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Assessment of location and anatomical characteristics of lingual foramen using cone beam computed tomography

Procena lokalizacije i anatomskih karakteristika lingvalnog foramena primenom kompjuterizovane tomografije konusnog zraka

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Abstract

Background/Aim. A lingual foramen (LF) is a small opening on the lingual surface of the mandible, most frequently located in the middle of the anterior part of the mandible, and shows significant variations in its location, size, and number. The aim of this study was to assess the location and anatomical characteristics of LF using cone beam computed tomography (CBCT). **Methods.** The research was designed as a retrospective study in which 99 CBCT scans were analyzed. The analysis covered the number of LF, their location concerning the teeth and the mandibular region itself, diameter, distance from the alveolar ridge crest, distance from the inferior border of the mandible, distance from the tooth apex, and position in relation to the tooth apex. **Results.** The average frequency of LF *per* patient was 2.4 ± 1.2. The largest number of LF were localized in the region of lower central incisors. Out of the total number of LF, 82.5% belonged to median LF, while 17.5% belonged to lateral LF. In 63.2% of cases, LF had a diameter of ≤ 1 mm, whereas, in 98.3% of cases, it was localized below the tooth apex. There was a statistically significant difference in the distance of LF from the alveolar ridge crest and the LF diameter in relation to gender ($p = 0.019$; $p = 0.008$). **Conclusion.** LF can be reliably localized and visualized using CBCT. It is recommended that CBCT scanning of the mandible be used while planning an oral surgical procedure and implant placement in order to prevent injuries of the neurovascular bundle, which passes through LF.

Key words:
anatomy; cone-beam computed tomography; mandible.

Apstrakt

Uvod/Cilj. Lingvalni foramen (LF) je mali otvor na lingvalnoj površini mandibule (donje vilice), najčešće lokalizovan u sredini anteriornog dela mandibule, koji pokazuje značajne varijacije u lokalizaciji, veličini i broju. Cilj rada bio je da se procene lokalizacija i anatomske karakteristike LF primenom kompjuterizovane tomografije konusnog zraka (KTKZ). **Metode.** Istraživanje je dizajnirano kao retrospektivna studija, u kojoj je analizirano 99 snimaka dobijenih primenom KTKZ. Analiziran je broj LF, njihova lokalizacija u odnosu na zube i samu regiju mandibule, dijametar, udaljenost od vrha alveolarnog grebena, udaljenost od donje ivice mandibule, udaljenost od vrha korena zuba, položaj u odnosu na vrh korena zuba i pravac pružanja. **Rezultati.** Prosečna zastupljenost LF po ispitaniku iznosila je 2,4 ± 1,2. Najveći broj LF bio je lokalizovan u regiji donjih centralnih sekutića. Od ukupnog broja LF, 82,5% pripadalo je tipu medijalnog LF, dok je 17,5% pripadalo tipu lateranog LF. U 63,2% slučajeva LF je imao prečnik ≤ 1 mm, dok je u 98,3% bio lokalizovan ispod vrha korena zuba. Utvrđena je statistički značajna razlika u udaljenosti LF od vrha alveolarnog grebena i dijametru LF u odnosu na pol ($p = 0{,}019$; $p = 0{,}008$). **Zaključak.** Metodom KTKZ snimanja, LF se može pouzdano lokalizovati i vizualizovati. Da bi se sprečile povrede neurovaskulrnog snopa koji prolazi kroz LF, preporuka je da se prilikom planiranja oralne hirurške i implantološke procedure koristi KTKZ mandibule.

Ključne reči:
anatomija; kompjuterizovana tomografija konusnog zraka; mandibula.

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Introduction

A lingual foramen (LF) is a small opening on the lingual surface of the mandible, most frequently located in the middle of the anterior part of the mandible, and shows significant variations in its location, size, and number [1, 2]. It can be located on the mandibular midline or near it [median lingual foramen (MLF)] or laterally [lateral lingual foramen (LLF)] [1, 3, 4]. When it is located on the mandibular midline, it can be under or above the mental spine [5].

