Assessment of lateral lingual foramen using cone-beam computed tomography

Emre Aytuğar[1], **Ceren Özeren Keşkek**[2]

[1] *Department of Oral and Maxillofacial Radiology, Faculty of Dentistry, Izmir Katip Celebi University, Izmir, Turkey*
[2] *Izmir Training Dental Hospital, Izmir, Turkey*

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SUMMARY

The lateral lingual foramen is an anatomical structure that can be found unilateral or bilateral in the lingual surface of the mandible. The aim of this study is to determine the localization and prevalence of the lateral lingual foramen (LLF) and to evaluate the lateral lingual canal (LLC) using cone-beam computed tomography (CBCT). CBCT images of 741 patients were examined retrospectively. The prevalence and localization of LLF were assessed by gender and age groups. The distance of the LLF to the mandibular alveolar crest (MAC) and to the inferior border of the mandible (MIB) was measured. The angle of entry of the LLC (LLCA) was also measured. These data were analyzed statistically.

582 LLFs were observed in 396 (53,4%) of 741 patients. LLFs were most frequently observed in the premolar region (87.6%). The mean of the LLF-MAC was 23.28 mm and the mean of the LLF-MIB was 4.71 mm. A statistically significant difference was found in LLF-MAC distance for gender and age groups (p=0.000). This study presented a high prevalence of LLF in the Turkish population. Since the LLF includes inferior alveolar canal or mandibular incisive canal structures, it is necessary to be informed about the existing variations before surgical procedures to prevent complications. Compared to previous studies, higher LLF-MAC distance and lower LLF-MIB distance were observed in the Turkish population. This result can provide confidence in implant applications.

Key words: Cone-beam computed tomography – Lateral lingual canal – Lateral lingual foramen – Mandible

INTRODUCTION

The anterior region of the mandible is considered to be a safe area for implant surgery after tooth loss or rehabilitation after trauma due to bone density and the absence of primary vascular structures (Kawai et al., 2007; He et al., 2016). However, an incomplete understanding of the anatomical structures of the region such as the lingual foramen, inferior alveolar canal and lingual surface may cause complications such as bleeding, hematoma, loss of sensation and edema (Kalpidis and Konstantinidis, 2005; Sekerci et

Corresponding author:
Ceren Özeren Keşkek. İzmir Training Dental Hospital, Fevzipasa Boulevard, Akinci district, No.172/2 Konak, Izmir, Turkey. E-mail: cerenozeren35@gmail.com

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al., 2014; He et al., 2016). The hematoma can cause swelling in the floor of the mouth and even obstruction of the respiratory tract (Kilic et al., 2014; Direk et al., 2018). This is usually caused by perforation of the cortical bone in the lingual surface during the drilling process or damage to the vessels by the implant material placed (Uchida et al., 2015). Therefore, it is important to determine the mandibular lingual foramen and associated neurovascular structures before surgical procedures such as implant applications (Yildirim et al., 2014).

Foramens in the lingual surface of the mandible are divided into two main groups. Those located at or near the midline are called medial lingual foramen (MLF), and those located laterally are called lateral lingual foramen (LLF) (Sahman et al., 2014; Krishnan et al., 2018). Since the canal structures of these foraminas contain different arterial branches or anastomoses of the arteries, they are called the vascular canal. The canal of the LLF is called the lateral lingual canal (LLC) (He et al., 2017). Nakajima et al. (2014) reported that the type of LLCs that anastomoses with the inferior alveolar artery are of submental artery origin and they defined it as the branch of communication. They reported that the non-anastomotic LLC divides into the incisal and labial branches, and surprisingly, the nourishment of the incisor area takes place only in this way.

It is very difficult to detect the presence of MLF or LLF with two-dimensional radiography techniques (Wang et al., 2015; Wei et al., 2020). Cone-beam computed tomography (CBCT) has become a very useful tool in the assessment of anatomical formations such as inferior alveolar canal, mental foramen, LLF as well as determining the size of the existing bone in dental implant applications (Gahleitner et al., 2001). It is widely used in the maxillofacial area due to fast scanning, high resolution and low radiation exposure (von Arx et al., 2011; He et al., 2016).

Clinicians may consider the likelihood of LLF injury to be low due to its distance from the alveolar crest. However, since life-threatening bleeding was reported to occur, it was necessary to study this issue with a large sample group (Kalpidis and Setayesh, 2004). For this reason, we aimed to obtain useful information by investigating the frequency and localization of LLF and the anatomical features of the LLC with CBCT.

