Research Article / Araştırma Makalesi

Evaluation of Vascular Structures in the Anterior Mandible with Cone Beam Computed Tomography

Konik Işınlı Bilgisayarlı Tomografi ile Anterior Mandibuladaki Vasküler Yapıların Değerlendirilmesi

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Abstract

Background: The aim of this article was to evaluate the regional frequency, location, and diameter of the lingual foramen in the anterior mandible using a retrospective analysis of clinically obtained cone-beam computed tomography (CBCT) images.
Materials and Methods: Two hundred thirty-four regions of the anterior mandible from 76 patients (41 female and 35 male) were examined retrospectively using CBCT for the presence of endosseous bony canals. The study focused on the lingual foramen, measuring both the maximum diameter of the artery and the diameter of the lingual foramen itself. Additionally, distances were measured between the lingual foramen and the alveolar ridge, tooth apex, mandibular border, and mental foramen. Data were analyzed using ANOVA and independent sample t-tests to determine statistical significance.
The distributions of the measured variables were assessed for normality prior to analysis. Normality was confirmed using appropriate statistical tests, such as the Shapiro-Wilk test, and visual inspection methods, including Q-Q plots. Since the data met the assumptions of normality, parametric tests were deemed appropriate for analysis. Consequently, ANOVA and independent sample t-tests were employed to evaluate the differences among groups and the relationships between variables. This approach allows for more robust statistical inferences, leveraging the properties of the normal distribution.
Results: The diameters of the lingual artery ranged from 0.3 mm to 1.67 mm, with the majority of lingual foramina (47.62%) located in the midline region. Notably, a quintuple canal was identified in the CBCT scans. The highest measurement of the artery diameter was statistically significant ($p < 0.01$), along with the longest distance between the lingual foramen and the alveolar ridge ($p < 0.05$), and the shortest distance between the lingual and mental foramen ($p < 0.01$), all observed on the right side. These findings highlight the anatomical variations and spatial relationships of the lingual artery and foramina, which are crucial for surgical planning in the anterior mandible.
Conclusions: The findings regarding the presence, diameter, and prevalence of vascular canals are critical for oral surgery and must be considered when planning any procedures in the anterior mandible. Notably, we report an uncommon case involving a quintuple lingual canal. To prevent potentially life-threatening bleeding during surgical interventions, it is essential to identify these vascular structures using CBCT prior to mandibular surgery. This proactive approach enhances surgical safety and reduces the risk of complications.

Keywords: Anterior Mandible, Lingual Vascular Canal, Lingual Foramen, Cone-Beam Computed Tomography