The anterior part of the mandible is considered a safe region for surgical interventions and implant placement due to the absence of large neurovascular structures and good bone density [1, 6–10]. Nevertheless, the area between mental foramina must deserve greater attention, especially concerning anatomical structures present in this region [7, 11]. This region has blood vessels that may be diverse and result from the branches of the external carotid artery, lingual artery, and facial artery [12, 13]. Some data indicate the formation of an enlarging hematoma caused by an injury of LF [1, 14]. A review of the literature identified 19 cases of a serious hematoma connected with the placement of implants located between mental foramina [6]. The cases of sublingual hematoma were recorded after some oral surgical procedures, including osteotomy, tooth extraction, and biopsy of the floor of the mouth [15]. Special importance is given to the communication between the sublingual and submandibular spaces in their distal portion, where, due to the expansion of a hematoma airway, obstruction occurs [16, 17]. Flanagan [3] stated that 420 mL of blood can flow from an artery with an inner diameter of 1 to 2 mm in 30 min.

By dissecting cadaver mandibles, Liang et al. [18] showed that the MLF placed superior to the mental spine can contain a lingual artery, vein, and nerve. The branches of the mylohyoid nerve, sublingual and submental arteries, and veins can be found in the MLF placed inferior to the mental spine. Furthermore, the final branches of the incisive nerve enter the composition of the MLF, i.e., mandibular foramen [19]. The vascular bundle of the LLF comes from the submental artery and the inferior alveolar artery [20]. The inferior alveolar nerve is part of the LLF, i.e., mandibular foramen [1].

The introduction of cone beam computed tomography (CBCT) has considerably advanced radiological diagnostics and planning of surgical procedures in oral and maxillofacial surgery [21]. It is difficult to visualize LF in conventional radiographs [22, 23]. CBCT exceeds the limitations of conventional radiography by producing undistorted three-dimensional images of the area under examination [24]. The error rate of CBCT displaying bony structures is less than 1%, whereas the error rate in panoramic radiographs is more than 30% [1]. The bony canals on the lingual surface of the mandible can be clearly observed from several different perspectives in CBCT scans [6]. It is supported by the fact that CBCT scanning results in accuracy are equal to that produced by direct visualization of anatomical structures in the mandible [25]. Preoperative analysis of LF is significant while planning a surgical procedure and must be taken into account in order to prevent injuries to neurovascular structures and avoid serious hematoma.

The aim of this study was to assess the location and anatomical characteristics of LF using CBCT.

Methods

The research was designed as a retrospective study in which 168 CBCT scans were analyzed. The CBCT images were made in the X-ray room of the Institute of Dentistry at the Faculty of Medical Sciences of the University of Kragujevac, Serbia. All scans of patients were made for diagnostic purposes. This research was approved by the Ethical Committee of the Faculty of Medical Sciences, University of Kragujevac, Serbia (No. 01-11060, from November 23, 2020).

The patients' images were made using The Orthophos XG 3D (Sirona Dental Systems GmbH, Bensheim, Germany) device (field of view 8 × 8 cm; isotropic voxel size 0.2 and 0.1 mm). The GALAXIS Software v1.9.4 (Sirona Dental Systems GmbH, Bensheim, Germany) was used for the three-dimensional reconstruction of images (image definition 100 μm). The patients' images were analyzed under standardized conditions in a room with diminished light on a Philips LED monitor (23 inches, 1,920 × 1,080 pixels).

The inclusion criteria in this study were the images of patients aged above 18 and the complete visibility of the mandible in the CBCT image. The scans that were not examined were those in which pathological lesions in the mandible, impacted teeth, and the presence of various deformities were noticed, as well as those with an incompletely visible mandible. Based on the mentioned criteria, 99 CBCT scans out of a total of 168 were taken for final data processing.

Two investigators, one oral surgeon and one dentist, with more than five years of experience in clinical practice, evaluated the LF. Software built-in meter was used to take all the measurements, and data were entered into an Excel table. All the measurements were repeated twice in 7-day intervals to ensure the objectivity of the measurement. The average value of the two recordings was used in the final data analysis in a situation where the measurement data differed.