MATERIALS AND METHODS

CBCT images of 1000 patients taken for various reasons in the Department of Oral and Maxillofacial Radiology were evaluated. Images of 259 patients were excluded from the study according to the exclusion criteria. The exclusion criteria were unerupted tooth or fracture, pathological condition and surgical treatment in the mandible, bone loss at the mental foramen level, and artifacts that prevented interpretation of the images. The study followed the Helsinki declaration and was conducted with the permission of the Izmir Katip Celebi University Non- Interventional Clinical Studies Ethics Committee (IRB:2018/220). Informed consent was obtained from all patients or their legal guardians before the CBCT procedure was performed.

All of the CBCT images used were acquired at 110 kVp using a CBCT device (NewTom 5G, Quantitative Radiology, Verona, Italy). CBCT images with 15 × 12 cm FOV range and 0.200 mm

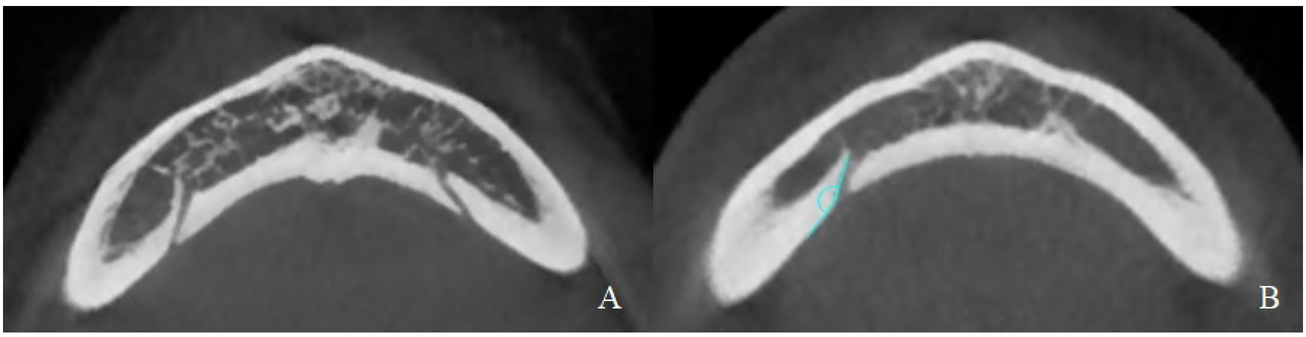

Fig. 1.- Images of the lateral lingual canal in axial sections. (**A**) Bilateral lateral lingual canal. (**B**) Measurement of lateral lingual canal angle.

voxel size were used. Digital images were analyzed using NNT (NNT Software Version 8.0; NewTom; Italy) computer software.

Firstly, the presence of LLC from the canine teeth to the second molars on both sides in the reconstructed axial sections was investigated (Fig. 1A). LLCs were defined as canals connected to the inferior alveolar canal or mandibular incisive canal. Canals not connected to the inferior alveolar canal or the mandibular incisive canal were considered as nutritional canals and were not included in LLF and LLC measurements.

The entry angle of the detected LLC to the mandible (LLCA) was measured in the axial section (Fig. 1B). Then, the distance of LLF to the mandibular alveolar crest (MAC) and the inferior border of the mandible (MIB) was measured in cross-sections (Fig. 2). After the occlusal plane is placed parallel to the ground in three-dimensional images, the localization of the LLF according to the tooth number was determined (Fig. 3). Individuals with tooth deficiency preventing detection of the localization of the LLF were excluded from the study. There was no tooth loss in the area where LLFs were detected.

The data obtained were evaluated using descriptive statistical methods (mean, frequency, percentage). Kolmogorov-Smirnov test was used to evaluate data distribution. Mann-Whitney U test and Kruskal-Wallis tests were used to test the differences between the means of groups that did not show normal distribution. The chi-square test was used to compare categorical variables. IBM SPSS Version 26 was used for statistical analysis. The level of significance (p-value) was accepted as 0.05.

RESULTS

The study population was 397 males (Mean age:41.3) and 344 females (Mean age:37.9). 582 LLFs were detected in 396 patients (53.4%). LLF was observed in 174 (50.6%) of the females and 222 of the males (56%). There was no significant difference between the presence of LLF and gender (p=0.169).

