Surgical and Radiologic Anatomy (2019) 41:927–934
https://doi.org/10.1007/s00276-019-02250-7

ORIGINAL ARTICLE

Cone-beam CT assessment of implant-related anatomy landmarks of the anterior mandible in a Chinese population

Liangkun Xie[1] · Ting Li[1] · Jianzhong Chen[2] · Dahai Yin[3] · Weihong Wang[4] · Zhigang Xie[1]

Received: 9 January 2019 / Accepted: 29 April 2019 / Published online: 8 May 2019

Abstract

Purpose To investigate the prevalence, location, and morphology of the mandibular lingual foramen (MLF), mandibular incisive canal (MIC), and anterior loop of the inferior alveolar canal (ALC) in a Chinese population using cone-beam CT (CBCT).

Materials and methods From 2014 to 2016, CBCT images from patients with various scanning purposes were obtained from the database of the Affiliated Stomatology Hospital of Kunming Medical University, China. Imaging analyses of the MLF, MIC, and ALC were performed via the NNT viewer software. The prevalence, location, length, classification of MLF, and its distances to the alveolar crest and the lower border of mandible were investigated, and the prevalence and length of MIC and the prevalence of ALC were also studied.

Results This study examined 1008 subjects, 521 (51.7%) males, and 487 (48.3%) females. 916 (90.9%) subjects showed the medial lingual foramina (LF), a single medial LF with the supraspinous-type predominating. Lateral LF were observed in 547 (54.3%) subjects mostly located in the premolar areas. 876 (86.9%) subjects had the MIC on the left side, whereas 877 (87.0%) had the MIC on the right side. The ALC was present in 147 (14.6%) subjects.

Conclusions This study showed a high prevalence of LF and MIC in the Southwest Chinese population. Therefore, caution should be taken during the implant treatment at the anterior mandible region.

Keywords Mandible · Lingual foramen · Lingual canal · Anterior loop · Mental nerve · Incisive nerve · Cone-beam computed tomography · Anatomical landmarks

Introduction

Lingual foramen (LF) of the mandible as a nutrient canal containing artery ramifications has gained increasing attention due to the rapid growth of implant dentistry in recent decades. The anterior mandibular region between the mental foramina is no longer considered a safe area for implant restoration, since many cases of life-threatening hemorrhage on the floor of the mouth following implant placement in that region have been reported [9, 10]. Damage of vascular content in the mandibular lingual canal (MLC) during implant surgery was a potential cause for life-threatening hemorrhage [15, 16]. Nevertheless, nerve-containing structures of the mandibular incisive canal (MIC), which runs beyond the mental foramen, and of the anterior loop of the inferior alveolar canal (ALC) exhibit risks of nerve injury [16]. Those clinical complications might be caused by the misdiagnosis of relevant anatomical structures.

✉ Weihong Wang
wwh2002191@163.com

✉ Zhigang Xie
13708425039@163.com

[1] Department of Oral Implantology, The Affiliated Stomatology Hospital of Kunming Medical University, Kunming 650106, China

[2] Department of Oral Anatomy and Physiology, School of Stomatology, Kunming Medical University, Kunming 650500, China

[3] Department of Oral Radiology, The Affiliated Stomatology Hospital of Kunming Medical University, Kunming 650106, China

[4] Department of Oral and Maxillofacial Surgery, The Affiliated Stomatology Hospital of Kunming Medical University, Kunming 650106, China

Advanced radiography technology has brought implant dentistry into a new era; mandibular lingual foramina (MLF), MIC, and ALC can be clearly observed by cone-beam computed tomography (CBCT) scanning [5]. Several studies that utilized CBCT have found these anatomic structures in different populations, such as Japanese [17], Iranian [11], and Brazilian populations [21]. In this respect, it is essential to preoperatively examine the anterior mandibular region by taking advantage of CBCT, which provides a more accurate image evaluation [4]. A recent meta-analysis showed a significantly high frequency of MLF [3]. However, there is considerable variation between studies from different countries in terms of the study sample size and measurement methods, and most of the studies only focused on one anatomic structure, since all three structures have a significant impact on causing severe complications with implant surgery [11, 17, 21].

