Lateral Lingual Foramina and Canals in the Mandible: CBCT Evaluation of 506 Patients in North China

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Objective: *To assess the prevalence, location, diameter, course and anastomosis of the lateral lingual foramina (LLF) and canals (LLCs) in a northern Chinese population using CBCT.*
Methods: *CBCT images of 506 patients (181 male and 325 female, mean age 21.03 ± 8.11 years) were collected. The prevalence, location, diameter, length, angle and anastomosis of the LLF and LLCs were assessed. The measurement variables were analysed by sex and age. Statistical analysis was performed using SPSS (v. 25, IBM, Armonk, NY, USA).*
Results: *A total of 461 LLF were detected in 307 (60.7%) subjects, 175 (57.0%) of whom had unilateral LLF and 132 (43.0%) of whom had bilateral LLF, with each lateral having one to four LLF. The majority of LLF (375/461, 81.3%) were located below the premolars, particularly the first premolar. The mean diameter of the LLF was 0.58 ± 0.20 mm. The mean vertical distance from the LLF to the inferior border and the alveolar crest was 6.68 ± 1.43 mm and 23.65 ± 2.89 mm, respectively. In total, 197 LLCs were visible in the cancellous bone and evaluated. The mean length of LLCs was 6.26 ± 1.29 mm, and the mean angle of LLCs was 140.64° ± 17.29°. The overwhelming majority (93.4%) of LLCs communicated with the mandibular incisive canal and the rest connected with the mandibular canal.*
Conclusion: *The prevalence of LLCs was high in the northern Chinese population. The presence of LLCs is a significant predictor of communication with the mandibular incisive canal.*
Key words: *CBCT, lateral lingual canals, lateral lingual foramina, mandible*
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The anatomical features and variations of accessory foramina and canals on the lingual side of the mandible have received extensive attention in recent years due to the rapid growth of dental implant treatment and widespread use of CBCT. There is an abundant blood supply in the lingual side of the mandible, involving the submental, sublingual and incisive arteries[1,2]. The branches of arteries and nerves enter or exit the mandible through these foramina[3].

It is essential to identify the precise and detailed anatomical characteristics of the mandibular lingual foramina and canals when planning surgical procedures such as implant treatment, mandibular osteotomy and bone grafting. Several reports have documented severe bleeding and hematoma in the floor of the mouth associated with mandibular implants mainly in the interforaminal zone[1,4-6], an area that was traditionally considered safe for surgery. The hematoma was induced by arterial injury on account of perforations of the lingual cortical bone and laceration of lingual periosteum[1]. Hematoma in the floor of the mouth may lead to upper airway obstruction and therefore may be life-threatening. Preoperative identification of the mandibular lingual foramina could prevent accidental bleeding during implant treatment. Identification of the network of canals in the mandible can also contribute to understanding the spread of oral cancer. The presence of the lingual foramina and canals in the mandibular body could predispose to cancer invasion and spread from the floor of the mouth to the cancellous bone, which should be considered in cancer treatment planning[7]. In addition, the mandibular lingual foramina and canals can be used for forensic identification[8].

Despite the importance of the mandibular lingual foramina and canals, their prevalence, anatomical morphology, variations and content are controversial topics[9]. According to their positions in the mandible, the mandibular lingual foramina and canals can be categorised as median (in the midline) and lateral (lateral to the midline)[10]. Median lingual foramina (MLF) and median lingual canals (MLCs) are frequently present, and have been observed in up to 100% of subjects in previous studies[11-15]. However, fewer studies have focused on lateral lingual foramina (LLF) and lateral lingual canals (LLCs)[11,13-19]. The most common location for LLF is the mandibular premolar area[13]. During implant surgery in this area, the implant may tend to the lingual side to avoid the mental foramen on the buccal plate, which may increase the risk of damage to the LLCs. Only two reports have studied the length, course and anastomosis of LLCs, and the results varied[18,19]. The anastomosis of LLCs is still a matter of debate. Krishnan et al[19] reported that LLCs generally connected with the mandibular canal. Von Arx et al[12] reported that canals originating from posterior lingual foramina mainly communicated with the mandibular incisive canal, followed by the mandibular canal and the apex of adjacent teeth. This discrepancy may be due to the anatomical variations between different populations, which should be considered during dental surgery.