LLF was most frequently detected at the level of the 35th tooth (24.9%) (FDI tooth notation system). LLFs were most frequently observed in the premolar region (87.6%) (Fig. 4). There was no statistically significant difference in the

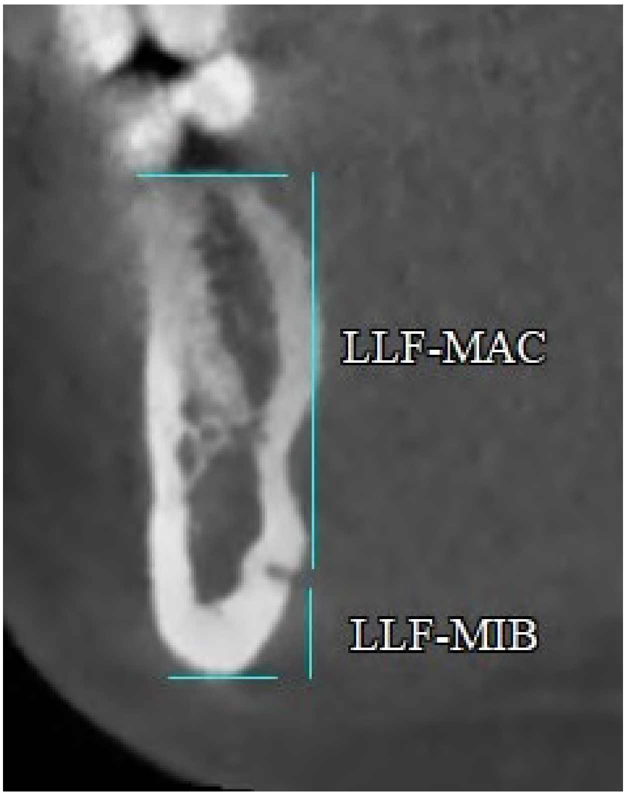

Fig. 2.- Measurement of the distance of the lateral lingual foramen to the mandibular alveolar crest (LLF-MAC) and mandibular inferior border (LLF-MIB).

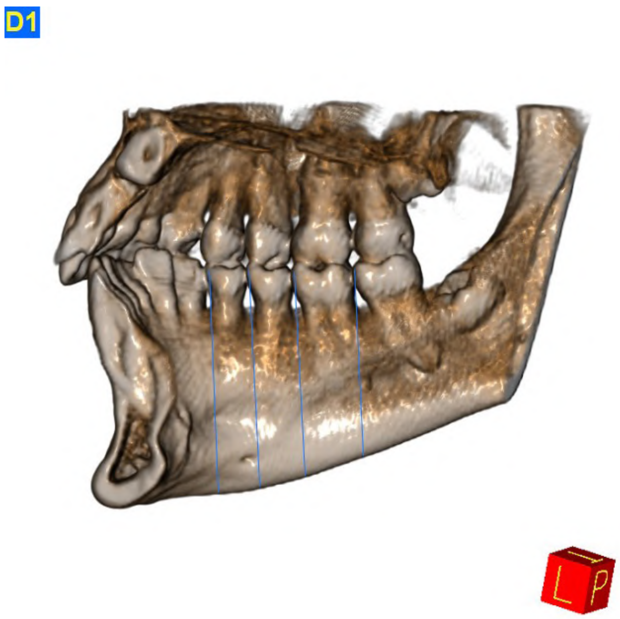

Fig. 3.- Determination of the localization of the lateral lingual foramen with 3D reconstruction.

localization of LLF according to gender and age groups (p=0.210, p=0.316). LLF was bilateral in 38.9% of patients with LLF.

Table 1 presents LLCA, LLF-MAC and LLF-MIB values by gender and age groups. While there was no statistically significant difference in LLCA, LLF-MIB values according to gender (p=0.979, p=0.148), LLF-MAC distance was higher in males with a statistically significant difference (p=0.000). The LLF-MAC and LLF-MIB distances were statistically significant according to age groups (p=0.000, p=0.015). LLF-MAC distance was significantly longer in the 20-49 age group than in other age groups, but this distance was similar in the 11-19 and 50≤ age groups. LLF-MIB distance was significantly shorter in the 11-19 age group compared to the other age groups, but this distance was similar in the 20-49 and 50≤ age groups.