Öz

Amaç: Bu çalışmanın amacı, klinik olarak elde edilen konik ışınlı bilgisayarlı tomografi (KIBT) görüntülerinin retrospektif analizini kullanarak anterior mandibuladaki lingual foramenin bölgesel sıklığını, yerini ve çapını değerlendirmektir.
Materyal ve Metod: Yetmiş altı hastanın (41 kadın ve 35 erkek) anterior mandibulalarındaki iki yüz otuz dört bölge, endosseöz kanalların varlığı açısından KIBT'ye dayalı olarak retrospektif şekilde incelenmiştir. Lingual foramen ile ilgili olarak, arterin maksimum çapı ve lingual foramenin çapı detaylı bir şekilde ölçülmüştür. Ayrıca, lingual foramen ile alveolar sırt, diş apeksi, mandibular sınır ve mental foramen arasındaki mesafeler de hesaplanmıştır. Elde edilen veriler, istatistiksel olarak analiz edilmek üzere ANOVA ve bağımsız örneklem t-testi kullanılarak değerlendirilmiştir.
Ölçülen değişkenlerin dağılımları analizden önce normallik açısından değerlendirilmiştir. Normallik, Shapiro-Wilk testi gibi uygun istatistiksel testler ve Q-Q grafikleri gibi görsel inceleme yöntemleri kullanılarak doğrulanmıştır. Veriler normallik varsayımlarını karşıladığı için, analiz için parametrik testlerin uygun olduğu düşünülmüştür. Sonuç olarak, gruplar arasındaki farklılıkları ve değişkenler arasındaki ilişkileri değerlendirmek için ANOVA ve bağımsız örneklem t-testleri kullanılmıştır. Bu yaklaşım, normal dağılımın özelliklerini kullanarak daha sağlam istatistiksel çıkarımlara olanak tanımaktadır.
Bulgular: Bu çalışmada, lingual arter çapları 0.3 ila 1.67 mm arasında değişiklik göstermiştir. Lingual foramenlerin çoğu (47,62%) orta hat bölgesinde tespit edilmiştir. Ayrıca, KIBT taramalarında beşli kanal gözlemlenmiştir. Arter çapının en yüksek ölçümü sağ tarafta bulunurken, bu sonuç istatistiksel olarak anlamlıdır ($p < 0,01$).
Lingual foramen ile alveolar sırt arasındaki en uzun mesafe de sağ tarafta kaydedilmiştir ve bu da istatistiksel olarak anlamlı bir sonuç göstermektedir ($p < 0,05$). Lingual foramen ile mental foramen arasındaki en yakın mesafe de sağ tarafta gözlemlenmiş olup, bu ölçüm de anlamlı bulunmuştur ($p < 0,01$).
Bu bulgular, anterior mandibulada cerrahi planlama için çok önemli olan lingual arter ve foraminaların anatomik varyasyonlarını ve mekansal ilişkilerini vurgulamaktadır.
Sonuç: Vasküler kanalların varlığı, çapı ve yaygınlığı ile ilgili bulgular, oral cerrahi uygulamaları açısından önemli sonuçlar ortaya koymaktadır. Anterior mandibulada gerçekleştirilecek her türlü operasyon planlanırken bu yapılar göz ardı edilmemelidir. Bu çalışmada, beşli lingual kanala sahip nadir bir vaka sunulmuştur.
Cerrahi müdahaleler sırasında potansiyel olarak yaşamı tehdit eden kanamayı önlemek için, mandibular cerrahiden önce bu vasküler yapıları KIBT kullanarak tanımlamak esastır. Bu proaktif yaklaşım cerrahi güvenliği artırır ve komplikasyon riskini azaltır.

Anahtar Kelimeler: Anterior Mandibula, Lingual Vasküler Kanal, Lingual Foramen, Konik Işınlı Bilgisayarlı Tomografi

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Introduction

The anterior mandibular region is the most preferred site for autologous bone harvesting and dental implant placement due to its relative safety, absence of major neurovascular structures, and quality of bone density (1-4). The interforaminal area of the mandible is particularly safe for dental implants supporting fixed partial dentures or overdentures. However, recent studies have assessed the vascularization of the symphysis region concerning the risk of hemorrhage. Some findings indicate that life-threatening hemorrhage and hematoma formation in the floor of the mouth can lead to serious upper airway obstruction. Research suggests a link between these critical incidents and the presence of the lateral lingual foramen (LLF), which may be associated with injury to the vasculature of the mandibular lateral foramina during implant surgery (1,2,5,6).

Lingual foramens (LF) are small holes on the mandible's lingual surface that are commonly found in the anterior areas (5). LFs are divided into two categories based on where they are located: in or near the midline [median lingual canal (MLC)] or laterally [lateral lingual canal (LLC)] (1,7-10). The lingual artery, sublingual artery, and branches of the mylohyoid nerve, lingual nerve, and mandibular incisive nerve (8,11-13) are demonstrated to supply the MLC with its contents. A neurovascular bundle from the submental artery, inferior alveolar artery, and inferior alveolar nerve (12,14) runs through the LLC. Mandibular LF has shown significant anatomical variance in many different populations, according to previous research (6,15). To minimize neurovascular injuries on the floor of the mouth, the presence, course, morphology, and location of mandibular LF must be determined. Confirming the presence and precise location of LF is crucial for both bone harvesting and dental implant placement.

Cone-beam computed tomography (CBCT) is widely utilized for preoperative evaluation due to its high resolution, rapid imaging capabilities, and low radiation exposure. CBCT scans of skeletal structures have an error rate of less than 1%, in contrast to panoramic radiographs, which have an error rate exceeding 30% (16-18). Given these advantages, a thorough examination of the region using CBCT is essential for achieving a more accurate assessment prior to oral procedures (19).