Due to craniofacial anatomy variations among different populations, implementation of implant treatment should consider this regional anatomical variation [13]. The implant therapy demand has dramatically increased in China, especially considering cases of implant placement at the anterior region of the mandible for edentulous patients. Therefore, data from the Chinese population that reveals the prevalence and other parameters of the MLF, MIC, and ALC can be a useful guideline for the reduction of risks. However, few Chinese studies have focused on those anatomical structures. One study from Sichuan province revealed that 85.07% of MLF were median lingual canals in 200 subjects [8]. A recent study reported a frequency of 99.3% of MLF at midline symphysis in 299 subjects in Southeast China [27]. There is a lack of data regarding those anatomical structures in Yunnan Province, Southwest China. Therefore, our research performed a larger sample size study for obtaining more thorough data about this issue.

The present study aimed to investigate the prevalence, location, and morphology of MLF, MIC, and ALC in the Chinese population in the southwestern region of China.

Materials and methods

CBCT images from patients with various scanning purposes between 2014 and 2016 were obtained from a database of the Affiliated Stomatology Hospital of Kunming Medical University, Kunming, Yunnan, China. The inclusion criteria were that images be of patients who were the age of 18 or older and that the images were of good quality and showing the whole mandible. Either dentation or partial edentulous conditions were included. The exclusion criteria were images of patients younger than 18 years; the absence of records of patients' status such as name, sex, or age; the presence of any deformities of the mandibles, pathologic conditions, history of fracture, or previous iatrogenic manipulation of the mandible that altered the anatomical structures. Total edentulous mandible images were excluded due to no tooth landmark for positioning the studied structures. The protocol and ethical concern of this study had been approved by Kunming Medical University and the Ethics Committee of Kunming Medical University, Kunming, Yunnan, China in 2013.

A CBCT machine (NewTom VG, Italy) was used for scanning all subjects, with technical parameters 110 kVp and 3.05 mA pulsed, an exposure time of 3.6 s and fields of view (FOV) 20 cm × 25 cm with a 14-bit grey scale signal, the voxel size was 0.3 mm. The NNT viewer (version 5.10, NewTom, Italy) was utilized for imaging analysis.

Mandibular lingual foramen (MLF)

Under the MPR (multi-planar reconstruction) view offered by the NNT viewer, a section in the sagittal plane in which a thin canal-like radiolucency from the lingual side entered to the middle line of the mandible was identified as the medial lingual foramen (medial LF) and medial lingual canal (medial LC). The number of medial lingual foramina and their canals in one subject were expressed as follows: if there was a single foramen presented, it was marked as Z1 foramen; if there were more than one foramen present in one subject, the uppermost one was still marked as Z1 foramen, the next one down was marked as Z2 foramen, and the followings were marked as Z3, Z4 foramen, etc. The length of the canal and distances from the middle point of the alveolar crest (labial–lingual direction) to the medial LF and from the medial LF to the lowest border of the mandible was measured (Fig. 1). According to Thompson's classification [23], the foramen located vertically, at a level that was superior or inferior to the genial spine, was classified as a supraspinous foramen (SF) or an infraspinous foramen (IFF), respectively. A foramen at the same level as the genial spine was classified as an interspinous foramen (ITF). The lateral lingual foramen (lateral LF) and its canal were identified as any canal-like radiolucency that showed an interruption of continuity of the lingual cortical surface that penetrated into the body of the mandible, similar to the medial LF but not present in the midline of the mandible. The length of the canal and distances from the middle point of the alveolar crest (labial–lingual direction) to the lateral LF and from the lateral LF to the lowest border of the mandible was measured. The location of lateral lingual foramen was registered by its vertically correlated the tooth position. A total of nine locations were categorized as type 1 (lateral incisor), type 2 (between lateral incisor and canine), type 3 (canine), type 4 (between the canine and first premolar),

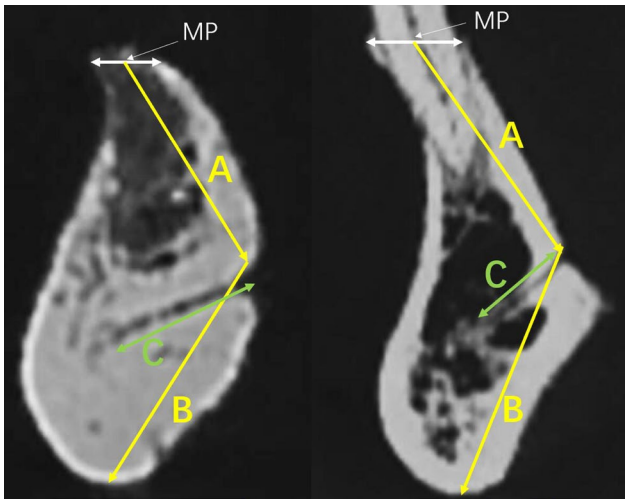

Fig. 1 Measurements of the medial lingual foramina. *MP* middle point of the alveolar crest (labial–lingual direction). **A** Distance from MP to the medial lingual foramen. **B** Distance from MP to the lowest border of the mandible. **C** Length of the canal

type 5 (first premolar), type 6 (between the first premolar and second premolar), type 7 (second premolar), type 8 (between the second premolar and first molar), or type 9 (first molar).

