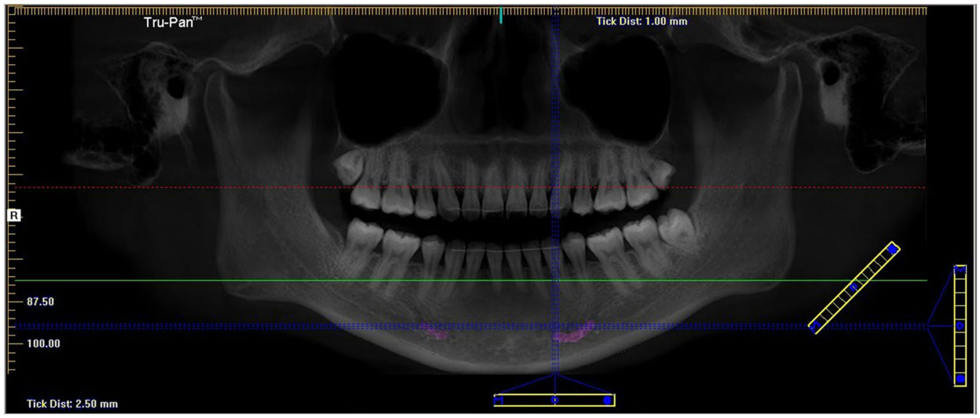

Fig. 2 Panoramic images were reconstructed from the CBCT scans. The length of the MIC was colour-marked in pink and measured from its starting point (*p1*) up to its endpoint (*p2*)

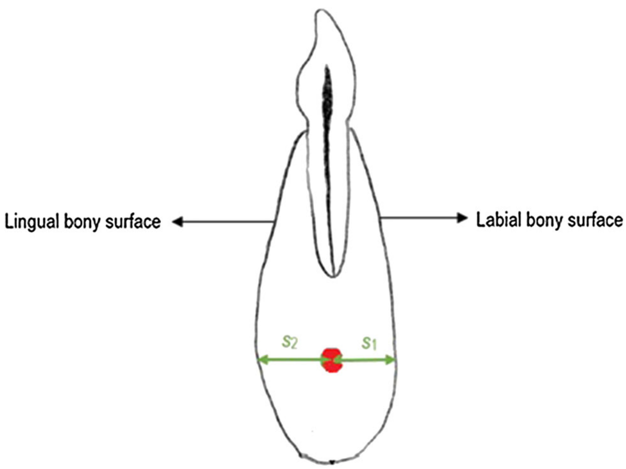

Fig. 3 Illustrated cross-sectional view of the mandible showing the MIC (red). *s1*, horizontal distance from the centre of MIC to the labial bony surface; *s2*, horizontal distance from the centre of MIC to the lingual bony surface

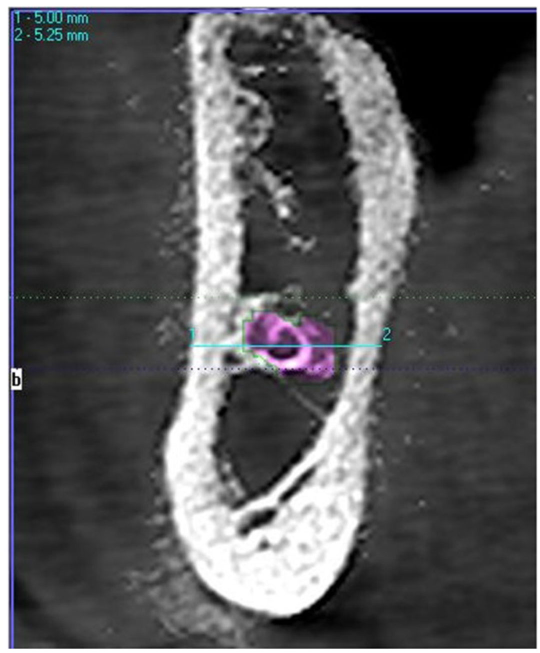

Fig. 4 The horizontal distances from the centre of the MIC to the buccal border (*s1*) and the lingual border (*s2*) of the mandibles were measured on the cross-sectional reconstructed images of the CBCT scans. *s1* was 5.00 mm and *s2* was 5.25 mm

ii. The distance (horizontal) from the centre of the MIC to the lingual cortical plate, *s2*

All measurements were taken twice by the same examiner, and the mean values were considered as the final data. Blinded to all patients' information not visible in the images, the examiner was calibrated to recognise and identify the anatomy of the MIC on ten CBCT images not included in this study.