DISCUSSION

LLF, accessory mental foramen (AMF), retromolar foramen and accessory mandibular foramen are anatomical variations observed in the mandible (Iwanaga et al., 2019). AMF is defined as the foramina in the mental foramen area that is connected with the mandibular canal and smaller than the mental foramen (Lam et al., 2019). The retromolar canal contains branches of the inferior alveolar nerve and terminates as the retromolar foramen distal to the third molar and in the retromolar region (Kikuta et al., 2018; Ngeow and Chai, 2021). On the lingual surface of the mandible, the foramen on the midline is called MLF, and the foramen on the lateral surfaces of the lingual surface of the mandible is called LLF (Krishnan et al., 2018). Accessory foramina are not rare. Therefore, radiological examination is recommended to prevent complications before a surgical procedure in the mandible (Haghanifar and Poorsattar Bejeh Mir, 2015).

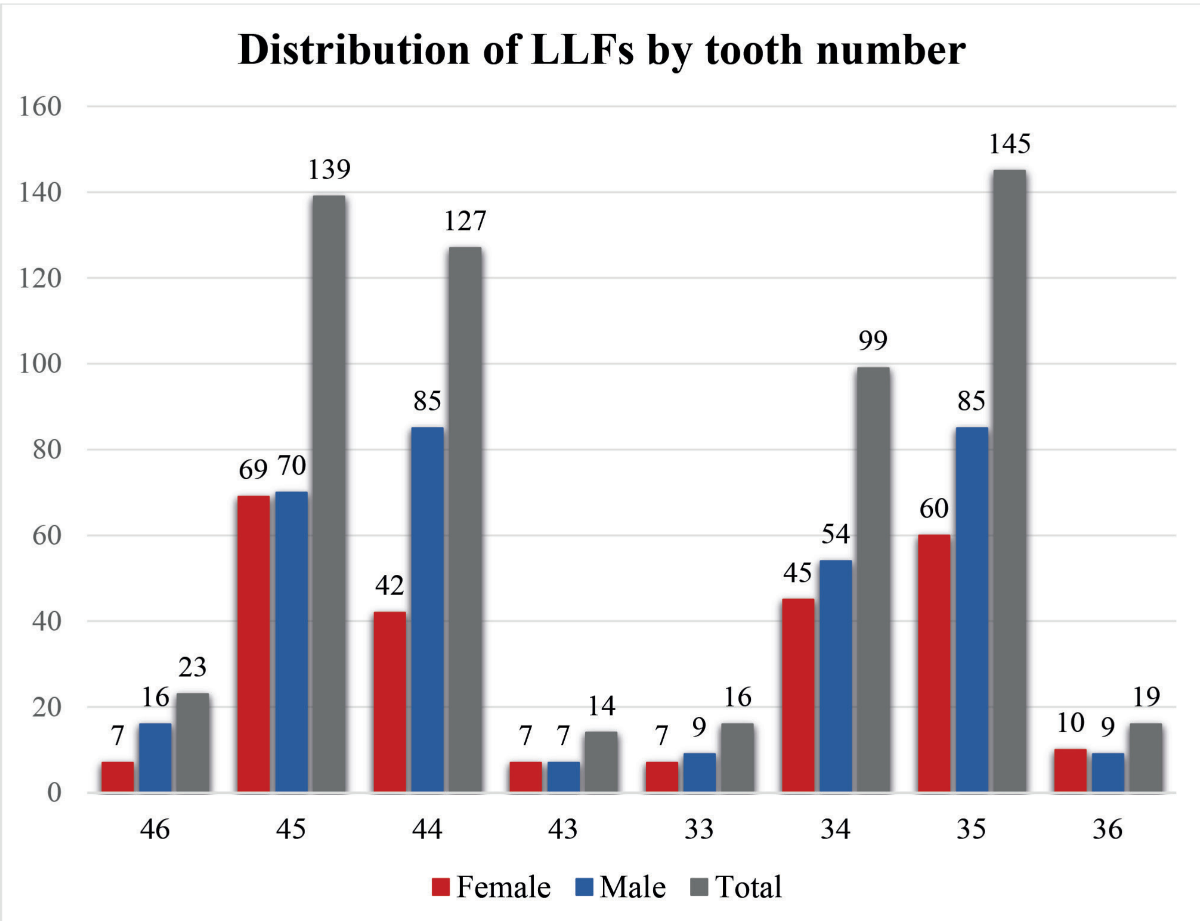

Fig. 4.- Distribution of the localization of lateral lingual foramen according to tooth numbers.