In these scans, the presence of LF, the number of LF, and their location concerning the teeth and the mandibular region (Figure 1) (MLF – in the mandibular midline or near it; LLF – molar and premolar region) were analyzed. In addition, analysing the general anatomical characteristics was done (Figure 2), such as foramen diameter (≤ 1 mm – lower risk of hemorrhage; > 1 mm – higher risk of hemorrhage), the distance from the alveolar ridge crest, the distance from the inferior border of the mandible, the distance from the tooth apex and the position in relation to the tooth apex (above the apex; below the apex).

Software SPSS 18.0 (IBM SPSS Statistics 18) was used for statistical data processing. The mean values and the standard deviation of examined parameters, as well as descriptive statistics, were calculated. The Chi-squared test, Mann-Whitney *U* test, and independent samples *t*-test were applied to data analysis.

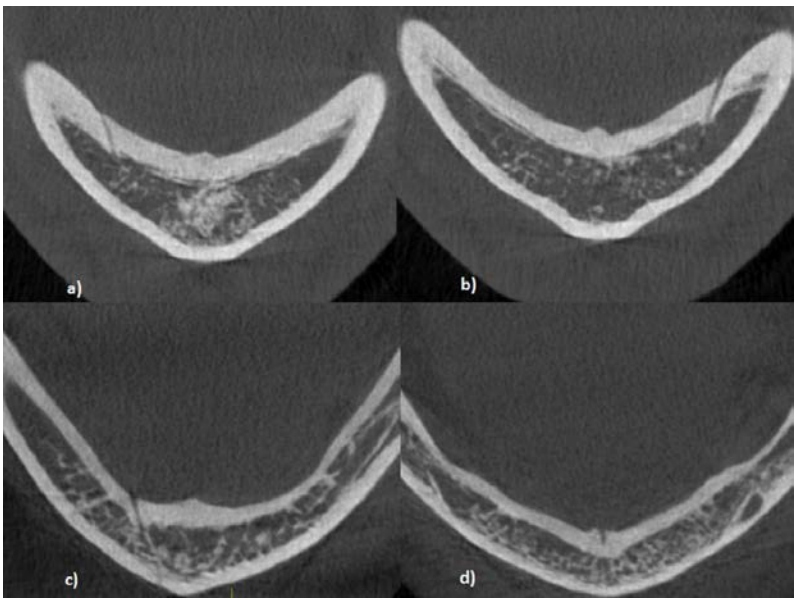

Fig. 1 – Display of lingual foramen (LF) position relative to mandibular region in axial view: a) and b) lateral LF; c) and d) median LF.

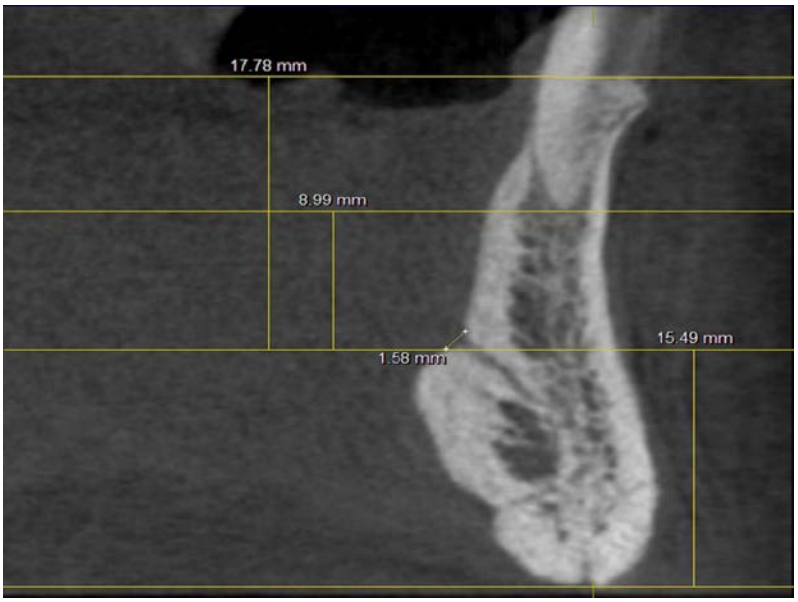

Fig. 2 – Display of diameter, the distance from the alveolar ridge crest and inferior border of the mandible, and the distance from the tooth apex to the lingual foramen in a cross-sectional view.