CBCT provides multiple high-quality images of hard tissue, offering a 3D view and detailed osseous anatomical information, and thus overcomes the limitations of panoramic radiographs. The radiation dose of CBCT is much lower than with spiral computed tomography (CT). CBCT has therefore been generally accepted as the most valuable imaging modality to visualise delicate structures such as LLCs[13].

There is a lack of data regarding anatomical features of LLCs in the northern Chinese population. We therefore performed a large sample size study to investigate the prevalence, location, morphology, course and anastomosis of LLCs in the healthy population of North China.

Materials and methods

This retrospective study included patients with full mandibular dentition who underwent a CBCT examination prior to orthodontic treatment between 2015 and 2016. The orthodontic indications for CBCT included 3D cephalometric analysis, temporomandibular disorders, impacted teeth, fenestration, dehiscence and preoperative evaluation of microscrew implants. Ethical approval was obtained from the Biomedical Institutional Review Board of Peking University School of Stomatology before the study began (PKUSSIRB-201949131).

The exclusion criteria were as follows:

- inadequate CBCT image quality;
- examinations not revealing the lower border of the mandible;
- mandibular defects;
- history of trauma;
- presence of deformities;
- pathological conditions;
- surgical treatment of the mandible.

A total of 506 subjects, with a mean age of 21.03 ± 8.11 years (range 11 to 56 years, 181 male and 325 female), were enrolled in this study.

CBCT images of all subjects were acquired with NewTom VGi (NewTom, Verona, Italy) using the default parameters (field of view 12 cm × 8 cm, 15 cm × 12 cm, 15 cm × 15 cm) and standard scanning protocol. The images were reconstructed with a voxel size of 0.25 mm.

The digital imaging and communications in medicine (DICOM) images were analysed with dental CT software (NNT Viewer version 5.0, NewTom), under multiplanar reformation (MPR) views (axial, coronal and sagittal). The axial images were aligned parallel to the occlusal plane, with the sagittal images parallel to the sagittal plane of the head (Fig 1). The axial images were searched for LLCs. Any canal-like radiolucency in the lingual cortical bone of the mandible that was not in the midline was identified as an LLC.

The location of LLFs was determined by the adjacent mandibular teeth (Fig 1a). The width and height of the LLF were measured (Figs 1b and 1c). The diameter was defined as the mean of width and height. The LLF were classified as < 1 mm and ≥ 1 mm according to the diameter to estimate the risk of severe bleeding[20]. The