Table 1. Comparison of measured values by gender and age groups.

Gender	LLCA	LLF-MAC	LLF-MIB
Female	152.1°	21.79	4.89
Male	152.6°	24.38	4.58
Total	152.4°	23.28	4.71
p-value	**0.979**	**0.000***	**0.148**
Age groups			
11-19 (N:132)	151.9°	22.50	4.47
20-49 (N:285)	152.9°	24.14	4.79
50≤ (N:165)	151.8°	22.43	4.78
p-value	**0.411**	**0.000***	**0.015***

LLCA, the angle of lateral lingual canal; MAC, mandibular alveolar crest; MIB, mandibular inferior border; *Significance ($p \leq 0.05$)

CBCT examinations are performed before surgical procedures in dentistry (Sanomiya Ikuta et al., 2016). CBCT devices provided a detailed assessment of the foramina in the mandible, with adequate image quality and lower radiation dose compared to computed tomography (CT). Large section thickness can mask smaller diameter structures (Wang et al., 2015). Therefore, small anatomical structures can be hidden and not detected in CT devices that generally use voxels larger than 0.3 mm, but CBCT provides detailed evaluation with high resolution with a voxel size of 0.3 mm or less in all three axes (He et al., 2017). Besides, Iwanaga et al. (2017) evaluated 20 AMF in surface-rendered images using CBCT, and reported that AMFs smaller than 1.3 mm² are not clearly defined in images created on the surface. In this study, images with a voxel size of 0.2 mm were obtained and the LLF was examined in detail in axial, cross-sections and three- dimensional images.

There is no consensus in the literature regarding the classification of mandibular lingual foramina. Some authors have classified the mandibular lingual foramina as midline, paramedian, and posterior lingual foramen (von Arx et al., 2011; Sekerci et al., 2014). Although some researchers classify foramen detected in the midline and near the symphysis as MLF and LLF determined in the lateral (He et al., 2016; Zhang et al., 2018; Trost et al., 2020), these studies have shown boundary differences. Krishnan et al. (2018) and Sanomiya Ikuta et al. (2016) defined LLF as foramina located in the lingual of the premolar and molar teeth. Gahleitner et al. (2001) and Sahman et al. (2014) have also included the foramina in the canine tooth region. In this study, the foramina located on the lingual surface of the mandible from the canine teeth to the second molars were evaluated as LLF, and the foramina located on the anterior of the canines as MLF.

It has been reported in the literature that the prevalence of LLF is between 14.9% and 80% (Tagaya et al., 2009; Sahman et al., 2014; He et al., 2016; Sanomiya Ikuta et al., 2016; Krishnan et al., 2018; Moro et al., 2018; Zhang et al., 2018; Xie et al., 2019; Trost et al., 2020; Wei et al., 2020). Previous studies are presented in table 2, together with the imaging techniques used and the prevalence of LLF. The wide variation in the prevalence of LLFs can be attributed to differences in study method, examination techniques, sample size, and differences in ethnic characteristics of individuals in the study. LLF prevalence was found between 21.1% and 32% in studies conducted in the Turkish population (Yildirim et al., 2014; Direk et al., 2018). In our study, it was observed in a higher percentage than in previous studies (53.4%). Yildirim et al. (2014) used images obtained with both spiral CT and CBCT in their studies and did not give information about the slice thickness. Direk et al. (2018) used multislice CT images in their study and examined the presence of LLF at 0.5 mm axial slice thickness. Some LLFs may be overlooked depending on the slice thickness. In our study, we think that we detected a higher rate of LLF due to the examination of the images with a slice thickness of 0.2 mm.

Krishnan et al. (2018) reported that LLF was most frequently detected at the level of the first premolar, while Zhang et al. (2018) and Sahman et al. (2014) reported that it was most frequently observed at the level of the second premolar. Although the prevalence of LLF varied widely across studies, LLF was most commonly observed in the premolar region (Tagaya et al., 2009; Sahman et al., 2014; Krishnan et al., 2018; Xie et al., 2019; Wei et al., 2020). In our study, LLF was found mostly at the level of the premolar teeth (87.6%), and among them, the most frequently at the level of the second premolar teeth.