Mandibular incisive canal (MIC)

The MPR view was used to measure the length of the mandibular incisive canal (MIC). A horizontal section was made along with the incisive canal and adjusted for showing the full length of the incisive canal. The length measurement started at the point of the mental foramen opening and ended at the tip of the last visible canal-like radiolucency (Fig. 2).

Anterior loop of the inferior alveolar canal (ALC)

A panoramic view offered by the NNT viewer was used for quick screening of this structure. A clear returning curve of the inferior alveolar canal at the mental foramen region was recorded as the presence of the loop, and then, the prevalence of this structure was studied.

Statistical analysis

The data were analyzed using SPSS 17.0 (IBM, Chicago, IL, USA). According to the distributions of data, the results were described as the means and their standard deviations (mean ± SD) and percentages. The *t* test, Chi-square test, Fisher exact test, and Wilcoxon rank test were adopted to detect differences between males and females in related

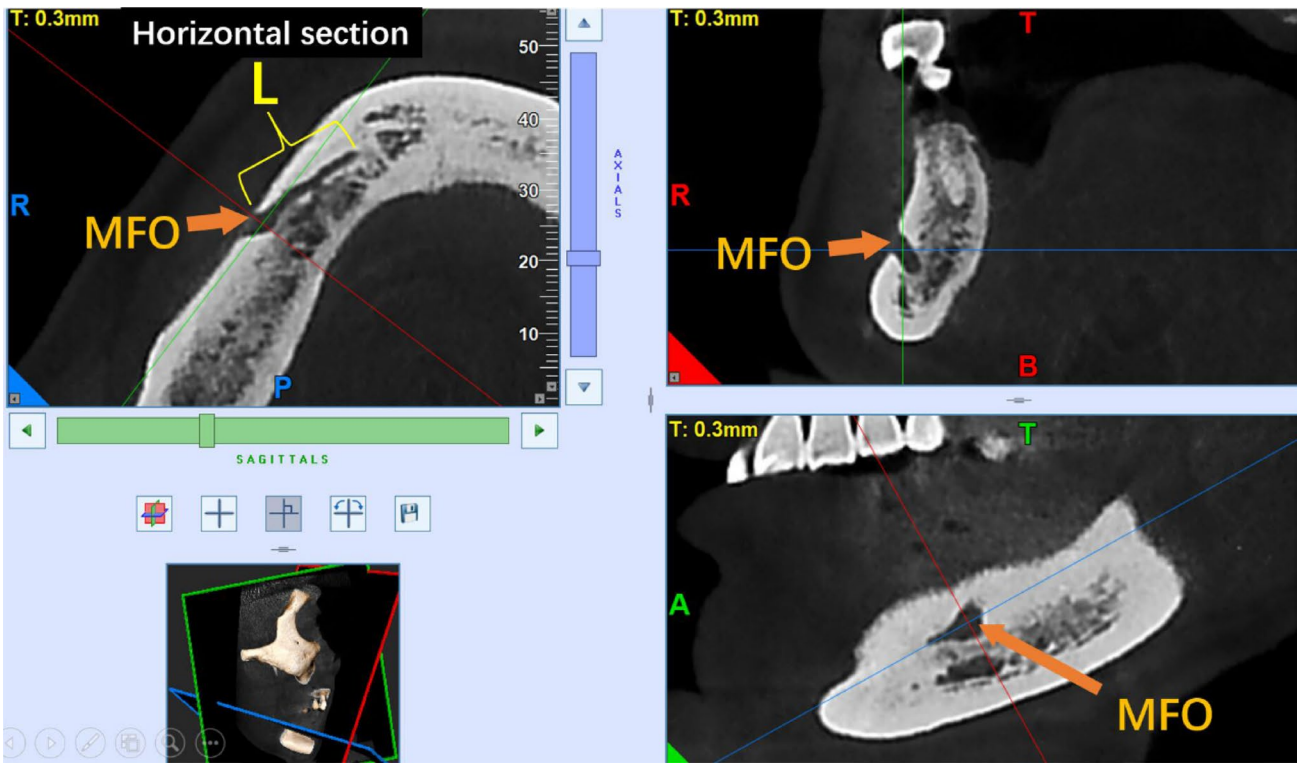

Fig. 2 The length measurement of lateral lingual canal. *L* the length of the lateral lingual canal. *MFO* mental foramen opening. Upper left-hand side image showed a horizontal section along with the long axis of the canal for showing the whole length

variables. The relationships between parameters of the lingual foramen and sexes and ages were tested by Spearman's rank correlation coefficient. All the significance tests were two-sided, and p values less than or equal to 0.05 were considered indicative of statistical significance.

