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ORIGINAL ARTICLE

A retrospective comparison of the location and diameter of the inferior alveolar canal at the mental foramen and length of the anterior loop between American and Taiwanese cohorts using CBCT

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Abstract
Purpose The aim was to retrospectively compare the measurements of the location and size of the inferior alveolar canal at the mental foramen and the length of the anterior loop between two cohorts of Americans and Taiwanese using cone-beam computed tomography (CBCT).
Methods CBCT was performed with an I-CAT® Cone-Beam 3D Dental Imaging System and reconstructed into multiple-plane views to measure two populations.
Results There was no statistically significant difference ($P = 0.2681$) in the distance from the mental foramen to the inferior border of the mandible (mandibular border height) between Americans (9.84 ± 2.01 mm) and Taiwanese (10.13 ± 1.66 mm). No significant difference was found ($p = 0.1161$) in the inferior alveolar canal diameter between these two cohorts (2.26 ± 0.67 and 2.13 ± 0.47 mm, respectively). However, the anterior loop length of Taiwanese (7.61 ± 1.81 mm) was significantly longer than that of Americans (6.22 ± 1.68 mm) ($P < 0.0001$).
Conclusion Our study indicated that (1) the location of mental foramen of Americans was closer to the inferior border of the mandible than Taiwanese; (2) the diameter of the inferior alveolar canal of Americans was larger than Taiwanese; (3) the anterior loop of Taiwanese was longer than Americans. These differences may be, at least partly, due to the racial influence and this information may possess potential valuable clinical relevance.

Keywords Mental foramen · Anterior loop · Cone-beam computed tomography

Abbreviations

CBCT	Cone-beam computed tomography
MBH	Mandibular border height
IACD	Inferior alveolar canal diameter
ALL	Anterior loop length

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Introduction

Understanding the detailed anatomy of the inferior alveolar nerve is essential for dental practitioners to avoid potential injuries to the nerve during surgical procedures or endodontic treatment. It has been reported that jawbone surgeries could cause damage to the inferior alveolar nerve [12, 13, 21, 22]. Neurosensory disturbances of the chin and lower lip are among the most frequent accidental complications during implant placements, often due to failure to identify and protect the structures of mental foramen and anterior loop [19, 20]. Consequently, the use of appropriate imaging techniques is important in identifying the exact location of the mental foramen and anterior loop structures when a dental implant is installed into the premolar and molar regions. Cone-beam computed tomography (CBCT) has been developed to produce a highly detailed 3-dimensional image of dentomaxillofacial structures and is widely employed in radiographic examinations for routine oral surgical procedures [19, 20].

Some studies [9, 15] have reported that CBCT imaging allows detection and measurement of the mental foramen with greater accuracy than conventional radiography. Kim et al. [11] reported a comparison of CBCT and direct measurement in the examination of the inferior alveolar nerve and adjacent structures. The authors showed that there was no statistically significant difference between anatomic measurements and measurements derived from CBCT. In addition, Hanihara and Ishida [7] reported that the frequencies of multiple mental foramina were high in central Asians and sub-Saharan Africans. However, to our knowledge, a comparative study on the length of the anterior loop and the location and diameter of the mental foramen between Americans and Taiwanese has not yet been demonstrated. Hence, the current retrospective study examined cohorts of American and Taiwanese patients using CBCT to compare the measurements of the size and location of mental foramen and anterior loop.

Materials and methods

Subjects

Imaging data from CBCT examinations of two different groups (Groups 1 and 2) of patients who had an anterior loop as detected radiographically were retrospectively analyzed. Group 1 consisted of 100 Americans (53 males and 47 females) ranging from 21 to 79 years with a mean age of 53.32 ± 12.75 years. The patients of Group 1 had been referred to the University of Detroit Mercy School of Dentistry Oral and Maxillofacial Imaging Center from 2009 to 2010 for CBCT examination before undergoing dental implant treatments. Group 2 contained 100 Taiwanese adults (55 males and 45 females) ranging in age from 20 to 82 years with an average age of 53.73 ± 13.15 years. The patients from Group 2 had been referred to the GIE 3D imaging center in Kaohsiung, Taiwan, from 2006 to 2009 for CBCT scans prior to implant treatments. This study was approved by the Institutional Review Board of our institution. Those patients from both Groups 1 and 2 with an anterior loop visible on CBCT images were selected for subsequent analyses.