Statistical Analysis

Statistical analysis was performed using the SPSS Statistics software version 24.0. Independent samples t-test, one-way ANOVA test and paired samples t-test were conducted to analyse the differences in age groups, gender, dental status, Malaysian races and measurements (p \ 0.05).

Results

The study population consists of 47 men and 53 women. The demographics of the patients are described in Fig. 5. The mean length of the MIC was found to be 11.31 mm, with a standard deviation of 2.65 mm. Table 1 summarises the mean length of the MIC based on age groups, gender, races and dental status. The Malays were found to have the longest MIC, while the Indians recorded the shortest MIC on both sides of the mandible ($p < 0.05$). Despite the length of the MIC being greater in males, it was not statistically significant ($p > 0.05$). Also, there was no important variation in measurements of the length of the MIC in different age groups and dental status ($p > 0.05$).

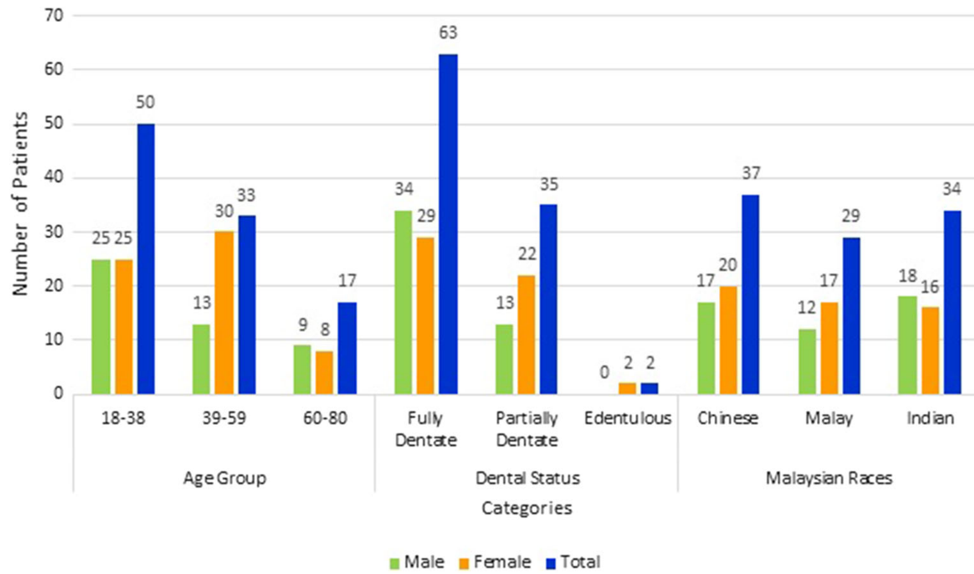

Fig. 5 Demographics of the study population

Tables 2 and 3 summarise the mean distances from the MIC to the lingual and the buccal cortical plates on both sides of the mandible. Overall, the mean horizontal distances from the MIC to the buccal and the lingual cortical plates were 5.06 mm and 5.47 mm, respectively. Therefore, the course of the MIC was slanted more towards the buccal border of the mandible. The mean horizontal distances from the buccal cortical plate were 3.76 ± 1.11 mm at the starting point, 5.54 ± 1.58 mm at the middle point and 5.89 ± 1.70 mm at the endpoint, showing an increasing trend. On the other hand, the mean horizontal distances from the lingual cortical plate revealed a decreasing trend, which was 6.63 ± 1.51 mm at the starting point, 5.07 ± 1.41 mm at the middle point and 4.72 ± 1.61 mm at the endpoint. Hence, it was significantly closer to the buccal cortical plate of the mandible at the starting points and the lingual cortical plate of the mandible at the endpoints, especially in the Indian and the male patients ($p < 0.05$). At the middle point, the canal was more lingually located, but it was only statistically significant in the right mandible ($p < 0.05$). Overall, the MIC ran lingually towards its endpoint. It was positioned further away from the buccal border of the mandible in males along its course on both sides of the mandible. In the edentulous patients, the MIC was closest to the buccal border of the mandible and furthest away from the lingual border of the mandible along its course on both sides of the jaw ($p > 0.05$). There was no significant variation in the course of the MIC in relation to age and dental status.