Results

In total, 1008 subjects were eligible for analysis, including 521 (51.7%) males and 487 (48.3%) females, with a median age of 41.1 ± 14.81 years.

Medial lingual foramen (medial LF)

916 (90.9%) subjects showed medial lingual foramina, including 322 (31.9%) males and 352 (34.9%) females who had a single medial LF, 134 (13.3%) males and 87 (8.6%) females who had two medial LF, and 17 (1.7%) males and 4 (0.4%) females who had three medial LF. 92 (9.1%) subjects had no medial LF (Fig. 3). The results from a Chi-square test that compared the distribution of the different numbers of medial LF present in both sexes showed the female subjects had a higher prevalence of having one medial lingual foramen rather than having more foramina ($p < 0.001$). Regardless of the number of foramina present in one subject (only one or more than one), the Z1 foramen (only or the uppermost foramen) was observed been 65.5% of the supraspinous type, followed by 20.8% of the interspinous type and 13.7% of the infraspinous type. The Chi-square test showed a significant difference in those three types of Z1 foramina were distributed in the sexes; males had a higher prevalence of the infraspinous type than females ($p < 0.001$). When the second and the third foramina presented, they were mostly the infraspinous type, and no significant difference was found between the sexes (Table 1). The length of the canal and distances from the middle point of the alveolar crest (labial–lingual direction) to the medial LF and from the medial LF to the lowest border of the mandible of those three types of foramina (SF, ITF, and IFF) is shown in Table 2. The t test showed that the Z1 foramen had a significantly longer canal length and a longer distance from the middle point of the alveolar crest (labial–lingual direction) to the foramen in male subjects ($p < 0.001$). A weak correlation was revealed

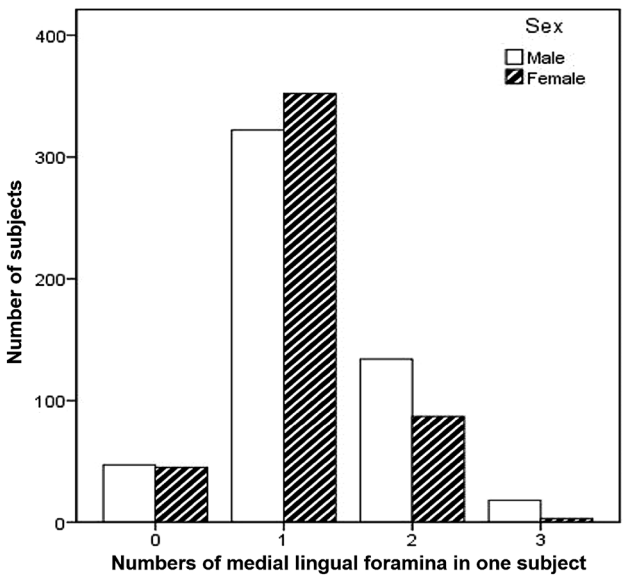

Fig. 3 Distribution of different numbers of medial lingual foramina in subjects

Table 1 Distribution and classifications of different medial lingual foramina in both sexes

Medial lingual foramina	Classifications	Male (n, %)	Female (n, %)	p value
Z1	SF	191 (45.8)	226 (54.2)	< 0.001
	ITF	64 (41.0)	92 (59.0)	
	IFF	67 (66.3)	34 (33.7)	
Z2	SF + ITF	26 (61.9)	16 (38.1)	0.851
	IFF	108 (60.3)	71 (39.7)	
Z3	SF + ITF	2 (66.7)	1 (33.3)	0.489*
	IFF	15 (83.3)	3 (16.7)	

Z1 the only or the first and most vertically upper medial lingual foramen, *Z2* the second upper medial lingual foramen, *Z3* the third upper medial lingual foramen, *SF* supraspinous foramen, *ITF* interspinous foramen, *IFF* infraspinous foramen