The goal of this study was to determine the regional frequency and anatomical aspects of mandibular LF using a retrospective analysis of clinically obtained CBCT images. In this respect, careful assessment of the region is essential utilizing the technical breakthrough represented by CBCT, which provides a more precise assessment.

Materials and Methods

This retrospective study enrolled a total of 76 patients—dentulous, partially edentulous, and edentulous—who were referred to an oral surgery center. Among them, 35 were male and 41 were female, with an average age of 47 years (range 25–67). Totally, 234 endosseous arteries were examined in 228 regions of 76 patients. 76 arteries located both in the midline (M) and the right-side (R), the rest of 82 arteries were in the left-side (L) regions.

Ethical approval was obtained from the Health Sciences Ethics Committee of Near East University (YDU/2020/77-1024) on February 27, 2020. The study adhered to the ethical standards set forth by the responsible committee on human experimentation (institutional and national) and complied with the Helsinki Declaration of 1975, as revised in 2000.

Anterior region images of the mandible were acquired using a CBCT device (MORITA, Kyoto, Japan), calibrated before each patient's scan. The exposure parameters included 8.0 mA, 90 kV, an exposure time of 9.4 seconds, a slice thickness of 0.960 mm, and a voxel size of 0.160 mm^3. An experienced investigator evaluated all CBCT scans. To assess reliability and repeatability, 50 randomly selected images were re-evaluated by the same observer two weeks after the initial assessment.

CBCT images of the mandibles were used for precise evaluation prior to dental implant placement and the extraction of impacted teeth. Patients with serious pathological lesions in the mandible, severe mandibular atrophy, impacted teeth near the foramina area, or low-quality CBCT images were excluded from the study.

The LF in the interforaminal area of the mandible were examined and classified based on their location. The midline (M) location was defined as the MLC, while the location between the canine and premolar regions was designated as the LLC (20), further divided into right (R) and left (L) sides. Measurements taken from the axial mandibular CT sections included the maximum diameter of the artery, the diameter of the LF, the distance between the LF and the alveolar ridge (AR), the distance between the LF and the tooth apex (TA), the vertical distance from the mandibular border (MB) to the LF, and the distance between the LF and the mental foramen (MF). Additionally, the presence of mono, bifid, and trifid canals was determined using the axial CT sections. Distance measurements were systematically obtained using tangent lines to the AR and the mental ridge, with vertical lines drawn to ensure accuracy in assessments (Figure 1).

The distributions of the measured variables were assessed for normality prior to analysis. Normality was confirmed using appropriate statistical tests, such as the Shapiro-Wilk test, and visual inspection methods, including Q-Q plots. Since the data met the assumptions of normality, parametric tests were deemed appropriate for analysis. Consequently, ANOVA and independent sample t-tests were employed to evaluate the differences among groups and the relationships between variables. This approach allows for more robust statistical inferences, leveraging the properties of the normal distribution.

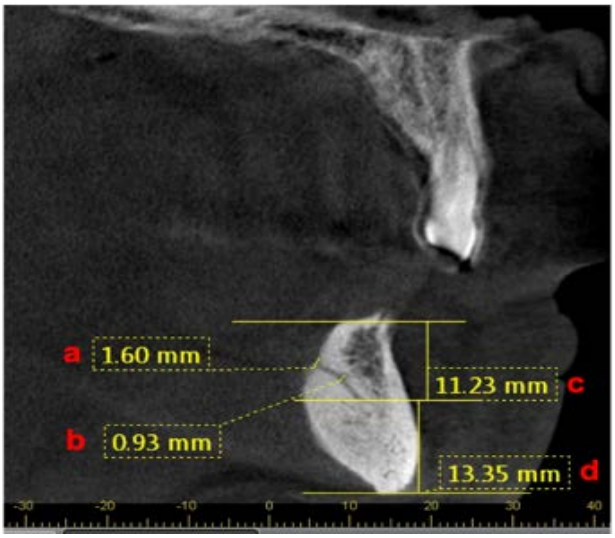

Figure 1. Linear measurements on axial mandibular CBCT sections. (a) diameter of the LF (b) maximum diameter of the artery (c) the distance between the LF and the AR (d) the distance between the LF and the MB

Results

A total of 70 participants were analyzed, with a greater number of females (n = 40) than males (n = 30) exhibiting a maximum diameter of the artery less than the mean (M = 0.71) (Table 1).