Discussion

Precise determination of the foramens and their variations in the anterior segment of the mandible is vital in executing the dental implant or any augmentation surgery. The mandibular incisive canal (MIC) is the continuation of the mandibular canal mesial to the mental foramen [7]. The terminal branches of inferior alveolar nerve in the MIC are important anatomic structures which should be preserved during surgeries in the anterior mandible area due to the significant risk of neurosensory damage.

The anatomic length of the MIC was found to be ranging from 20.58 to 21.45 mm in a study conducted by De Andrade et al. [24]. Table 4 compares the mean length of the MIC obtained by radiographic assessment through several studies in different populations. The mean length of the MIC found in all studies, the greatest being 17.84 mm reported by Kong et al. [25] in the Han Chinese population, was less than the ones reported in the cadaveric dissection study, probably due to limitations in the methodology used, as suggested by Makris et al. [7]. With the inclusion of only healthy adults with a full set of dentitions, Kong et al. [25] found that the left and the right MICs were interconnected in some mandibles. In our study, the MIC had an average length of 11.31 mm, which fell within the range of measurements recorded by other studies. There was a variation in the values obtained by different studies. This might be due to population difference, as described by Orhan et al. [2]. Besides, it could be due to the difficulty in identifying the terminal parts of the MIC because it was too small to be visualised on the CBCT scans [17]. Three Tesla magnetic

Table 1 The length of the MIC according to age groups, gender, races and dental status

Length of MIC (mm)	Age groups			p^A	Gender		p^t	Races			p^A	Dental status			p^A	Total
	18–38	39–59	60–80		Male	Female		Chinese	Malay	Indian		Fully dentate	Partially dentate	Edentulous		
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)
Right side	11.36 (3.04)	10.91 (2.57)	11.71 (2.47)	0.60	11.61 (2.69)	10.97 (2.86)	0.25	11.57 (2.78)	12.21 (2.61)	10.15 (2.62)	0.01*	11.10 (2.91)	11.63 (2.50)	10.50 (4.95)	0.61	11.27 (2.79)
Left side	11.40 (2.68)	11.27 (2.70)	11.39 (1.71)	0.98	11.51 (2.37)	11.22 (2.67)	0.57	11.54 (1.95)	12.23 (2.95)	10.40 (2.44)	0.01*	11.33 (2.69)	11.36 (2.31)	12.00 (1.41)	0.94	11.36 (2.53)

The asterisk (*) indicated statistical significance ($p < 0.05$)

p^A, One-way ANOVA test; p^t, Independent samples t-test; *SD*, Standard deviation

Table 2 Horizontal distances from the MIC to the buccal (*s1*) and the lingual (*s2*) border of the right hemimandibles according to age groups, gender, races and dental status

Right side (mm)	Age groups			p^A	Gender		p^t	Races			p^A	Dental status			p^A	Total	p^{tt}
	18–38	39–59	60–80		Male	Female		Chinese	Malay	Indian		Fully dentate	Partially dentate	Edentulous			
	Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	Mean (SD)	Mean (SD)		Mean (SD)	
Starting point, *p1*																	
s1	3.80 (1.12)	3.76 (1.13)	3.61 (1.37)	0.84	3.80 (1.12)	3.72 (1.19)	0.74	4.07 (1.11)	3.89 (1.23)	3.30 (1.01)	0.01*	3.83 (1.16)	3.70 (1.13)	2.38 (1.24)	0.21	3.76 (1.15)	0.0001*
s2	6.49 (1.45)	6.48 (1.41)	7.28 (1.78)	0.14	6.60 (1.61)	6.63 (1.43)	0.92	6.69 (1.48)	6.47 (1.46)	6.67 (1.62)	0.83	6.42 (1.43)	6.86 (1.58)	8.75 (0.35)	0.05	6.62 (1.51)	
Middle point, *p3*																	
s1	5.67 (1.51)	5.52 (1.58)	5.64 (1.49)	0.92	5.76 (1.67)	5.48 (1.37)	0.35	5.72 (1.74)	5.43 (1.44)	5.66 (1.34)	0.74	5.61 (1.55)	5.69 (1.50)	4.50 (0.00)	0.57	5.61 (1.52)	0.01*
s2	4.89 (1.49)	4.87 (1.58)	5.41 (1.16)	0.41	4.93 (1.53)	5.01 (1.43)	0.80	5.04 (1.15)	5.27 (1.88)	4.64 (1.35)	0.22	4.92 (1.53)	5.00 (1.40)	6.13 (0.18)	0.52	4.97 (1.47)	
Endpoint, *p2*																	
s1	5.77 (1.43)	5.88 (1.33)	6.67 (2.29)	0.12	6.24 (1.69)	5.71 (1.48)	0.10	6.07 (1.66)	5.54 (1.28)	6.20 (1.73)	0.23	5.98 (1.53)	5.99 (1.71)	4.75 (2.12)	0.56	5.96 (1.59)	0.0001*
s2	4.88 (1.58)	4.30 (1.55)	4.49 (1.53)	0.24	4.68 (1.59)	4.56 (1.56)	0.70	4.56 (1.41)	5.31 (1.87)	4.09 (1.25)	0.01*	4.63 (1.51)	4.51 (1.65)	5.88 (2.65)	0.49	4.62 (1.57)	