*Fisher's exact test

Table 2 Measurements of different medial lingual foramina in both sexes in millimeter (mean ± SD)

Measurements	Sex		p value
	Male	Female	
Z1-C	6.69 ± 1.62	6.27 ± 1.63	< 0.001
Z1-A	21.33 ± 4.46	19.63 ± 3.71	< 0.001
Z1-B	14.14 ± 3.11	13.76 ± 2.66	0.047
Z2-C	6.20 ± 1.96	6.02 ± 1.88	0.483
Z2-A	26.38 ± 4.81	25.18 ± 4.74	0.060
Z2-B	8.79 ± 3.36	8.54 ± 3.44	0.575
Z3-C	5.20 ± 1.28	4.50 ± 1.23	0.392
Z3-A	29.05 ± 5.56	18.87 ± 11.68	0.112*
Z3-B	6.08 ± 4.07	13.47 ± 13.03	0.186*

Z1/2/3-A the distance from the middle point of the alveolar crest to the Z1/2/3 medial lingual foramen (as the opening), *Z1/2/3-B* the distance from the middle point of the alveolar crest to the lowest border of the mandible, *Z1/2/3-C* the length of the Z1/2/3 canals

*Wilcoxon rank test

by Spearman's rank correlation coefficient between the number of medial lingual foramina and the age ($r=0.069$, $p=0.029$) and the sexes ($r=-0.108$, $p=0.001$).

Lateral lingual foramen (lateral LF)

The lateral LF was found in 547 (54.3%) subjects; of those subjects, 365 (36.2%) had only one foramen, 178 (17.7%) had two foramina, and 4 (0.4%) had three or more than three foramina. 461 (45.7%) subjects presented no lateral lingual foramen. With regard to the distribution of foramina between the sexes, no difference was found by the Fisher exact test ($p=0.904$). The length of the canal and distances from the middle point of the alveolar crest (labial–lingual direction) to the lateral LF and from the lateral LF to the lowest border of the mandible is shown in Table 3. Regardless the length of the canal, the distances (as described above in relation to the foramina) from different sexes showed the significance by *t* test. In short, male subjects had longer distances both from the foramen to the crest and to the border of the mandible. Moreover, based on Spearman's rank correlation coefficient, a weak correlation was found between the number of lateral LF and the age ($r=-0.085$, $p=0.007$), but no correlations between the number of lateral LF and the number of medial LF ($r=0.049$, $p=0.118$) and sexes ($r=0.011$, $p=0.718$) were found. The most frequent appearance of lateral LF vertically correlated with the positions of teeth was the premolar areas, with 78.5% on the left side and 79.9% on the right side (Table 4).

Table 3 Measurements of different lateral lingual foramina and the length of the incisive canal in different sexes in mini meter (mean ± SD)

Measurements	Sex		*p* value
	Male	Female	
LL-D	6.09 ± 1.70	5.99 ± 1.66	0.580
LL-A	23.54 ± 3.31	22.17 ± 2.93	< 0.001
LL-B	9.22 ± 2.18	8.71 ± 1.84	0.022
RL-D	6.12 ± 1.67	6.35 ± 2.79	0.600
RL-A	23.66 ± 3.29	22.46 ± 3.27	< 0.001
RL-B	9.11 ± 1.99	8.86 ± 2.51	0.290
LIC	9.65 ± 2.94	9.27 ± 2.98	0.062
RIC	9.65 ± 3.20	9.42 ± 4.25	0.367

LL/RL-A on the left/right side, the distance from the middle point of the alveolar crest (labial–lingual direction) to the lateral lingual foramen (as the opening), *LL/RL-B* on the left/right side, the distance from the lateral lingual foramen to the lowest border of the mandible, *L/RL-D* on the left/right side, the length of the lateral lingual canal, *L/RIC* the length of left/right incisive canal

Mandibular incisive canal (MIC)

876 (86.9%) subjects were found to have the MIC on the left side with a length of 9.46 ± 2.97 mm, 877 (87.0%) subjects had it on the right side with a length of 9.46 ± 3.14 mm, and 795 (78.9%) subjects had the MIC on both sides. No difference was detected in the length of the MIC between the left and right sides and sexes by *t* test (Table 3).

Anterior loop of the inferior alveolar canal (ALC)

According to the panoramic image, the ALC was observed in 147 (14.6%) subjects. 41 subjects had the ALC only on the left side, 41 subjects had it only on the right side, and 65 subjects had the ALC on both sides. The distribution of ALC in different sexes was not significantly different as determined by the Chi-square test ($p=0.3943$).