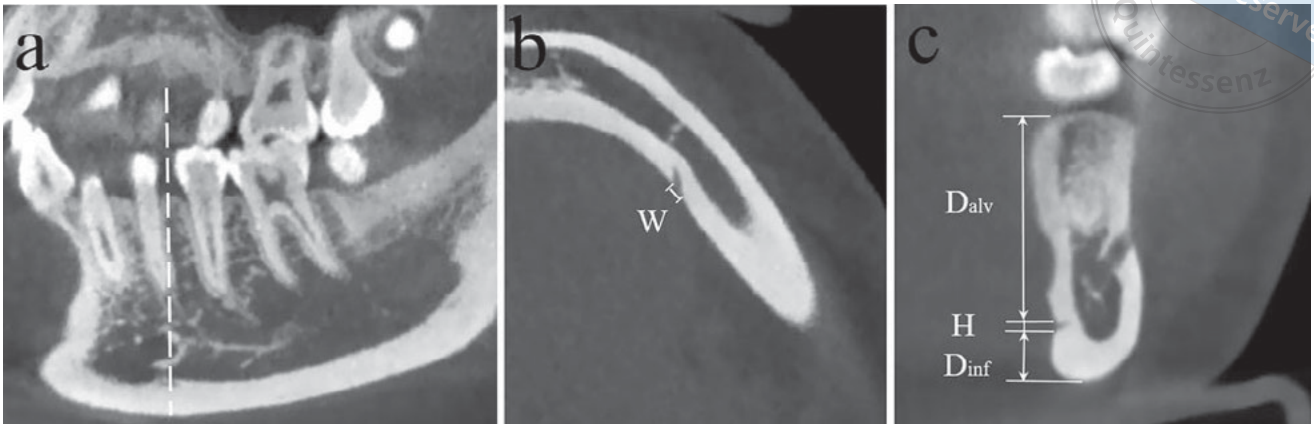

Fig 1 **(a)** The location of the LLF was recorded according to the teeth determined by the extrapolation of a vertical line (white dotted line) from the foramen to the alveolar ridge. **(b)** W indicates the width of the LLF. **(c)** H indicates the height of the LLF; D_{alv} denotes the vertical distance from the LLF to the alveolar crest and D_{inf} represents the vertical distance from the LLF to the inferior border of the mandible.

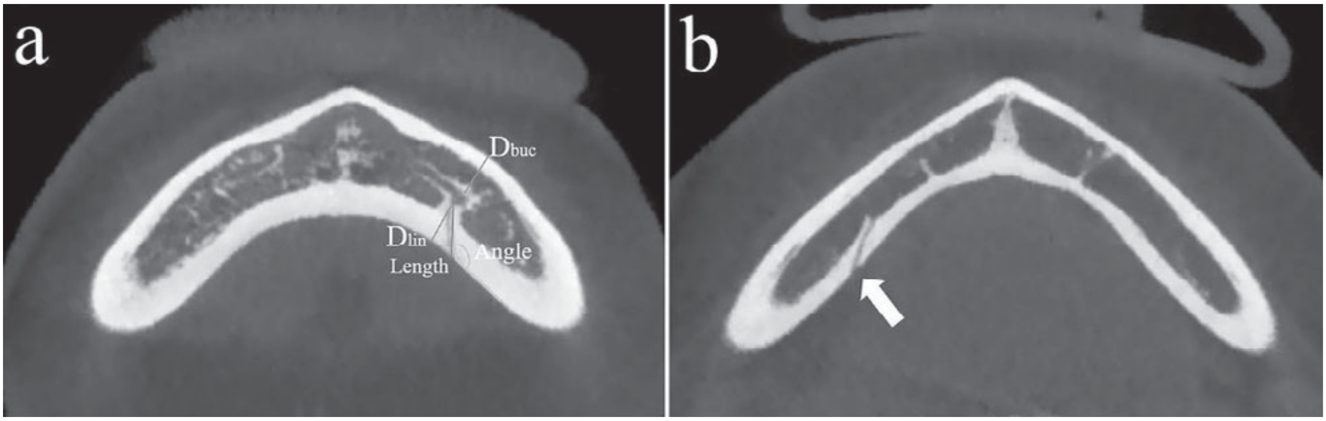

Fig 2 **(a)** The axial plane was aligned to show the full length of the LLC. The length (green line) was measured as the distance from the LLF to the point of joining the mandibular incisive canal. D_{buc} and D_{lin} (blue lines) indicate the horizontal distance from the point of joining to the buccal and lingual cortical surfaces, respectively. Angle (yellow) indicates the angle of entry of the LLC. **(b)** This LLC (marked with arrow) was invisible in the cancellous bone.

vertical position of the foramen was measured by its distance from the alveolar crest and the inferior border, respectively (Fig 1c).

The course of LLCs and their communication in the intraosseous region were verified under MPR view. The axial plane was aligned to show the full length of the LLC, with the LLC measured as the distance from the LLF to the point of joining the mandibular canal or mandibular incisive canal, and the angle of entry of the LLC was measured (Fig 2). The horizontal distances from the point of joining the mandibular/incisive canal to the buccal and lingual cortical surface were recorded (Fig 2).

The presence of LLCs and their communication were evaluated by two radiologists independently. When there was disagreement between the two radiologists, a consensus was reached after discussion. The quantitative measurements were recorded twice by the same radiologist at an interval of 2 weeks, and the mean was used for analysis. The length, angle and communication of LLCs that were difficult to confirm in the cancellous bone were not evaluated (Fig 2b). To check the inter-observer reliability, another radiologist remeasured every tenth patient's image on the data list.

Statistical analysis

SPSS version 25 (IBM, Armonk, NY, USA) was used for statistical analysis. The numerical values were described as means and standard deviations (SD). An independent samples *t* test was used to compare the differences in the measured variables of LLF and LLCs between males

Table 1 Number of LLF in the mandible.