Knowledge of the LLF-MAC distance is particularly important, as it represents the safe area for invasive procedures such as implant placement (He et al., 2017). Uchida et al. (2015) and Yildirim et al. (2014) reported that they found the mean of LLF-MAC distance of 19.3 and 18.4 mm, respectively, and it was statistically significantly higher in males. In our study, this distance was determined as 23.2 mm and a statistically significant difference was observed. In previous studies, the mean of LLF-MIB distance has been determined between 5.2 mm and 7.7 mm (Tagaya et al., 2009; Krishnan et al., 2018). Zhang et al. (2018), He et al. (2016) and Wei et al. (2020) reported that they found the LLF-MIB distance of 7.02, 7.08 and 7.1 mm, respectively, and it was statistically significantly higher in males. In our study, this distance was determined as 4.7 mm and no statistically significant difference was observed according to gender. Compared to previous studies, higher LLF-MAC distance and lower LLF-MIB distance may provide confidence in surgical procedures such as implant applications in the Turkish population. According to this result, regional anatomical differences should be taken into consideration before implant applications due to anatomical variations in different racial groups.

He et al. (2016) reported the LLF-MAC distance as 16.82 mm in the 10-19 age group, 16.42 mm in the 20-49 age group and 16.62 mm in the 50 and over age group. They reported the LLF-MIB distance as 12.69 mm in the 10-19 age group, 14.11 mm in the 20-49 age group and 13.91 mm in the 50 and over age group. There was no statistically significant difference between LLF-MAC and LLF-MIB distances and age groups. In our study, LLF-MAC and LLF-MIB distances were found as 24.14 and 4.79 mm in the 20-49 age group, respectively.

Table 2. Literature comparison in studies reporting the presence of LLF.

	Imagine Technique	Number of Patients	Presence of LLF (%)
Tagaya et al., 2009	CT	200	80
Sahman et al., 2014	CBCT	500	24.8
Yildirim et al., 2014	CT	639	21.1
Ikuta et al., 2016	CBCT	100	39
He et al., 2016	CBCT	200	14.9
Direk et al., 2018	CT	100	32
Moro et al., 2018	CT	58	75.9
Krishnan et al., 2018	CBCT	109	20.4
Zhang et al., 2018	CBCT	299	63.2
Xie et al., 2019	CBCT	1008	54.3
Wei et. al., 2020	CBCT	306	69.9
Trost et al., 2020	CT	460	38.9
Present Study	CBCT	741	53.4

There was a statistically significant difference in these distances for age groups. The shorter LLF-MAC and LLF- MIB distances in the 11-19 age group compared to the 20-49 age group may be due to incomplete bone development. The short LLF-MAC distance in individuals aged 50 and over may be due to the decrease in alveolar bone sizes with age.

LLCs are admitted to have a connection with the inferior alveolar canal or mandibular incisive canal (Sahman et al., 2014). It has been shown that the canals in the molar region are connected with the inferior alveolar canal, and those in the premolar region with the mandibular incisive canal (von Arx et al., 2011). In this study, canals connected to the inferior alveolar canal or mandibular incisive canal were evaluated as LLC.

The measurement of LLCA was reported in one study to the best of our knowledge (Krishnan et al., 2018). The mean of LLCA was reported as 148.2°. In our study, the mean of LLCA was 152.4° and there was no statistically significant difference according to gender and age groups. This angle may be especially important during dental implant applications because the reduction of LLCA may increase the risk of damage. As the LLCA increases, the canal may become parallel to the mandibular lingual surface and may move slightly away from the implant site.

Procedures such as reconstruction, implant surgery, removal of roots, a biopsy of cysts and tumors, and osteotomy are performed in the mandible where the lingual foramina are located. Therefore, data on the localization and prevalence of lingual foramina are necessary to reduce the risk of complications, to perform the procedure safely and to avoid damage to important structures.

In conclusion, the radiological characteristics of LLFs are presented using the data obtained with the largest sample size among studies conducted in the Turkish population, and it is noteworthy that the LLF prevalence has the highest value among these studies. Compared to previous studies, higher LLF-MAC distance and lower LLF-MIB distance were observed in the Turkish population. This can provide confidence in surgical procedures such as implant applications. However, it is recommended to perform a radiological examination of the relevant region, especially the premolar region, before the surgical procedure and to have knowledge about anatomical variations.

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