Discussion

Medial lingual foramen

This study, which had a large sample size from the Southwest Chinese population, showed baseline data of anatomical

Table 4 Frequencies of the lateral lingual foramina vertically correlated with the positions of teeth

Locations	Numbers of subjects presented the lateral lingual foramina (*n*, %)	
	Left (339, 100.0%)	Right (383, 100.0%)
Lateral incisor	17 (5.0)	10 (2.6)
Between the lateral incisor and canine	5 (1.5)	5 (1.3)
Canine	13 (3.8)	10 (2.6)
Between the canine and first premolar	18 (5.3)	13 (3.4)
First premolar	43 (12.7)	71 (18.5)
Between the first premolar and second premolar	119 (35.1)	108 (28.2)
Second premolar	104 (30.7)	127 (33.2)
Between the second premolar and first molar	7 (2.1)	29 (7.6)
First molar	13 (3.8)	10 (2.6)

structures related to implant treatment in the anterior mandible. Medial LF had been reported with a prevalence between 78.9 and 100% [22, 24, 26], revealing a considerable variation among studies. Our data showed that 90.9% of 1008 subjects having medial lingual foramina showing a lower prevalence compared to another study of Chinese population with a 98% prevalence in 200 subjects [8]. However, the study had a smaller sample size and looked at a different region in China comparing to our study. Unfortunately, to the best of our knowledge, a study with the largest sample size (4051 subjects) performed an evaluation of anatomic accessory canals in the jaws that did not reveal the prevalence of medial LF clearly, but rather reported 'the presence of two lingual canals at the midline of the mandible (12.6%)' [6]. Overall, it seems that the sex is not a significant factor related to the prevalence of medial LF, as both sexes had a similar prevalence. Interestingly, female subjects had a higher prevalence of having only one medial LF rather than having more foramina when compared to males. This was the only correlation found between the different sexes in presenting different numbers of medial LF. Unlike many studies with no classification of individual medial LF [8, 26], we implemented Thompson's classification system for every medial LF. The solid data showed that the supraspinous type was dominant when a single foramen or the uppermost foramen presented. Moreover, this dominant type of foramen had longer distances measured to the alveolar crest and to the border of the mandible and a longer canal length in male subjects. Therefore, it seems that the male subjects had a larger size in the vertical length of the mandible in this region. Regarding measuring the distances, unlike other studies that measured vertical distances (perpendicular to horizontal plane) from the foramen to the alveolar crest and the lower border of the mandible [8, 26], we directly measured the point-to-point distances (as previously described). This was more practicable as a clinically application view, because the point-to-point measuring direction was closer and more relevant to a direction of implant placement than it was to a vertical direction placement. This point-to-point distance might become a warning limit for placing an implant that required the drilling depth no deeper than this distance. Nevertheless, the vertical distance measurement relied on a fixation of the horizontal plane which was not easily or reliably achieved.

Lateral lingual foramen

The appearance rate of lateral LF was even more variable; prevalence rates from 16.69 to 80% [22, 26] have been reported. This study showed a medium level of prevalence of this foramen. The location of lateral LF was an interesting observation, since it reminded clinicians to avoid penetrating or damaging this structure and to especially kept it intact at the entering point of the lingual side. Developing on other studies, Romanos [19] found that the lateral incisor and canine region mostly showed lateral LF. Whereas the Chinese study showed similar distributions from lateral incisor to second premolar [8]. We found that a prominent appearing region was premolar areas. Again, males showed a longer length in a vertical dimension of the mandibular body region. Interestingly, among subjects having lateral LF, a weak correlation was found between the number of lateral LF and the age, and it was suggested that the elder subjects might be prone to having more numbers of lateral LF compared to younger subjects. Therefore, a careful radiographic analysis of lateral LF is needed for all implant therapy candidates, especially the elder patients.