Results

In this study, the average age of the patients was 43.8 ± 16.2 (age range 19–84). Out of the total number of patients, 50.5% were male, whereas 49.5% were female. The analysis of 99 CBCT scans identified 234 LF. LF was detected in all patients. The number of LF *per* patient ranged from 1 to 6. The average frequency of LF *per* patient was 2.4 ± 1.2. In the largest number of cases, 42.4% of patients had 2 LF each, whereas only 2% of patients had 5 or 6 LF each. There is no statistically significant difference in the number of LF in relation to gender ($p = 0.956$) (Table 1).

By analyzing the regional frequency, 82.5% of LF belonged to MLF, while 17.5% belonged to LLF (Figure 3). Moreover, 67.7% of patients had only MLF, while 32.3% of patients had both MLF and LLF. There is no statistically significant difference in the regional frequency of LF (MLF/MLF and LLF) in relation to gender ($p = 0.558$) (Table 2). Concerning the tooth position, LF was mostly localized in the region of the lower central incisors, whereas they were least present in the region of the lower first molar (Figure 4).

In relation to the tooth apex, 98.3% of LF were localized below the tooth apex, while 1.7% were localized above the tooth apex. The average distance of LF from the tooth apex, for the LF localized above the tooth apex, was 2.8 ± 4.2 mm, whereas for the LF localized below the tooth apex, it was 10.8 ± 5.6 mm. There is no statistically signifi-

Table 1

Frequency of lingual foramen in relation to gender

Gender	Number of lingual foramen						Total
	one	two	three	four	five	six	
Male	12 (12.1)	23 (23.2)	6 (6.1)	7 (7.1)	1 (1.0)	1 (1.0)	50 (50.5)
Female	11 (11.1)	19 (19.2)	9 (9.1)	8 (8.1)	1 (1.0)	1 (1.0)	49 (49.5)
Total	23 (23.2)	42 (42.4)	15 (15.2)	15 (15.2)	2 (2.0)	2 (2.0)	100 (100.0)

All values are expressed as numbers (percentages).
Chi-Squared test $p = 0.956$.

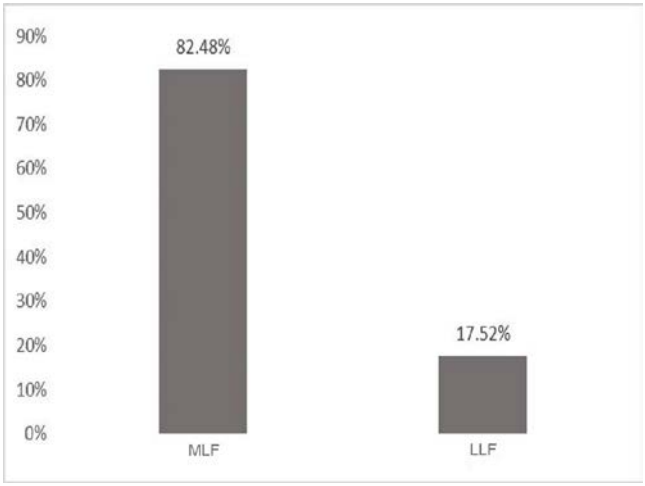

Fig. 3 – Graphical display of regional frequency of lingual foramen (LF).
MLF – median LF; LLF – lateral LF.

Table 2

Regional frequency of lingual foramen (LF) in relation to gender

Gender	Localization of LF		Total
	MLF	MLF and LLF	
Male	34 (34.3)	16 (16.2)	50 (50.5)
Female	33 (33.3)	16 (16.2)	49 (49.5)
Total	67 (67.7)	32 (32.3)	99 (100.0)

MLF – median LF; LLF – lateral LF. All values are expressed as numbers (percentages).
Chi-Squared test $p = 0.558$.