Table 1. Sex - maximum diameter of the artery crosstabulation

		<=0.71	>0.71
Sex	**Female**	40	15
	Male	30	19
	Total	70	34

The independent t-test comparisons for the distances between the lingual foramen (LF) and the mental foramen (MF) and alveolar ridge (AR) revealed no significant differences between genders (See Table 2). Specifically, the distances measured were:

Distance from LF to TA:

Female:

Mean (M) = 9.18

Standard Deviation (SD) = 3.46

Male:

M = 10.60

SD = 3.57

t-test Results:

t(26) = −1.06

p = 0.30 (not statistically significant)

Distance from LF to AR:

Female:

M = 14.45

SD = 4.54

Male:

M = 15.40

SD = 4.13

t-test Results:

t(101) = −1.10

p = 0.27 (not statistically significant)

In both cases, the p-values (0.30 and 0.27) indicate that there is no significant difference between the distances for males and females at the given alpha level (typically 0.05).

Table 2. Mean and standart deviations of distance between LF and TA, AR by gender

	Sex	n	Mean	Std. Deviation	Std. Error Mean
The distance between the LF and the TA	Female	14	9.18	3.46	0.93
	Male	14	10.60	3.57	0.95
The distance between the LF and the AR	Female	54	14.45	4.54	0.62
	Male	49	15.40	4.13	0.59

LF: Lingual foramen; TA: Tooth apex; AR: Alveolar ridge

Effect of Artery Location

One-way ANOVA revealed significant effects of artery location (Right, Left, Middle) on various measurements (Table 4):

Maximum Diameter of the Artery:

Right: M=0.96,

Left: M=0.68,

Middle: M=0.64,

Statistical Significance: F(2,101)=9.532, p<0.01 (Table 5).

Distance from LF to AR:

Right: M=17.43

Left: M=15.17

Middle: M=13.88

Statistical Significance: F(2,100)=4.33, p=0.016

Distance from LF to MF:

Right: M=11.91

Left: M=16.37

Middle: M=20.79

Statistical Significance: F(2,101)=21.28, p<0.01

Frequency of Lingual Canals

The detection rates of lingual arteries varied by location:

- Right: Not detectable in 59 patients (45.74%).
- Middle: Not detectable in 26 patients (20.15%).
- Left: Not detectable in 44 patients (34.11%).

Of the 76 patients analyzed, the frequency of lingual arteries was recorded as:

- Middle: 65.78% (50 patients).
- Left: 43.42% (33 patients).
- Right: 22.36% (17 patients).

Table 3 compares the distances between LF & TA and LF & AR, showing that there is no statistically significant difference in either case (p-values > 0.05). The mean differences (-1.41 for LF-TA and -0.95 for LF-AR) suggest small variations, but they are not meaningful. Levene's test confirms that variances are equal, meaning the variability in distances is similar across groups

Table 3. LF, TA and AR Comparison

		Levene's Test for Equality of Variances		t-test for Equality of Means			Mean Difference
		F	Sig.	t	df	Sig. (2-tailed)	
The distance between the LF and the TA	Equal variances assumed	0.03	0.87	-1.06	26	0.30	-1.41
	Equal variances not assumed			-1.06	25.76	0.30	-1.41
The distance between the LF and the AR	Equal variances assumed	0.36	0.55	-1.10	101	0.27	-.095
	Equal variances not assumed			-1.11	101	0.27	-0.95