The asterisk (*) indicated statistical significance ($p < 0.05$)

p^A, One-way ANOVA test; p^t, Independent samples t-test; p^{tt}, Paired samples t-test; *SD*, Standard deviation

Table 3 Horizontal distances from the MIC to the buccal (*s1*) and the lingual (*s2*) border of the left hemimandibles according to age groups, gender, races and dental status

Left Side (mm)	Age groups 18–38 Mean (SD)	39–59 Mean (SD)	60–80 Mean (SD)	p^A	Gender Male Mean (SD)	Female Mean (SD)	p^t	Races Chinese Mean (SD)	Malay Mean (SD)	Indian Mean (SD)	p^A	Dental status Fully dentate Mean (SD)	Partially dentate Mean (SD)	Edentulous Mean (SD)	p^A	Total Mean (SD)	p^{tt}
Starting point, *p1*																	
s1	3.85 (1.00)	3.74 (1.16)	3.54 (1.08)	0.59	3.83 (1.16)	3.70 (0.97)	0.54	4.01 (1.07)	4.11 (1.08)	3.20 (0.79)	0.001*	3.84 (1.04)	3.69 (1.06)	2.75 (1.77)	0.32	3.76 (1.06)	0.0001*
s2	6.51 (1.58)	6.61 (1.34)	7.06 (1.58)	0.43	6.60 (1.58)	6.67 (1.45)	0.83	6.65 (1.52)	6.23 (1.44)	6.97 (1.49)	0.15	6.59 (1.50)	6.64 (1.50)	8.13 (1.94)	0.37	6.64 (1.50)	
Middle point, *p3*																	
s1	5.40 (1.62)	5.39 (1.67)	5.75 (1.65)	0.72	5.78 (1.89)	5.18 (1.33)	0.08	5.61 (1.73)	5.82 (1.61)	4.99 (1.46)	0.10	5.49 (1.71)	5.47 (1.51)	4.38 (1.24)	0.64	5.46 (1.63)	0.24
s2	5.14 (1.44)	5.17 (1.14)	5.24 (1.55)	0.96	4.99 (1.33)	5.32 (1.37)	0.23	5.10 (1.36)	4.91 (1.34)	5.45 (1.35)	0.27	5.19 (1.19)	5.05 (1.61)	6.50 (1.06)	0.33	5.16 (1.35)	
Endpoint, *p2*																	
s1	5.62 (1.68)	5.78 (1.48)	6.44 (2.58)	0.27	6.43 (2.03)	5.27 (1.39)	0.001*	6.15 (2.08)	5.50 (1.28)	5.72 (1.86)	0.33	5.79 (1.91)	5.92 (1.63)	4.88 (2.30)	0.72	5.82 (1.81)	0.001*
s2	5.10 (1.89)	4.56 (1.39)	4.56 (1.31)	0.27	4.57 (1.41)	5.06 (1.83)	0.14	4.53 (1.38)	5.31 (1.66)	4.75 (1.87)	0.16	5.01 (1.77)	4.45 (1.36)	5.75 (2.47)	0.21	4.83 (1.66)	

The asterisk (*) indicated statistical significance ($p < 0.05$)

p^A, One-way ANOVA test; p^t, Independent samples t-test; p^{tt}, Paired samples t-test; *SD*, Standard deviation

resonance imaging scanners could be employed in future studies [17].