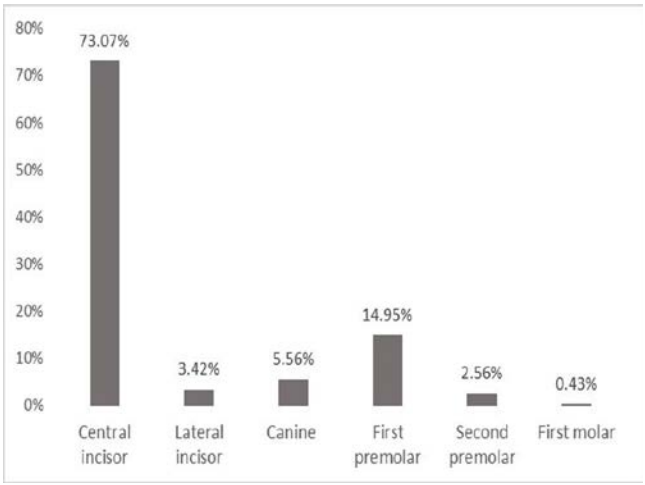

Fig. 4 – Graphical display of frequency of lingual foramen in relation to the tooth position.

cant difference in the localization of LF (above/below the tooth apex) in relation to gender ($p = 0.065$) (Table 3).

The average distance of LF from the alveolar ridge crest and the inferior border of the mandible, as well as the average diameter of LF in relation to gender, are presented in Table 4. There is a statistically significant difference in the distance of LF from the alveolar ridge crest and in the diameter of LF in relation to gender ($p = 0.019$; $p = 0.008$). There is no statistically significant difference in the distance of LF from the inferior border of the mandible in relation to gender ($p = 0.159$).

The average distance of LF from the alveolar ridge crest and the inferior border of the mandible, as well as the average diameter of LF in relation to the regional localization, are presented in Table 5. There is a statistically significant difference in the distance of LF from the alveolar ridge crest and the inferior border of the mandible in relation to the regional localization ($p = 0.000$; $p = 0.003$). There is no statistically significant difference in the diameter of LF in relation to the regional localization ($p = 0.059$).

In our study, 63.2% of LF had a diameter of ≤ 1 mm, whereas a diameter > 1 mm was recorded in 36.8% of LF (Figure 5).

Table 3

Frequency of lingual foramen above the apex or below the apex in relation to gender

Gender	Localization		Total
	above the tooth apex	below the tooth apex	
Male	0 (0.0)	115 (49.1)	115 (49.1)
Female	4 (1.7)	115 (49.1)	119 (50.9)
Total	4 (1.7)	230 (98.3)	234 (100.0)

All values are expressed as numbers (percentages).
Chi-Squared test $p = 0.065$.

Table 4

Distance of lingual foramen (LF) from the alveolar ridge crest, the inferior border of the mandible, and the diameter of LF in relation to gender

Gender	Average distance from the alveolar ridge crest	Average distance from the inferior border of the mandible	Average diameter
Male	21.8 ± 6.3	9.8 ± 5.5	1.0 ± 0.4
Female	19.9 ± 5.9	8.9 ± 5.2	0.9 ± 0.4
p	$^1p = 0.019$	$^2p = 0.159$	$^2p = 0.008$

All values are expressed in millimeter as mean value ± standard deviation.
[1] Independent samples t-test; [2] Mann-Whitney *U* test

Table 5

Distance of lingual foramen (LF) from the alveolar ridge crest, the inferior border of the mandible, and the diameter of LF in relation to the regional localization

Regional localization	Average distance from the alveolar ridge crest	Average distance from the inferior border of the mandible	Average diameter
MLF	20.2 ± 6.5	10.0 ± 5.6	0.9 ± 0.4
LLF	23.8 ± 3.4	6.5 ± 1.8	0.8 ± 0.2
p	$^1p = 0.000$	$^2p = 0.003$	$^2p = 0.059$

MLF – median LF; LLF – lateral LF. All values are expressed in milimmeter, as mean value ± standard deviation.
[1] Independent samples t-test; [2] Mann-Whitney *U* test

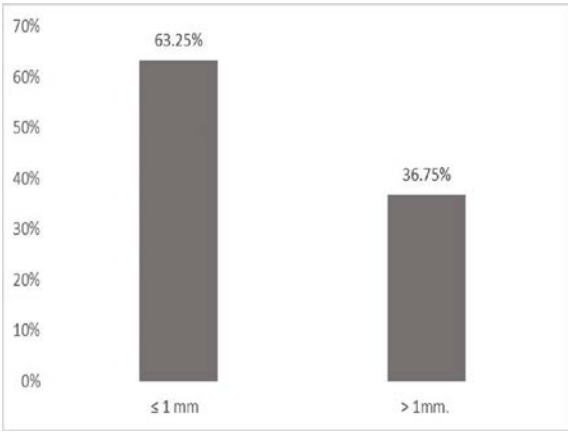

Fig. 5 – Graphical display of frequency of lingual foramen in relation to diameter.