Sex	Number of LLF (%)					
	0	1	2	3	4	Total
Female	133 (40.9)	109 (33.5)	77 (23.7)	6 (1.8)	0 (0.0)	325
Male	66 (36.5)	60 (33.1)	47 (26.0)	6 (3.3)	2 (1.1)	181
Overall	199 (39.3)	169 (33.4)	124 (24.5)	12 (2.4)	2 (0.4)	506

Table 2 Measurements of LLF and LLCs (mean ± SD, mm).

		Total	Female	Male	*P* value
LLF	Width	0.55 ± 0.19	0.54 ± 0.18	0.58 ± 0.20	0.094
	Height	0.59 ± 0.22	0.56 ± 0.19	0.63 ± 0.26	0.011*
	Diameter	0.58 ± 0.20	0.56 ± 0.18	0.61 ± 0.22	0.014*
	Distance (inf)	6.68 ± 1.43	6.51 ± 1.36	6.96 ± 1.51	0.007**
	Distance (alv)	23.65 ± 2.89	23.37 ± 2.74	24.12 ± 3.09	0.027*
LLCs	Length	6.26 ± 1.29	6.21 ± 1.27	6.35 ± 1.32	0.473
	Angle	140.64 ± 17.29	140.67 ± 16.35	140.58 ± 19.20	0.873
	Distance (buc)	5.99 ± 1.22	5.75 ± 1.17	6.49 ± 1.19	0.000**
	Distance (lin)	4.08 ± 0.88	4.10 ± 0.89	4.06 ± 0.86	0.777

*P < 0.05; **P < 0.01. alv, the vertical distance from the LLF to the alveolar crest; buc, the horizontal distance from the point of joining to the buccal cortical surface; inf, the vertical distance from the LLF to the inferior border of the mandible; lin, the horizontal distance from the point of joining to the lingual cortical surface.

and females. A chi-square test was used to compare the proportions of the presence of LLF between males and females. The partial correlation analysis controlled with sex was used to explore the relationships between the variables of the LLCs and LLF and age. Intraclass correlation coefficients (ICCs) were used to determine the interobserver reliability. $P < 0.05$ was considered statistically significant.

Results

A total of 461 LLF were detected in 307 (60.7%) subjects. Of these 307 subjects, 175 (57.0%) had unilateral LLF and 132 (43.0%) had bilateral LLF. Most patients had one or two foramina, and the rest had three or four (Table 1). No difference was found between the sexes regarding the prevalence of LLCs. The majority of LLF (375, 81.3%) were observed in the premolar areas, especially the first premolar (Fig 3), while 69 (15.0%) were found in the canine areas and 17 (3.7%) in the molar areas.

The mean diameter of the LLF was larger for males (0.61 ± 0.22 mm) than females (0.56 ± 0.18 mm) ($P < 0.05$) (Table 2). The mean LLF diameter for each patient was negatively correlated with age (r = −0.126, $P = 0.027$). A total of 20 LLF in 20 patients (9 female and 11 male) had diameters ≥ 1 mm, and all were in the premolar area. The mean vertical distance from the LLF to the inferior border and the alveolar crest, respectively, was 6.68 ± 1.43 mm (range 3.45 to 14.10 mm) and 23.65 ± 2.89 mm (range 16.20 to 34.30 mm). Male participants had longer vertical distances from the LLF to the alveolar crest and inferior border (Table 2). The mean vertical distance from the LLF to the alveolar ridge was correlated with age (r = 0.387, $P = 0.000$), but no statistical correlation was observed between the mean vertical distance from the LLF to the inferior border and age (r = −0.024, $P > 0.05$).