The major races in Malaysia comprise of the Malays (68.6%), the Chinese (23.4%) and the Indians (7.0%) [26]. In the present study, the length of the MIC was significantly influenced by the races ($p < 0.05$). It was the greatest in the Malays, followed by the Chinese and the Indians. It could be possibly correlated with the significant variation in facial index among races in Malaysia, as found by Shetti et al. [27] and Irfan et al. [28].

Orhan et al. [2] found that the MIC was longer in males ($p < 0.05$) due to the reason that the size of the mandible was larger in males [2]. However, in the present study, despite the mean length of the MIC being greater in males on both sides of the mandible, it was not statistically significant ($p > 0.05$). Nevertheless, Pereira-Maciel et al. [29] reported that the MIC was longer in females ($p > 0.05$). Differences in their sample size as well as the population [2] might be the contributing factors. Also, in our study, the length of the MIC did not vary significantly in different age groups and dental status ($p > 0.05$). Similar results were obtained by Orhan et al. [2]. However, there were limitations in the present study in obtaining sufficient subjects for the older age groups as well as the partially dentate or the edentulous group.

In this study, the MIC deviated lingually from its starting point towards its endpoint in the mandible. This was in agreement with other studies conducted by Al-Ani et al. [23], Orhan et al. [2] and Ramesh et al. [11]. Overall, we found that the MIC had a higher proximity to the buccal cortical plate of the mandible, especially at its starting point. This characteristic was also described by Makris et al. [7], Pires et al. [17], Al-Ani et al. [23], Orhan et al. [2] and Kong et al. [25]. In our study, at the middle point and the endpoint, the MIC was located more lingually in the mandible, with an exception in the edentulous patients and the Indian race. This was in contrast with the findings obtained by Pires et al. [17], Ramesh et al. [11] and Pereira-Maciel et al. [29], where the MIC was closer to the buccal cortical plate of the mandible at its endpoint. At the middle point, Orhan et al. [2] located the MIC closer to the buccal cortical plate of the mandible except in the older and edentulous patients ($p > 0.05$).

The findings of this study suggest that there may be some ethnic features which can influence the course of the MIC and which can be of importance in clinical practice. In this study, the MIC deviated towards the lingual cortical plate of the mandible in all races along its course towards the midline. However, Al-Ani et al. [23] discovered that the MIC in the Malaysian Chinese was consistently against the buccal mandibular border. In contrast, the Malays had their MIC positioned closer to the lingual border and further away from the buccal border of the mandible [23].

Table 4 Comparison of the length of the MIC in different studies

Study	Population	*N*	Mean length of MIC (mm)
Makris et al. [7]	Athens, Greece	100 patients	15.13 ± 5.68
Pires et al. [17]	Northeast Ohio, USA	89 patients	7.0 ± 3.8
Orhan et al. [2]	Turkish	356 patients	12.4
Pereira-Maciel et al. [29]	Brazilian	100 patients	9.8 ± 3.8
Ramesh et al. [11]	Indian, India	120 patients	10.173 ± 4.682
Kong et al. [25]	Han Chinese, China	50 patients	17.84 (left), 17.73 (right)

Nevertheless, in the present study, it was found that the MIC of the Malays was significantly furthest away from the lingual cortical plate of the right hemimandible at its endpoint ($p < 0.05$). The MIC was located nearest to the buccal cortical plate in the Indian race ($p < 0.05$) at its starting points on both sides of the mandible.

Moreover, we found that the MIC was closer to the buccal cortical plate of the mandible in females. It was statistically significant at the endpoint in the left hemimandible. Similarly, Al-Ani et al. [23] described the MIC to be further away from the buccal border in males ($p < 0.05$) because the median distances were greater in males due to their more prominent and bigger chin. However, the size of the mandible and the jaw relationship were not measured to identify the presence of any correlation [23]. Besides, in our study, there was no statistically important variation in the course of the MIC in relation to age and dental status. Nonetheless, Orhan et al. [2] found that the buccal course of the MIC at the starting point was significant ($p < 0.05$) in the older and edentulous patients due to the pattern of mandibular resorption with loss of teeth and ageing process [2, 30].

On the other hand, Al-Juboori et al. [31] stated that the position of the mental foramen varied in relation to Malaysian races, gender and age. Levine et al. [32] found that the buccolingual location of inferior alveolar nerve canal was related to age and race in the USA. The canal was closer to the buccal border of the mandible in the older and the White patients [32]. Owing to proximity to the anatomic structures, future studies with enhanced methodology needed to be performed to verify the significance of anatomic variation of the MIC in these aspects.