LF: Lingual foramen; TA: Tooth apex; AR: Alveolar ridge

Table 4. LF, AR, TA, MB, MF Statistics

Variable	Mean ± SD	Median (Min - Max)
Maximum diameter of the artery	0.71 ± 0.28	0.68 (0.30 - 1.67)
Diameter of the LF	1.11 ± 0.40	1.00 (0.50 - 3.02)
Distance LF to AR (mm)	14.90 ± 4.36	15.17 (0.00 - 24.65)
Distance LF to TA (mm)	9.89 ± 3.52	10.50 (3.36 - 17.70)
Vertical distance MB to LF (mm)	11.11 ± 3.03	11.00 (0.00 - 21.28)
Distance LF to MF (mm)	17.96 ± 5.54	18.50 (1.23 - 26.39)

LF: Lingual foramen; AR: Alveolar ridge; TA: Tooth apex; MB: Mandibular border; MF: Mental foramen

Table 5. LF, AR, TA, MB and MF Comparisons

		Sum of Squares	df	Mean Square	F	Sig.
Maximum diameter of the artery	Between Groups	1.240	2	.620	9.532	.000
	Within Groups	6.567	101	.065		
	Total	7.807	103			
The distance between the LF and the AR	Between Groups	154.312	2	77.156	4.334	.016
	Within Groups	1780.315	100	17.803		
	Total	1934.626	102			
The distance between the LF and the TA	Between Groups	4.870	1	4.870	.384	.541
	Within Groups	330.147	26	12.698		
	Total	335.016	27			
Diameter of the LF	Between Groups	.157	2	.078	.493	.612
	Within Groups	16.047	101	.159		
	Total	16.204	103			
The vertical distance from the MB to the LF	Between Groups	47.211	2	23.605	2.657	.075
	Within Groups	897.403	101	8.885		
	Total	944.614	103			
The distance between the LF and the MF	Between Groups	936.544	2	468.272	21.276	.000
	Within Groups	2222.898	101	22.009		
	Total	3159.442	103			

LF: Lingual foramen; AR: Alveolar ridge; TA: Tooth apex; MB: Mandibular border; MF: Mental foramen

Discussion

Frequency and Distribution of Lingual Canals

In this study, we evaluated the frequency, distribution, and arterial diameters of bony canals within the anterior mandible using CBCT scans, as these structures are challenging to visualize through conventional radiography. Previous studies have reported the incidence of the lingual foramen in the mandible to range from 58.8% to 99.0%, findings that are consistent with our observations (18, 21-23). Gahleitner et al. reported that all patients in their study had at least one lingual canal in the anterior mandibular region (20). Among the anatomical variations observed, while the trifid mandibular canal type is relatively rare (24, 25), our investigation identified a quintuple canal type in a female patient (Figure 2); however, this patient was excluded from statistical analyses. Gahleitner et al. classified the location of the lingual foramen as MLC and LLC, whereas we categorized it as left, midline, and right (20).

Presence of Lingual Arteries

Out of 76 patients with detectable lingual arteries, 65.78% exhibited the arteries solely on the midline of the mandible. In comparison, the frequency of lingual arteries was found to be 43.42% on the left side and 22.36% on the right side. He et al. found a presence ratio of 69.85% for lingual arteries in the middle region, which aligns with our findings (5). Tepper et al. observed that lingual arteries were located at the midline in all 70 patients studied (26). Additionally, various studies have reported a significantly higher frequency of lingual arteries in the middle section of the anterior mandible compared to the lateral aspects (8, 27, 28).

Romanos et al. noted a 9% prevalence of multiple canals (two or three) in their study (29). However, in our analysis, only five out of 76 patients (6.58%) exhibited two arteries on the left side.

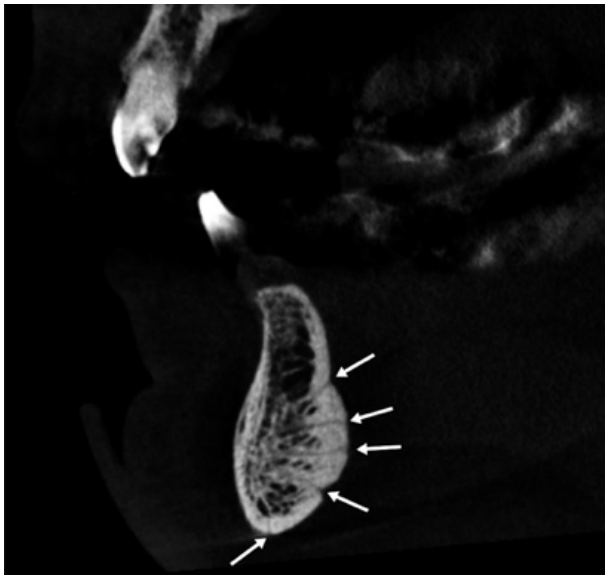

Figure 2. Quintuple lingual canal (arrows)