Mandibular incisive canal and anterior loop of the inferior alveolar canal

CBCT provided advanced image quality with minimal distortion and accurate magnification measuring the MIC compared with 2D radiography [12]. Our study took the horizontal section along the longitudinal axis of the mandible for displaying and measuring the whole course of the canal. This method was practicable, less time-consuming, repeatable and feasible for large sample size screening. Unsurprisingly, the MIC and ALC have been studied extensively. Regarding the prevalence of the MIC, our study agrees with Pires [18], Makris [14], and Apostolakis [2]. However, one study with 50 Chinese subjects of CBCT scanning showed a 100% appearance of MIC, and the average lengths of MIC at the left and right sites were 17.84 mm and 17.73 mm, respectively, which showed a higher prevalence and longer length of MIC comparing to our study [12]. However, it had a relatively small sample size. Moreover, Yang performed a similar CBCT study of Chinese population that also revealed a high incidence of 97.33% of MIC, but they showed an average length of 9.97 mm of MIC, which was very close to our results [25]. ALC has long been noticed in the literature, and it should not be misdiagnosed before implant surgery. However, it is difficult and time-consuming to distinguish and measure the ALC when performing analyses of a large number of images. Therefore, our study used a fast way to screen for the ALC by observing the panoramic view under the NNT viewer software. Though the recent literature on using CBCT showed the prevalence of ALC varying from 28.5% [20], 48% [1], 70.1% [24], to 100% [7], the prevalence of 14.6% in our study was relatively low. This might be due to the observation of the panoramic image simulated by the software, of which the shortcoming of two-dimensional imaging would limit the sensitivity of detection, or might be truly due to the anatomical variations of different populations. Avoiding the shortcoming of screening the panoramic view, a study from China investigated the relationship

between the ALC and the mental foramen by CBCT and a 3D reconstruction software showed precise measurements of ALC [4]. However, it was a time-consuming process for analyses and only 60 subjects were investigated.

In conclusion, the present study with a large sample size revealed a high prevalence of the lingual foramina in the Chinese population in Southwest China. A single medial lingual foramen with the supraspinous type showed the highest prevalence among lingual foramina, whereas lateral lingual foramina were often detected at premolar areas. Together with the data of the mandibular incisive canal and anterior loop of the inferior alveolar canal, the caution should be taken during the implant treatment at the anterior mandible region.

Author contributions LX project development, data management, data analysis, manuscript writing, and editing. TL, JC, and DY data management. WW project development, data analysis, and editing. ZX data management and data analysis.

Funding This work was supported by the National Natural Science Foundation of China (Grant No. 81660184) and the Science and Technology Innovation Team Project of Kunming Medical University (CXTD201711).

Compliance with ethical standards

Conflict of interest Authors declared no conflict of interest.