Considering the course of the MIC along its starting points up to the endpoints, it can be recommended, in Malaysian races, to give bone harvesting cuts deep up to 3–4 mm to provide some safe distance from the MIC in the anterior mandible. This is in accordance with the recommendation by Pommer et al. [33] who suggested depth of cuts up to 4 mm in Caucasians. Also, since the course of the MIC in the symphysis area is more towards the lingual cortical plate, deeper harvesting of cancellous bone from the symphysis region can be done close to the midline of the mandible. However, it is important to explore the possibility of the presence of the mandibular incisive nerve trunk. Moreover, since the MIC is close to the buccal cortical plate, implant placement should be oriented towards the lingual border of the mandible, especially in the premolar and the canine areas with prosthetic-driven insertions.

In conclusion, we found variations in measurement of the length and the course of the MIC. Penetration of the MIC could occur if the decision was made only based on the average length and course of the MIC. Therefore, assessment of the MIC should be performed using CBCT on a case-by-case basis as it provides essential information during the preoperative planning for surgery in the anterior mandible.

Acknowledgements This work was supported by the Grant BDS I1-14(03)2017 from the International Medical University, Malaysia.

References

1. Von Arx T, Häfliger J, Chappuis V (2005) Neurosensory disturbances following bone harvesting in the symphysis: a prospective clinical study. Clin Oral Implants Res 16(4):432–439
2. Orhan K, Icen M, Aksoy S, Ozan O, Berberoglu A (2014) Cone-beam CT evaluation of morphology, location, and course of mandibular incisive canal: considerations for implant treatment. Oral Radiol 30(1):64–75
3. Jacobs R, Mraiwa N, van Steenberghe D, Sanderink G, Quirynen M (2004) Appearance of the mandibular incisive canal on panoramic radiographs. Surg Radiol Anat 26(4):329–333
4. Bavitz JB, Harn SD, Hansen CA, Lang M (1993) An anatomical study of mental neurovascular bundle-implant relationships. Int J Oral Maxillofac Implants 8(5):563–567
5. Mardinger O, Chaushu G, Arensburg B, Taicher S, Kaffe I (2000) Anatomic and radiologic course of the mandibular incisive canal. Surg Radiol Anat 22(3–4):157–161
6. McDonnell D, Reza Nouri M, Todd ME (1994) The mandibular lingual foramen: a consistent arterial foramen in the middle of the mandible. J Anat 184(Pt 2):363–369
7. Makris N, Stamatakis H, Syriopoulos K, Tsiklakis K, Van Der Stelt PF (2010) Evaluation of the visibility and the course of the mandibular incisive canal and the lingual foramen using cone-beam computed tomography. Clin Oral Implants Res 21(7):766–771
8. Mraiwa N, Jacobs R, Moerman P, Lambrichts I, van Steenberghe D, Quirynen M (2003) Presence and course of the incisive canal