Discussion

Numerous studies have described the presence of additional foramina on the inner side of the mandible without clear classification and nomenclature, pointing out their potential clinical importance [26, 27]. LF is often neglected while planning surgical procedures in the mandible, particularly in the anterior part of the mandible, which is regarded as a safe zone for the placement of implants [1, 6, 18].

The frequency of LF in our study is 100%, i.e., it was detected in all 99 patients. The systematic review and meta-analysis, which covered ten computed tomography studies of patients and cadavers, showed that the frequency of LF in the mandible ranged from 96.2% to 100% [28]. Furthermore, several similar studies, which covered the analysis of CBCT scans, showed a high frequency of LF, from 96.6% to 100% [2, 5, 7, 29]. Isman et al. [30] state that panoramic radiography can identify LF in the anterior part of the mandible in only 8 (4%) patients with certainty, whereas a high degree of probability for its existence was recorded in 25 (12.5%) patients. The use of CBCT results in obtaining cross-sections of high resolution and different thicknesses, which makes it superior to the other radiographic techniques for visualization of LF [31, 32].

In our study, the number of LF *per* patient ranged from 1 to 6. The largest number of patients had 2 LF each, whereas the smallest number of patients had 5 or 6 LF each. Such a result coincides with the results of the study conducted by Demiralp et al. [7]. However, Denny et al. [2] showed that the number of LF *per* patient ranged from 1 to 3. In the study by He et al. [1], most patients had 3 or 4 LF each, whereas the patients with 8 LF each were the least present. The differences noticed in the results of the studies probably come from different CBCT devices and software used in the visualization of mandibles, as well as from potential anatomical geographical differences in the mandible [1].

Out of the total number of analyzed LF, our study showed that 82.5% belong to the MLF type, whereas 17.5% belong to the LLF type. Likewise, LF was most frequently localized in the region of the lower central incisors, whereas it was least present in the region of the lower first molar. Such a result coincides with the results of the studies conducted by He et al. [1], Denny et al. [2], and Trost et al. [33], who showed that most of the total number of LF belonged to MLF. Only the study by Chirita et al. [34] presented that most of the total number of LF belonged to LLF. These results indicate that both the anterior and lateral regions of the mandible must be taken into account while planning oral surgery interventions because of possible complications due to the injury of the neurovascular bundle passing through LF.

In our study, LF was localized below the tooth apex in 98.3% of cases. Several previous investigations also showed that LF was mostly localized below the tooth apex [1, 34]. The average LF distance from our study's tooth apex is 10.8 ± 5.6 mm. A similar result was obtained in the study by Yildirim et al. [4], where the average distance of LF from the tooth apex is 10.1 ± 4.4 mm. Even though our study showed a high average distance of LF from the tooth apex, it is recommended that CBCT scanning be done before surgical procedures, particularly if the immediate placement of implants is planned [4]. Attention should also be paid to the LF located above the tooth apex, which is much more easily injured during endodontic surgery, especially if it is known that in our study, the average distance from the tooth apex is 2.8 ± 4.2 mm [1].

In our study, the average distance of LF from the alveolar ridge crest is somewhat higher in males, and it is 21.8 ± 6.3 mm, whereas in females, it is 19.9 ± 5.9 mm. Our study showed a statistically significant difference in the distance of LF from the alveolar ridge crest in relation to gender (p = 0.019). The study by Yildirim et al. [4] also showed a statistically significant difference in the distance of LF from the alveolar ridge crest in relation to gender (p = 0.000). The distance between LF and the alveolar ridge crest is clinically significant for surgical intervention because it can limit the length of the implant placed (especially in elderly patients) [1]. In our research, the average distance of LF from the inferior border of the mandible is somewhat smaller in females, and it is 8.9 ± 5.2 mm, whereas in males, it is 9.8 ± 5.5 mm. Our study showed that there is no statistically significant difference in the distance of LF from the inferior border of the mandible in relation to gender (p = 0.159), which coincides with the results of the study by Wang et al. [6] (p = 0.220). Moreover, in our study, the average diameter of LF is more pronounced in males, and it is 1.0 ± 0.4 mm, whereas, in females, it is 0.9 ± 0. 4 mm. In contrast to our study (p = 0.008), the study by Trost et al. [33] (p = 0.106) showed no statistically significant difference in the diameter of LF in relation to gender.