References

1. 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 23:1022–1030. https://doi.org/10.1111/j.1600-0501.2011.02261.x
2. Apostolakis D, Brown JE (2013) The dimensions of the mandibular incisive canal and its spatial relationship to various anatomical landmarks of the mandible: a study using cone beam computed tomography. Int J Oral Maxillofac Implants 28:117–124. https://doi.org/10.11607/jomi.2372
3. Bernardi S, Bianchi S, Continenza MA, Macchiarelli G (2017) Frequency and anatomical features of the mandibular lingual foramina: systematic review and meta-analysis. Surg Radiol Anat 39:1349–1357. https://doi.org/10.1007/s00276-017-1888-x
4. Chen Z, Chen D, Tang L, Wang F (2015) Relationship between the position of the mental foramen and the anterior loop of the inferior alveolar nerve as determined by cone beam computed tomography combined with mimics. J Comput Assist Tomogr 39:86–93. https://doi.org/10.1097/RCT.0000000000000166
5. do Carmo-Oliveira M, Tedesco TK, Gimenez T, Allegrini S Jr (2018) Analysis of the frequency of visualization of morphological variations in anatomical bone features in the mandibular interforaminal region through cone-beam computed tomography. Surg Radiol Anat 40:1119–1131. https://doi.org/10.1007/s00276-018-2040-2
6. Eshak M, Brooks S, Abdel-Wahed N, Edwards PC (2014) Cone beam CT evaluation of the presence of anatomic accessory canals in the jaws. Dentomaxillofac Radiol 43:1–8. https://doi.org/10.1259/dmfr.20130259
7. Gomez-Roman G, Lautner NV, Goldammer C, McCoy M (2015) Anterior loop of the mandibular canal-a source of possible complications. Implant Dent 24:578–585. https://doi.org/10.1097/ID.0000000000000312
8. He X, Jiang J, Cai W, Pan Y, Yang Y, Zhu K, Zheng Y (2016) Assessment of the appearance, location and morphology of mandibular lingual foramina using cone beam computed tomography. Int Dent J 66:272–279. https://doi.org/10.1111/idj.12242
9. Jo JH, Kim SG, Oh JS (2011) Hemorrhage related to implant placement in the anterior mandible. Implant Dent 20:33–37. https://doi.org/10.1097/ID.0b013e3182181c6b
10. Kalpidis CD, Setayesh RM (2004) Hemorrhaging associated with endosseous implant placement in the anterior mandible: a review of the literature. J Periodontol 75:631–645. https://doi.org/10.1902/jop.2004.75.5.631
11. Khorshidi H, Raoofi S, Ghapanchi J, Shahidi S, Paknahad M (2017) Cone beam computed tomographic analysis of the course and position of mandibular canal. J Maxillofac Oral Surg 16:306–311. https://doi.org/10.1007/s12663-016-0956-9
12. 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 45:1142–1146. https://doi.org/10.1016/j.ijom.2016.04.019
13. Kuroe K, Rosas A, Molleson T (2004) Variation in the cranial base orientation and facial skeleton in dry skulls sampled from three major populations. Eur J Orthod 26:201–207
14. 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 21:766–771. https://doi.org/10.1111/j.1600-0501.2009.01903.x
15. Miller RJ, Edwards WC, Boudet C, Cohen JH (2011) Maxillofacial anatomy: the mandibular symphysis. J Oral Implantol 37:745–753. https://doi.org/10.1563/AAID-JOI-D-10-00136
16. Mraiwa N, Jacobs R, van Steenberghe D, Quirynen M (2003) Clinical assessment and surgical implications of anatomic challenges in the anterior mandible. Clin Implant Dent Relat Res 5:219–225
17. Patil S, Matsuda Y, Okano T (2013) Accessory mandibular foramina: a CT study of 300 cases. Surg Radiol Anat 35:323–330. https://doi.org/10.1007/s00276-012-1044-6
18. Pires CA, Bissada NF, Becker JJ, Kanawati A, Landers MA (2012) Mandibular incisive canal: cone beam computed tomography. Clin Implant Dent Relat Res 14:67–73. https://doi.org/10.1111/j.1708-8208.2009.00228.x
19. Romanos GE, Gupta B, Davids R, Damouras M, Crespi R (2012) Distribution of endosseous bony canals in the mandibular symphysis as detected with cone beam computed tomography. Int J Oral Maxillofac Implants 27:273–277
20. Sahman H, Sisman Y (2016) Anterior loop of the inferior alveolar canal: a cone-beam computerized tomography study of 494 cases. J Oral Implantol 42:333–336. https://doi.org/10.1563/aaid-joi-D-15-00038
21. Sanchez-Perez A, Boix-Garcia P, Lopez-Jornet P (2018) Cone-beam CT assessment of the position of the medial lingual foramen for dental implant placement in the anterior symphysis. Implant Dent 27:43–48. https://doi.org/10.1097/ID.0000000000000719
22. Tagaya A, Matsuda Y, Nakajima K, Seki K, Okano T (2009) Assessment of the blood supply to the lingual surface of the mandible for reduction of bleeding during implant surgery. Clin Oral Implants Res 20:351–355. https://doi.org/10.1111/j.1600-0501.2008.01668.x

23. Thomson A (1915) On the presence of genial tubercles on the mandible of man, and their suggested association with the faculty of speech. J Anat Physiol 50:43–74
24. von Arx T, Matter D, Buser D, Bornstein MM (2011) Evaluation of location and dimensions of lingual foramina using limited cone-beam computed tomography. J Oral Maxillofac Surg 69:2777–2785. https://doi.org/10.1016/j.joms.2011.06.198
25. Yang XW, Zhang FF, Li YH, Wei B, Gong Y (2017) Characteristics of intrabony nerve canals in mandibular interforaminal region by using cone-beam computed tomography and a recommendation of safe zone for implant and bone harvesting. Clin Implant Dent Relat Res 19:530–538. https://doi.org/10.1111/cid.12474
26. Yildirim YD, Guncu GN, Galindo-Moreno P, Velasco-Torres M, Juodzbalys G, Kubilius M, Gervickas A, Al-Hezaimi K, Al-Sadhan R, Yilmaz HG, Asar NV, Karabulut E, Wang HL, Tozum TF (2014) Evaluation of mandibular lingual foramina related to dental implant treatment with computerized tomography: a multicenter clinical study. Implant Dent 23:57–63. https://doi.org/10.1097/ID.0000000000000012
27. Zhang C, Zhuang L, Fan L, Mo J, Huang Z, Gu Y (2018) Evaluation of mandibular lingual foramina with cone-beam computed tomography. J Craniofac Surg 29:e389–e394. https://doi.org/10.1097/SCS.0000000000004390