CBCT system

CBCT was performed at both institutions with an I-CAT® Cone-Beam 3D Dental Imaging System Model 17–19 (Imaging Sciences International, Hatfield, PA, USA) using default parameters (120 kVp, 23.87 mAs, 6 cm field of view, 0.3 or 0.4 mm voxel size, medium sharpness filter) and measurement software (i-CATVision™ VisionQ version 1.8.1.10). The occlusal plane of each patient was set parallel to the floor base using a chin rest and the acquired images were reconstructed into multiple-plane views (axial, panoramic and cross-sectional views) and 3-dimensional representations (Fig. 1). The CBCT units were calibrated at least once per week.

CBCT image analyses

The cross-sectional views perpendicular to the mandibular dental arch (Fig. 2a) were used to measure the following parameters: the distance from the inferior aspect of the inferior alveolar canal to the inferior border of the mandible (the mandibular border height, or MBH) and inferior alveolar canal diameter (IACD). The part of panoramic view along the inferior alveolar nerve canal reconstructed from the axial view (Fig. 2b) was used to measure the anterior loop length (ALL) (Fig. 2c). Measurements were made on the right side only, by two examiners (J.C.H. Chen and Y.K. Chen) independently. Both examiners have been experienced in acquiring and interpreting CBCT scans. When a disagreement existed between the two examiners, agreement was reached by mutual discussion.

Comparisons of CBCT image measurements between the patients of the cohorts of Taiwanese and Americans were tested using independent two-sample t tests for comparisons of measurements between males and females, and ANOVA tests for comparisons by age interval. The patients were classified into age intervals as follows: (1) 20–29 years, (2) 30–39 years, (3) 40–49 years, (4) 50–59 years, and (5) 60 years and older. Two-sample t tests were performed to compare all measurements between males and females by independent population and ANOVA tests were used to compare differences between various age intervals by independent population. All measurements were denoted as mean ± standard deviation. All statistical assessments were two-sided and considered significant if $P < 0.05$. Statistical analyses were done using SPSS 15.0 statistical software (SPSS Inc, Chicago, IL, USA).

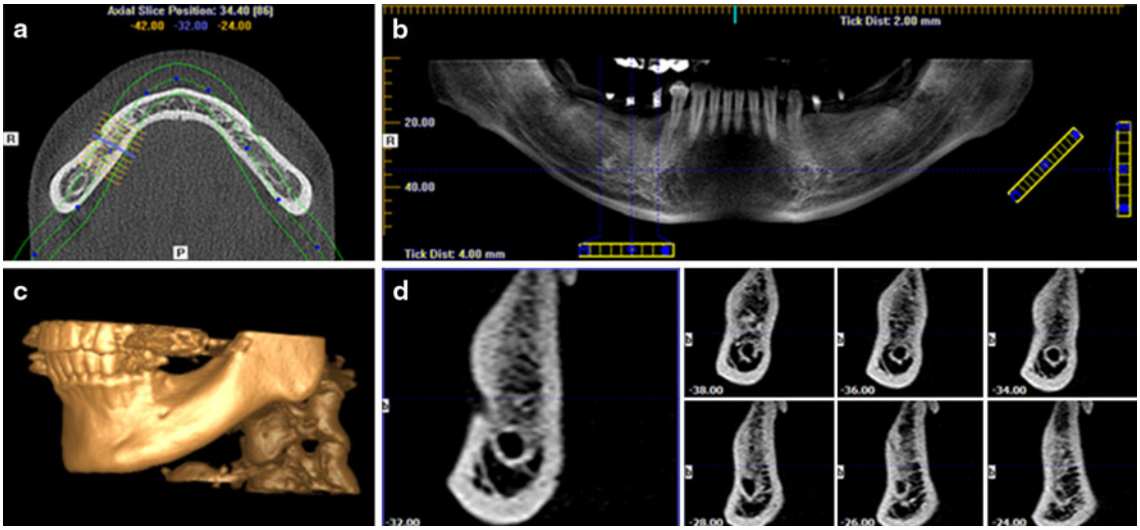

Fig. 1 Cone-beam CT images: **a** axial, **b** panoramic, **c** 3-dimensional reconstruction, and **d** cross-sectional views