A total of 197 (42.7%) LLCs were visible in the cancellous bone and evaluated. There was no statistical difference for age and sex between the two groups with visible and invisible LLCs in the cancellous bone. The majority of the 197 LLCs (159/197, 80.7%) originated from the premolar area, 30 (15.2%) from the canine area and 8 (4.1%) from the molar area. The mean length of LLCs was 6.26 ± 1.29 mm (range 3.50 to 11.30 mm). No statistical correlation was observed between the mean length of LLCs and sex/age. The mean angle of LLCs was 140.64 ± 17.29° (range 95.07° to 168.81°). In cancellous bone, LLCs always tend to course anteriorly. The majority (93.4%, 184/197) of LLCs had a connection with the mandibular incisive canal (Fig 4). The rest connected with the mandibular canal, including the eight LLCs originating from the molar areas and five from the premolar areas. The mean horizontal distance from the joining point to the buccal and lingual cortical surface was 5.99 ± 1.22 mm (range 3.10 to 9.80 mm) and 4.08 ± 0.88 mm (range 1.90 to 7.00 mm), respectively. The interobserver ICC ranged from 0.873 to 0.902 for the different variables.

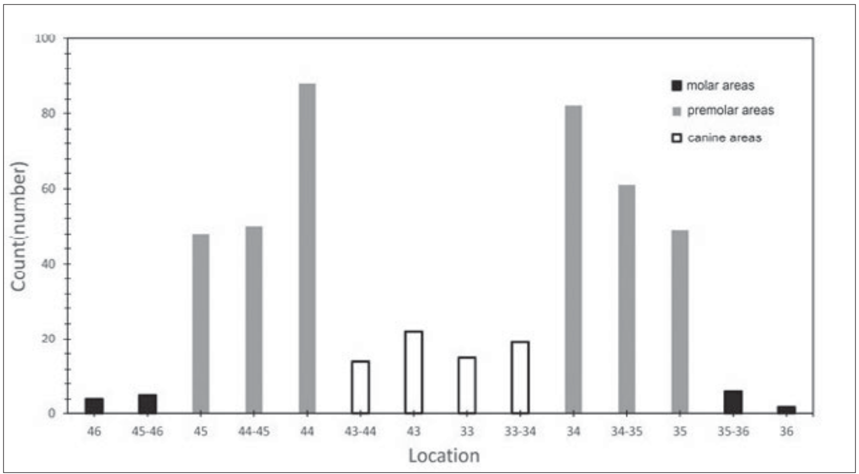

Fig 3 Prevalence of LLF in the mandible (teeth numbered according to the FDI system).

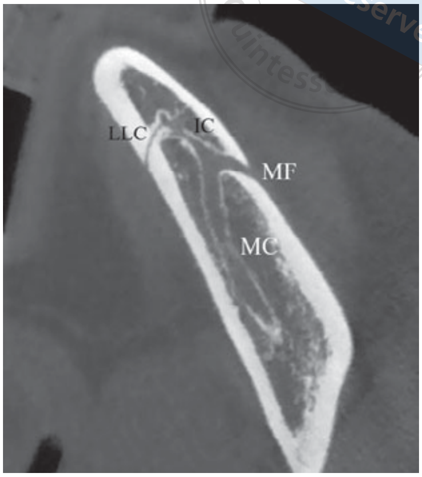

Fig 4 The oblique axial section showed the communication of the LLC with the mandibular incisive canal. MC, mandibular canal; IC, mandibular incisive canal; MF, mental foramen.

Discussion

There is considerable variation in the prevalence of LLF among studies from different countries and regions, ranging from 24.8% to 99.0%[11,16,18-21]. These discrepancies may be due to variation in the sample size, interpopulation differences, terminology, imaging equipment and settings, measurement methods and observer detection variability. The impact that different imaging equipment and settings have on image quality should not be underestimated. The visibility of delicate structures such as LLCs is heavily dependent on image quality (resolution, contrast, slice thickness, etc.). CBCT was chosen as the method of investigation because it has proven to be superior to other radiographic modalities for revealing lingual foramina and canals[13]. Naitoh et al[22] argued that the depiction of LLCs in the mandibular structures is consistent between CBCT and spiral CT, but the sample size was limited. However, there are still significant differences between the studies using CBCT, which may be due to the variation in other factors mentioned above. The frequency of LLF in our study was similar to that in the study conducted by Zhang et al[11], which included CBCT images of 299 patients in East China. We also found that the frequency of LLF was not related to sex.