By analyzing the regional localization, our study showed a statistically significant difference in the distance of LF from the alveolar ridge crest and the inferior border of the mandible in relation to the regional localization (p = 0.000; p = 0.003). In our study, the average distance between MLF and the alveolar ridge crest was 20.2 ± 6.5 mm, while the average distance between LLF and the alveolar ridge crest was higher, i.e., it was 23.8 ± 3.4 mm. However, in the study by Yildirim et al. [4], the distances of MLF and LLF from the alveolar ridge crest are approximately equal (MLF: 18.2 ± 5.8 mm; LLF: 18.4 ± 5.1 mm). The differences in distance are probably the consequence of anatomical variations and ethnicity [11]. A shorter distance of LF from the alveolar ridge crest increases the risk of injury of the neurovascular bundle during surgical procedures, particularly in the anterior part of the mandible. With atrophy, the height of the edentulous ridge decreases, and the crest approaches the LF, thus putting the vascular bundle in peril of being cut by an implant drill. The distance from the LF to the residual ridge was ~7 mm less in edentulous patients compared to dentulous patients. In patients with alveolar ridge atrophy, shorter implants can reduce the risk of undesired incidents [33]. In our study, the average distance between MLF and the inferior border of the mandible is 10.0 ± 5.6 mm, whereas the average distance between LLF and the inferior border of the mandible is smaller, i.e., 6.5 ± 1.8 mm. Likewise, in the study by Zhang et al. [22], the average distance between MLF

and the inferior border of the mandible is higher than the average distance between LLF and the inferior border of the mandible (MLF: 13.8 ± 2.2 mm; LLF: 7.0 ± 1.9 mm).

In our study, the average LF diameter values in relation to the regional localization were approximately equal (MLF: 0.9 ± 0.4 mm; LLF: 0.8 ± 0.2 mm). Furthermore, in the research by Zhang et al. [22], the average values of the diameter of LF in relation to the regional localization were approximately equal (MLF: 0.7 ± 0.2 mm; LLF: 0.6 ± 0.2 mm). In contrast to our study, where there was no statistically significant difference in the diameter of LF in relation to the regional localization ($p = 0.059$), the study by Yildirim et al. [4] showed that the diameter of MLF was larger than the diameter of LLF ($p = 0.002$). LF with larger diameters may have a negative influence on the osseointegration of implants, i.e., they may be involved in postoperative sensory disturbances and serious hematoma [1]. The diameter of LF influences the degree of risk of hemorrhage. In the previous studies, the risk of hemorrhage was established based on the diameter of LF (≤ 1 mm – lower risk of hemorrhage; > 1 mm – higher risk of hemorrhage). Our research showed that 63.2% of LF have a diameter ≤ 1 mm, whereas 36.8% have a diameter > 1 mm. Several similar investigations also showed that LF had a diameter ≤ 1 mm [1, 4, 6, 7] in most cases. However, in the study by Trost et al. [33], most LF had a diameter > 1 mm. Knowing that there is a higher risk of hemorrhage in the arteries whose diameter is ≥ 1 mm, it is necessary to preoperatively assess the risk of hemorrhage if the radiological analysis detects that the diameter of LF is > 1 mm [3, 35].

Conclusion

The results of this study indicate variability in the location and anatomical characteristics of LF, which is confirmed by other studies. LF can be reliably localized and visualized using CBCT scanning because there is no superimposition of the anatomical structures, better contrast resolution, and fewer or no artifacts. To prevent operative complications such as the possibility of injury of the neurovascular bundle which passes through it, particular attention should be paid to the distance from the alveolar ridge crest in women (especially in elderly patients) and to the distance from the alveolar ridge crest in relation to the regional localization (especially in MLF).

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