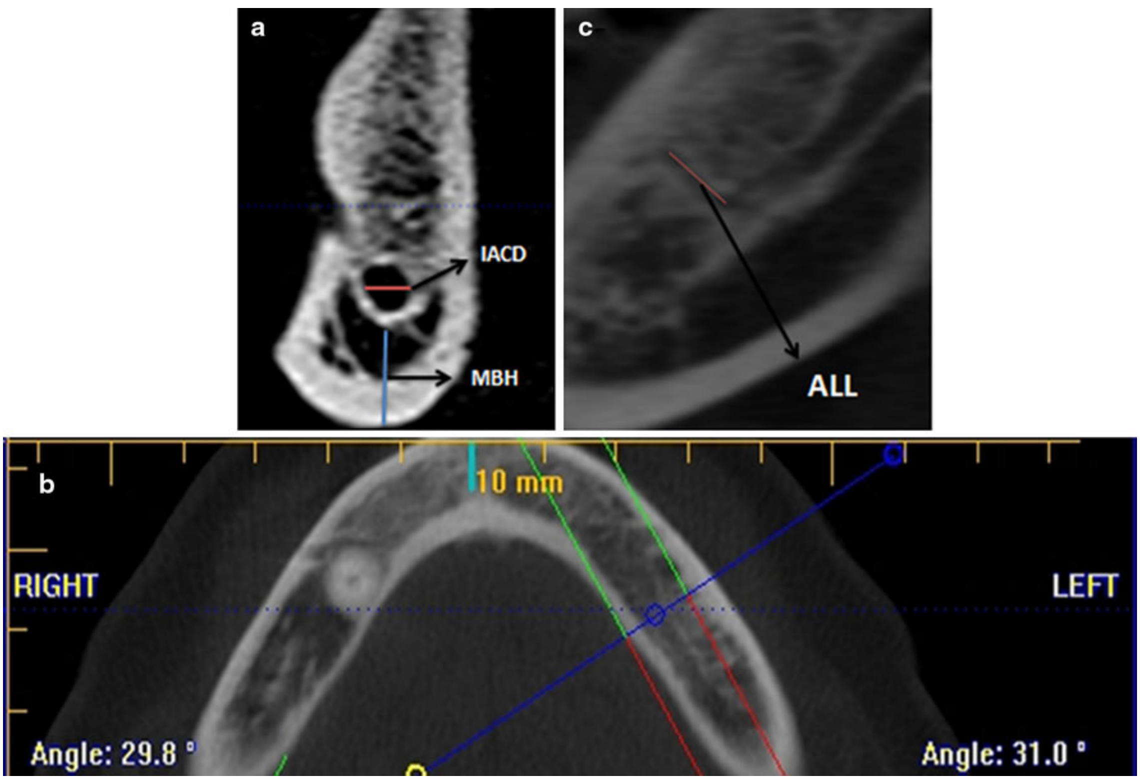

Fig. 2 **a** The cross-sectional view with enhanced resolution demonstrated the longest diameter of the inferior alveolar canal (IAC) at the level of the mental foramen (*red line*) and the distance from the inferior border of the IAC to the mandibular border height (*blue line*); **b** the axial view was used to reconstruct part of the panoramic view along the inferior alveolar nerve canal; **c** the distance between the anteriormost point and the inferior alveolar canal was measured (colour figure online)

Results

Measurements of MBH, IACD and ALL are listed in Table 1

The mean MBH measurements for Group 1 (Americans) and Group 2 (Taiwanese) were 9.84 and 10.13 mm, respectively. There was no statistically significant difference in MBH when compared between Groups 1 and 2 ($P = 0.2681$). In addition, no significant difference in IACD was found between Groups 1 and 2 ($P = 0.1161$). However, the ALL of Group 2 (7.61 ± 1.81 mm) was significantly longer than that of Group 1 (6.22 ± 1.68 mm) ($P < 0.0001$).