LLF were found from the canine area to the first molar area, but the majority (81.3%) were observed in the premolar areas, consistent with previous reports[11,13,15,18-20]. The most vulnerable region was the canine area, according to the review that reported haemorrhage during dental implant surgery in the mandible[13]. In our study, 15.0% of the LLF were observed in the canine area.

The mandibular lingual foramina indicate adjacent penetrating arteries. Reviewing the literature, the mandibular lingual foramina derive from a branch of the sublingual artery or submental artery, or anastomosis of the two arteries. A gross anatomical study of 75 human cadavers in Japan found that the LLCs contained a branch of the submental artery, named the “communicating branch”, which either connected with the inferior alveolar artery or coursed anteriorly to the incisor area[23]. Few studies have verified the course of LLCs in the cancellous bone. Krishnan et al[19] reported that LLCs always had a communication with the mandibular canal, based on limited CBCT findings. Also based on limited findings, Von Arx et al[12] found that LLCs originating from the premolar areas primarily communicated with the mandibular incisive canal, and canals from the molar areas mainly connected with the mandibular canal or the apices of adjacent teeth. In the present study, 197 of the 461 (42.7%) LLCs were visible in the cancellous bone, and most communicated with the incisive canal, which was in agreement with Von Arx et al[12]. The presence of LLF is a strong predictor of communication with the incisive canal. The fact that not all the canals were visible might be due to the characteristics of the anatomical structure and the limited resolution of the imaging equipment. With osteoporosis and other related factors, ossification of the cancellous bone may decrease, thus reducing the visibility of canals. In addition, the diameter of some canals may be too small to be detected. Krishnan et al[19] and Von Arx et al[12] reported that all LLCs could be observed, which might be due to the higher resolution of small field of view of CBCT.

Blood vessels entering the mandibular lingual bone are usually considered as terminal vessels. Small vessels with a diameter < 1 mm are rarely problematic when injured during implant surgery[24]; however, damage to vessels > 1 mm in diameter may lead to a significant hematoma[13]. Only 4.3% of the 461 LLF had diameters ≥ 1 mm in the present study, which was less than in the study by Wang et al[20] (13.4%). Our results showed that male participants had LLF with a larger diameter, which was consistent with Wang et al[20]. Female participants had shorter distances from the LLF to the alveolar crest and to the inferior border, which was consistent with previous studies[11,18]. The vertical distance from the LLF to the alveolar crest was weakly correlated to age, which might be due to the young subjects we chose. To assess the prevalence and morphology of LLCs in a healthy population with no pathological conditions in the mandible, we collected images of patients before orthodontic treatment, who had growth potential. Most of the other reports involve dentulous patients[11,18,19]. Nevertheless, edentulous patients usually have significant osseous atrophy and a greater need for dental implants. The mean vertical distance from the LLF to the alveolar crest was 23.65 ± 2.89 mm, similar to previous reports. Uchida et al[25] reported that the distance between the LLF and the alveolar crest was 22.8 ± 6.1 mm in dentate patients and 15.7 ± 4.7 mm in edentulous patients. As the distance between the LLF and alveolar crest decreases, the risk of complications may increase.

This study has some limitations. As previously mentioned, only healthy groups were included in the study. Further research with a larger sample including patients with missing teeth or alveolar bone resorption is needed. In addition, the quantitative measurements were taken by one radiologist, but the intraobserver variability was checked and proved to be negligible.

Conclusion

Our study demonstrated the characteristics of LLCs in the northern Chinese population. The prevalence of LLCs was high. The majority of LLF were in the premolar areas. The mean distance from the LLF to the alveolar crest suggested that the premolar region is safe for implantation in patients without alveolar resorption. The diameter of LLF was greater in male participants and decreased with age. The presence of LLF is a significant predictor of communication with the mandibular incisive canal. CBCT can provide detailed information about LLF and LLCs, which is essential to ensure safe dental surgery and prevent accidental bleeding.

Conflicts of interest

The authors declare no conflicts of interest related to this study.

Author contribution

Dr Mu Qing LIU contributed to the methodology, validation, formal analysis, investigation, writing of the original draft and visualisation; Dr Ke Jia CHEN contributed to the methodology, validation, formal analysis, investigation and data curation; Dr Kai Yuan FU contributed to the conceptualisation, revision of the manuscript, supervision and project administration.

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