in the human mandibular interforaminal region: two-dimensional imaging versus anatomical observations. Surg Radiol Anat 25(5–6):416–423
9. Yovchev D, Deliverska E, Indjova J, Zhelyazkova M (2013) Mandibular incisive canal: a cone beam computed tomography study. Biotechnol Biotechnol Equip 27(3):3848–3851
10. Sokhn S, Nasseh I, Noujeim M (2011) Using cone beam computed tomography to determine safe regions for implant placement. Gen Dent 59(2):e72–e77
11. Ramesh AS, Rijesh K, Sharma A, Prakash R, Karthik KA (2015) The prevalence of mandibular incisive nerve canal and to evaluate its average location and dimension in Indian population. J Pharm Bioallied Sci 7:594–596
12. Wismeijer D, van Waas MA, Vermeeren JI, Kalk W (1997) Patients' perception of sensory disturbances of the mental nerve before and after implant surgery: a prospective study of 110 patients. Br J Oral Maxillofac Surg 35(4):254–259
13. Raitz R, Shimura E, Chilvarquer I, Fenyo-Pereira M (2014) Assessment of the mandibular incisive canal by panoramic radiograph and cone-beam computed tomography. Int J Dent. https://doi.org/10.1155/2014/187085
14. Kütük N, Demirbaş AE, Gönen ZB et al (2013) Anterior mandibular zone safe for implants. J Craniofac Surg 24(4):e405–e408
15. Apostolakis D, Brown JE (2012) The anterior loop of the inferior alveolar nerve: prevalence, measurement of its length and a recommendation for interforaminal implant installation based on cone beam CT imaging. Clin Oral Implants Res 23(9):1022–1030
16. Kalender A, Orhan K, Aksoy U (2012) Evaluation of the mental foramen and accessory mental foramen in Turkish patients using cone-beam computed tomography images reconstructed from a volumetric rendering program. Clin Anat 25(5):584–592
17. Pires CA, Bissada NF, Becker JJ, Kanawati A, Landers MA (2012) Mandibular incisive canal: cone beam computed tomography. Clin Implant Dent Relat Res 14(1):67–73
18. Uchida Y, Noguchi N, Goto M et al (2009) Measurement of anterior loop length for the mandibular canal and diameter of the mandibular incisive canal to avoid nerve damage when installing endosseous implants in the interforaminal region: a second attempt introducing cone beam computed tomography. J Oral Maxillofac Surg 67(4):744–750
19. Sahman H, Sekerci AE, Sisman Y, Payveren M (2014) Assessment of the visibility and characteristics of the mandibular incisive canal: cone beam computed tomography versus panoramic radiography. Int J Oral Maxillofac Implants 29(1):71–78
20. de Santos TS, Gomes ACA, de Melo DG et al (2012) Evaluation of reliability and reproducibility of linear measurements of cone-beam-computed tomography. Indian J Dent Res. 23(4):473–478
21. Kajan ZD, Salari A (2012) Presence and course of the mandibular incisive canal and presence of the anterior loop in cone beam computed tomography images of an Iranian population. Oral Radiol 28(1):55–61
22. Kamburoğlu K, Kılıç C, Özen T, Yüksel SP (2009) Measurements of mandibular canal region obtained by cone-beam computed tomography: a cadaveric study. Oral Surgery Oral Med Oral Pathol Oral Radiol Endodontol 107(2):e34–e42
23. Al-Ani O, Nambiar P, Ha KO, Ngeow WC (2013) Safe zone for bone harvesting from the interforaminal region of the mandible. Clin Oral Implants Res 24(A100):115–121
24. De Andrade E, Otomo-Corgel J, Pucher J, Ranganath KA, St George N (2001) The intraosseous course of the mandibular incisive nerve in the mandibular symphysis. Int J Periodontics Restor Dent 21(6):591–597
25. Kong N, Hui M, Miao F, Yuan H, Du Y, Chen N (2016) Mandibular incisive canal in Han Chinese using cone beam computed tomography. Int J Oral Maxillofac Surg 45(9):1142–1146
26. Malaysian Department of Statistics. Current Population Estimates, Malaysia, 2014-2016. Department of Statistics, Malaysia. 2016. https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=155&bul_id=OWlxdEVoYlJCS0hUZzJyRUcvZEYxZz09&menu_id=L0pheU43NWJwRWVSZklWdzQ4TlhUUT09. Accessed 7 Feb 2017
27. Shetti VR, Pai SR, Gupta C (2011) Study of prosopic (Facial) index of Indian and Malaysian students. Int J Morphol 29(3):1018–1021
28. Irfan M, Wai Leng C, RanikaMalissa Perera L, Kumar Palaniappan K, Fatima Z (2016) Facial index among the ethnic races of Malaysian population—an anthropometric study. IOSR J Dent Med Sci 15:2279–2861
29. Pereira-Maciel P, Tavares-De-Sousa E, Oliveira-Sales MA (2015) The mandibular incisive canal and its anatomical relationships: a cone beam computed tomography study. Med Oral Patol Oral Cir Bucal 20(6):e723–e728
30. Enlow DH, Bianco HJ, Eklund S (1976) The remodeling of the edentulous mandible. J Prosthet Dent 36(6):685–693
31. Al-Juboori MJ, Atya BK, Balachandran SA, Eirutharajan N, Fang LY (2014) Inter-mental foramina distance significant and variation among races: mini review. Unique Res J Med Med Sci 2(3):19–31
32. Levine MH, Goddard AL, Dodson TB (2007) Inferior alveolar nerve canal position: a clinical and radiographic study. J Oral Maxillofac Surg 65(3):470–474
33. Pommer B, Tepper G, Gahleitner A, Zechner W, Watzek G (2008) New safety margins for chin bone harvesting based on the course of the mandibular incisive canal in CT. Clin Oral Implants Res 19(12):1312–1316