Table 1 Measurements of mental foramen to mandibular border height (MBH), mental foramen diameter (IACD) and anterior loop length (ALL) for the images cone-beam CT of Group 1 (American) and Group 2 (Taiwanese) patients

	Group 1				Group 2				
	Number	Mean ± SD[a]	Lower 95 %	Upper 95 %	Number	Mean ± SD	Lower 95 %	Upper 95 %	*P* value
MBH	100	9.84 ± 2.01	9.44	10.24	100	10.13 ± 1.66	9.80	10.46	0.2681
IACD	100	2.26 ± 0.67	2.13	2.40	100	2.13 ± 0.47	2.04	2.23	0.1161
ALL	100	6.22 ± 1.68	5.88	6.55	100	7.61 ± 1.81	7.25	7.97	<0.0001[b]

[a] Standard deviation

[b] Statistically significant

Measurements and comparisons of MBH with various age intervals and sex (Fig. 3a–d; Table 2)

Within each of Groups 1 and 2, there were no significant differences in MBH when compared, respectively, with different age intervals (Group 1: $P = 0.6510$, Group 2: $P = 0.1890$; Fig. 3a). However, as indicated in Fig. 3b, there was a significant difference in MBH between Groups 1 and 2 when compared for the age interval 1 (20–29 years; $P = 0.0461$).

For comparisons of MBH with sex, there were significant differences in MBH between male and female for each of Groups 1 ($P = 0.0224$; Fig. 3c) and 2 ($P = 0.0086$; Fig. 3c). However, as observed in Fig. 3d, there were no significant differences in MBH when compared between Groups 1 and 2 for females ($P = 0.3698$) and males ($P = 0.5086$).

Measurements and comparisons of IACD with various age intervals and sex (Fig. 4a–d; Table 2)

Within each of Groups 1 and 2, there were no significant differences in IACD when compared, respectively, with different age intervals (Group 1: $P = 0.3142$, Group 2: $P = 0.9952$; Fig. 4a). Moreover, as depicted in Fig. 4b, there were no significant differences in IACD between

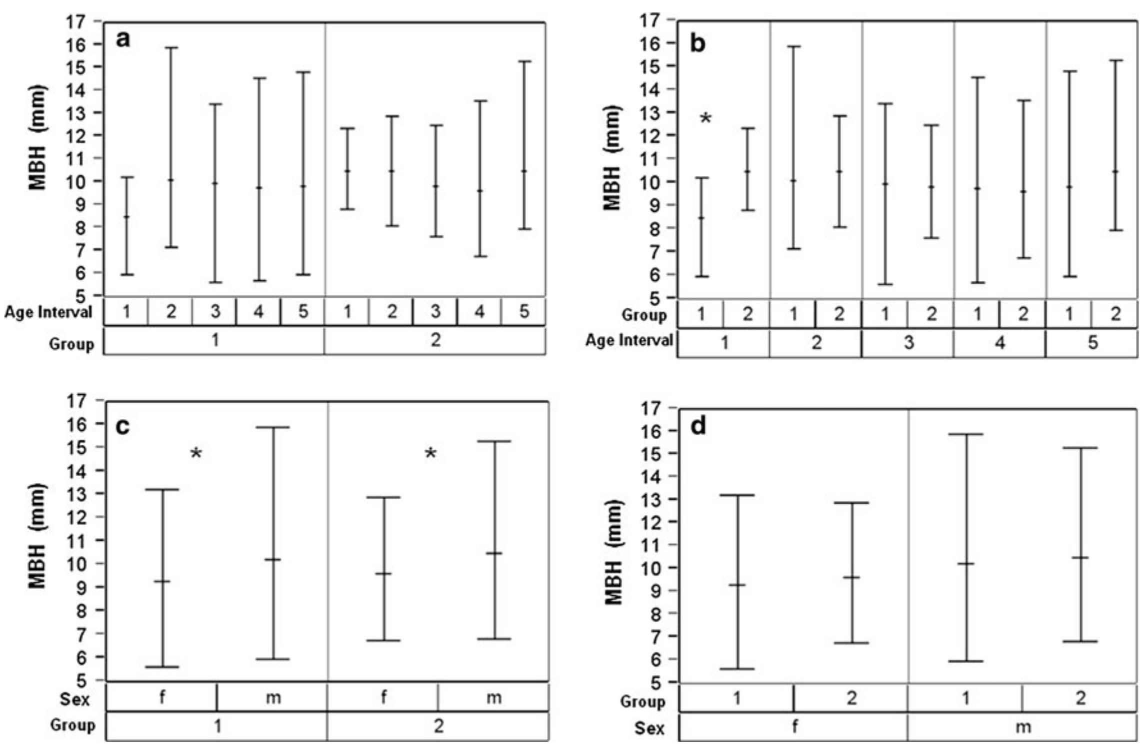

Fig. 3 Comparisons of mental foramen the mandibular border height (MBH) (distance from the inferior aspect of the inferior alveolar canal (IAC) at the level of the mental foramen to the inferior border of the mandible) with various age intervals and sex. **a** Age intervals within each of Groups 1 (American) and 2 (Taiwanese), **b** Groups 1 and 2 within various age intervals, **c** sex within each of Groups 1 and 2, **d** Groups 1 and 2 within each sex. Age intervals *1* 20–29 years, *2* 30–39 years, *3* 40–49 years, *4* 50–59 years, *5* ≥60 years, *f* female, *m* male; *statistically significance

Table 2 Measurements of mental foramen to mandibular border height (MBH), mental foramen diameter (IACD) and anterior loop length (ALL) with various age intervals and sex for the images cone-beam CT of Group 1 (American) and Group 2 (Taiwanese) patients

	MBH Mean ± SD[a]	IACD Mean ± SD	ALL Mean ± SD
Sex (female)	9.50 ± 1.57	2.14 ± 0.53	6.52 ± 1.62
Sex (male)	10.40 ± 1.96	2.24 ± 0.62	7.25 ± 2.02
Age interval 1	9.61 ± 1.68	2.07 ± 0.55	6.70 ± 1.36
Age interval 2	10.33 ± 2.24	2.13 ± 0.50	7.20 ± 1.96
Age interval 3	9.95 ± 1.86	2.20 ± 0.56	6.88 ± 1.89
Age interval 4	9.74 ± 1.82	2.30 ± 0.64	6.95 ± 1.81
Age interval 5	10.24 ± 1.77	2.13 ± 0.55	6.85 ± 2.04
Group 1	9.84 ± 2.01	2.26 ± 0.67	6.22 ± 1.68
Group 2	10.13 ± 1.66	2.130 ± 0.47	7.61 ± 1.81
Group 1: Sex (female)	9.36 ± 1.74	2.21 ± 0.57	6.04 ± 1.56
Group 1: Sex (male)	10.27 ± 2.14	2.30 ± 0.75	6.37 ± 1.79
Group 2: Sex (female)	9.65 ± 1.38	2.07 ± 0.49	7.01 ± 1.54
Group 2: Sex (male)	10.52 ± 1.78	2.19 ± 0.46	8.10 ± 1.88
Group 1: Age interval 1	8.54 ± 1.65	2.05 ± 0.38	6.29 ± 0.82
Group 1: Age interval 2	10.15 ± 2.42	2.11 ± 0.59	6.96 ± 1.55
Group 1: Age interval 3	10.02 ± 2.09	2.32 ± 0.68	6.01 ± 1.73
Group 1: Age interval 4	9.82 ± 2.02	2.42 ± 0.74	6.14 ± 1.91
Group 1: Age interval 5	9.87 ± 1.88	2.11 ± 0.60	6.18 ± 1.52
Group 2: Age interval 1	10.50 ± 1.18	2.09 ± 0.69	7.05 ± 1.68
Group 2: Age interval 2	10.56 ± 2.12	2.15 ± 0.39	7.51 ± 2.45
Group 2: Age interval 3	9.88 ± 1.67	2.10 ± 0.42	7.66 ± 1.71
Group 2: Age interval 4	9.65 ± 1.57	2.14 ± 0.46	7.92 ± 1.07
Group 2: Age interval 5	10.56 ± 1.63	2.15 ± 0.52	7.42 ± 2.27

Age intervals 1: 20–29 years; 2: 30–39 years; 3: 40–49 years; 4: 50–59 years; 5: ≥60 years

[a] Standard deviation

Groups 1 and 2 when compared, respectively, for all the age intervals (1: 20–29 years, $P = 0.9058$; 2: 30–39 years, $P = 0.8742$; 3: 40–49 years, $P = 0.2325$; 4: 50–59 years, $P = 0.0718$ and 5: ≤60 years, $P = 0.7957$).

There was no significant difference in IACD between male and female for each of Groups 1 ($P = 0.5090$; Fig. 4c) and 2 ($P = 0.2085$; Fig. 4c). Also, as noted in Fig. 4d, there were no significant differences in IACD when compared between Groups 1 and 2 for each of female ($P = 0.1832$) and male ($P = 0.3277$).

Measurements and comparisons of ALL with various age intervals and sex (Fig. 5a–d; Table 2)

Within each of Groups 1 and 2, there were no significant differences in ALL when compared, respectively, with different age intervals (Group 1: $P = 0.6857$, Group 2: $P = 0.7678$; Fig. 5a). However, as indicated in Fig. 5b, there were significant differences in ALL between Groups 1 and 2 when compared, respectively, for the age intervals 3 (40–49 years; $P = 0.0044$), 4 (50–59 years; $P < 0.0001$) and 5 (≤60 years; $P = 0.0148$).

There was no significant difference in ALL between males and females within Group 1 ($P = 0.3246$; Fig. 5c) but, as shown in Fig. 5d, there was a significant difference in ALL between males and females within Group 2 ($P = 0.0025$). On the other hand, there was a significant difference in ALL when compared between Groups 1 and 2 for each of female ($P = 0.0033$) and male ($P < 0.0001$).

Discussion

The mental foramen is an important anatomic landmark for dental practitioners and there is a possibility that an anterior loop of the mental nerve may exist, as reported by Haktanir et al. [6] using multi-detector CT. Such information should be considered and is critical prior to dental implant insertion to avoid potential mental nerve injury [5]. Panoramic radiography has been used to study the position of mental foramen [1, 23]; the modern imaging resource CBCT provides a more accurate 3-dimensional evaluation of mental foramen as well as the identification of its variations. However, in earlier studies [3, 14], measurements of the anterior loop at the mental foramen were performed on cadavers, which present limitations to real clinical applications. In the present study, CBCT images of patients were employed and this would have an advantage on clinical practices. In addition, to the best of our knowledge, our study is the first to focus on comparative measurements

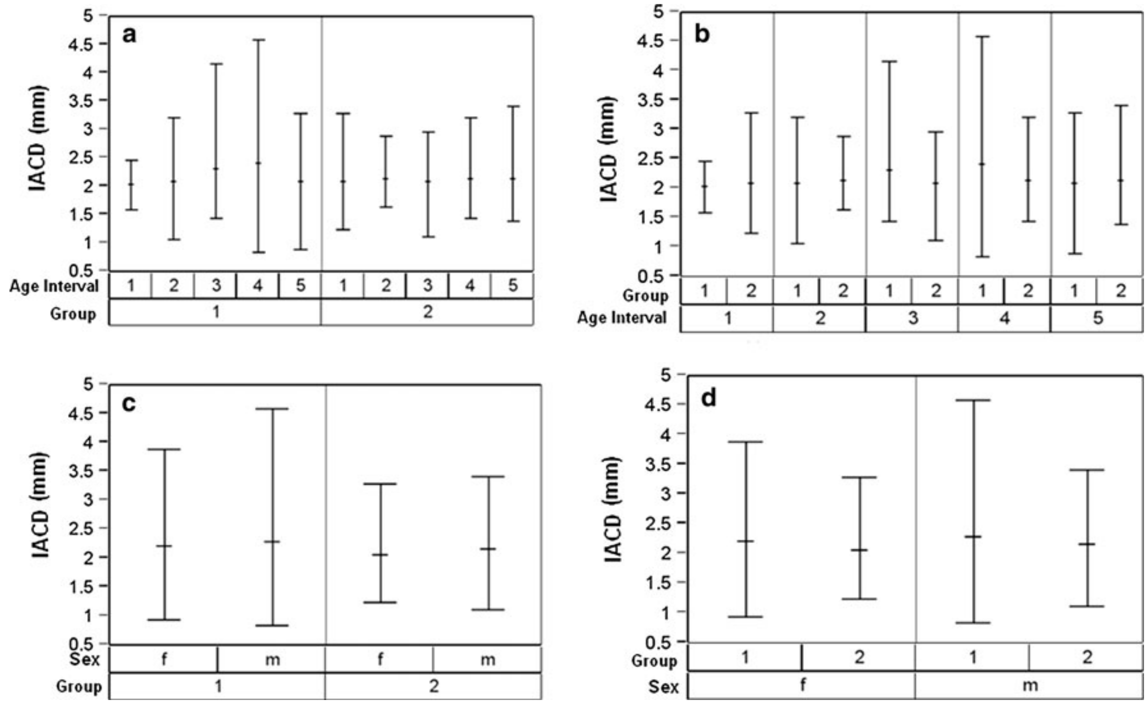

Fig. 4 Comparisons of diameter of the inferior alveolar canal (IAC) at the level of the mental foramen with various age intervals and sex. **a** Age intervals within each of Groups 1 (American) and 2 (Taiwanese), **b** Groups 1 and 2 within various age intervals, **c** Sex within each of Groups 1 and 2, **d** Groups 1 and 2 within each sex. Age intervals *1* 20–29 years; *2* 30–39 years; *3* 40–49 years; *4* 50–59 years; *5* ≥60 years; *f* female, *m* male; *statistically significant

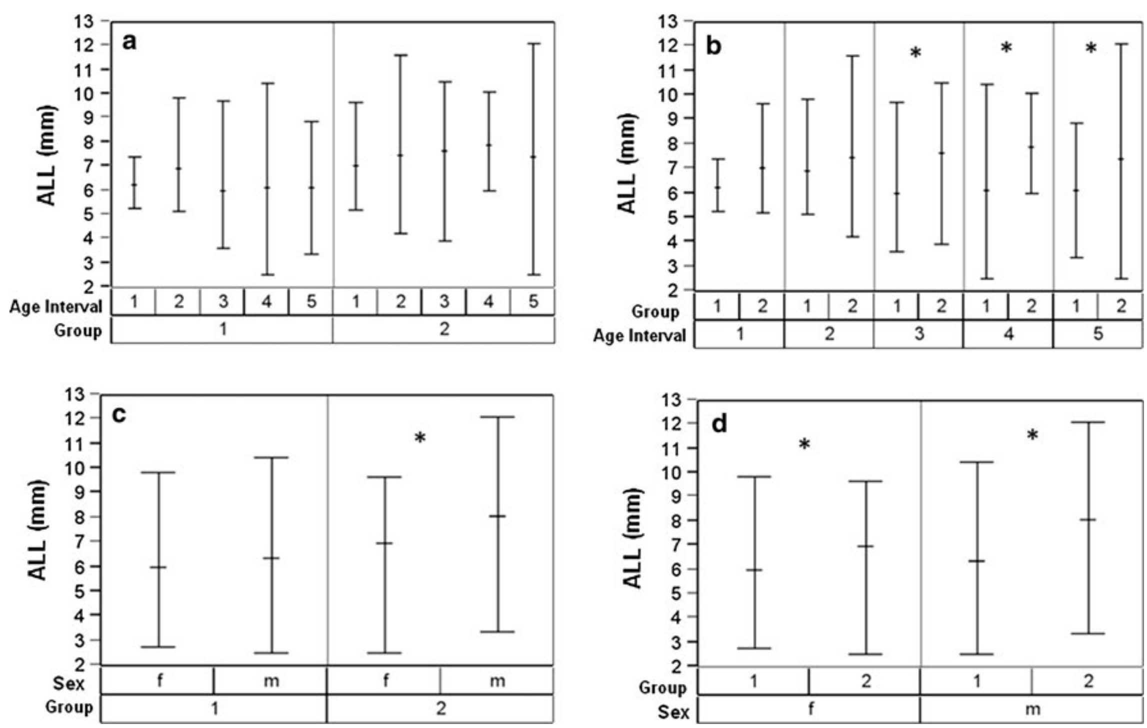

Fig. 5 Comparisons of anterior loop length (ALL) with various age intervals and sex. **a** Age intervals within each of Groups 1 (American) and 2 (Taiwanese), **b** Groups 1 and 2 within various age intervals, **c** Sex within each of Groups 1 and 2, **d** Groups 1 and 2 within each sex. Age intervals *1* 20–29 years; *2* 30–39 years; *3* 40–49 years; *4* 50–59 years; *5* ≥60 years; *f* female, *m* male; *statistically significance

of the inferior alveolar canal at mental foramen and anterior loop between Americans and Taiwanese using CBCT images.

Yu and Wong [26] in 2008 found that the inferior alveolar nerve canal was located at 7.6 mm above the lower border of the mandible. Also, Kilic et al. [10] in 2010 demonstrated that the mean distance from the inferior alveolar nerve canal to the lower border of the mandible was 10.52 ± 1.7 mm. In the present study, the mean IAC to mandibular border height (MBH) was 9.84 and 10.13 mm, respectively, for the American and Taiwanese groups without statistically significant differences between these two cohorts. Research indicates that the distance from the inferior border of the mandible to the IAC at the level of the mental foramen remains relatively unchanged during life [25]. This would support our finding of no significant difference in MBH over age groups within each cohort. The significant difference between cohorts in various age intervals may be related to racial variation between the Taiwanese and American populations. In 2006, Apinhasmit et al. [2] examined the distance of the mental foramen from the inferior border of the mandible in an Asian population and an anatomical variation related to gender and side. There were no measurements varied according to the sides, but gender differences were significant in all measurements.

Chung et al. [4] reported the diameter of the mental foramen to be 2.4 mm in Koreans, whereas Oguz and Bozkir [18] demonstrated the diameter was 2.93 mm on the right side and 3.14 mm on the left side for Turkish subjects. Chung et al. [4] as well as Oguz and Bozkir [18] were measuring the actual mental foramen, whereas our measurement is the buccal-lingual diameter of the IAC, measured at the site of the mental foramen. These measurements, despite not actually the same thing, are probably similar, since a large part of the IAC exits through the mental foramen and therefore the foramen should have the same diameter as the IAC. In addition, Hanihara and Ishihara [7] in 2001 determined a high frequency of multiple mental foramina in central Asians and sub-Saharan Africans. Mental foramen diameters in our study were 2.26 mm in American and 2.13 mm in Taiwanese, with no significant difference between these two different cohorts.

Neiva et al. [16] and Hwang et al. [8] reported that the length of the anterior loop was more than 5 mm. In our study, the mean lengths of the anterior loop of Taiwanese and Americans were 7.61 ± 1.81, 6.22 ± 1.68 mm, respectively (both greater than 5 mm), and are consistent with the aforementioned findings. Consequently, for clinical considerations such as dental implant surgery, an ALL greater than 5 mm could be considered as a reliable criterion, and this knowledge might help implant surgeons avoid potential nerve injury. Uchida et al. [24] in 2007 showed no significant differences in the comparison of ALL with side (right or left) or dental status. Accordingly, measurements were made on only one side without consideration on the dental status in the current study. Uchida et al. [24] also found that there were statistically significant differences in ALL with gender and age. Ngeow et al. [17] indicated that the frequency of anterior loops decreases with age. By contrast, in the current study, we found no significant difference in ALL when compared, respectively, with different age intervals of both cohorts of American and Taiwanese. However, there were significant differences in ALL between cohorts of American and Taiwanese when compared, respectively, for older age intervals (40–49, 50–59 and $\leq$60 years). Also, there was no significant difference of ALL between male and female for American cohort, but a significant difference between male and female was noted for Taiwanese cohort. In addition, there was a significant difference of ALL when compared between American and Taiwanese cohorts for both males and females.

Conflict of interest The authors declare that they have no conflict of interest.

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