Diameter of Lingual Arteries

The diameter of the lingual artery is critical due to its association with the risk of significant bleeding during surgical procedures. Lustig et al. reported blood flow velocities in lingual arteries with diameters ranging from 0.18 mm to 1.8 mm, measuring between 0.7 to 3.7 ml/min (30). In our study, the diameter of the lingual arteries ranged from 0.3 mm to 1.67 mm (Figure 3). These findings underscore the necessity for CBCT imaging of the lingual arteries in the anterior mandibular region prior to surgical interventions.

Dubois et al. (31) and Kusum et al. (32) reported several cases of life-threatening bleeding in the anterior mandible during or after implant surgery.

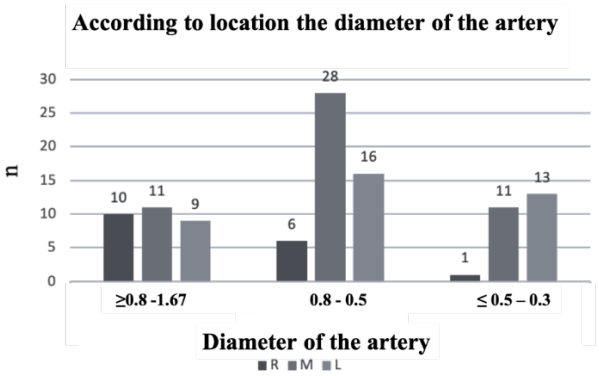

Figure 3. According to location the diameter (mm) of the artery.

Measurements from CBCT Scans

From a total of 234 CBCT scans of 76 patients, lingual arteries were detected in 105 measurements. The results indicated:

- Mono Canal: Detected in 68 measurements (64.76%, comprising 14 right, 23 midline, and 31 left) across 50 patients (65.79%).
- Bifid Canal: Identified in 24 measurements (22.86%, including 2 right, 17 midline, and 5 left) from 24 patients (31.58%).
- Trifid Canal: Found in 13 measurements (12.38%, with 1 right, 10 midline, and 2 left) across 13 patients (17.11%).

Additionally, one canal was detected in all three regions (right, midline, and left) in four patients. Among the 105 measurements of lingual arteries, 17 (16.19%) were on the right side, 50 (47.62%) were on the midline, and 38 (36.19%) were on the left side.

These findings emphasize the importance of understanding the anatomical variations and distributions of the lingual arteries in the anterior mandible, highlighting the role of advanced imaging techniques such as CBCT in surgical planning.

Conclusion

This study demonstrates that the examination of the surgical site using computed tomography, particularly prior to mandibular implant surgery, can yield valuable information. Notably, we report a rare case of a unilateral quintuple lingual canal in the symphysis region of the mandible in a female patient, a type not previously documented among multi-trunk canals.

Our findings underscore the significance of these anatomical variations for oral surgery, revealing arteries with a maximum diameter ranging from 0.3 to 1.67 mm and a 98.68% prevalence of vascular channels. Such details are crucial and should not be overlooked when working in the anterior mandible. To prevent potentially life-threatening bleeding, it is essential to detect these vessels CBCT before undertaking mandibular surgery. These findings highlight significant anatomical variations in the lingual artery influenced by both gender and anatomical location, underscoring their

importance in clinical practice.

Ethical Approval: *The ethical approval was taken from the Health Sciences Ethics Committee of Near East University (YDU/2020/77-1024) on February 27, 2020.*

Author Contributions:
Concept: A.B., A.E.E., Ü.C.Ş., Ö.E.B.
Literature Review: A.B., A.E.E.
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Data acquisition: A.B.
Analysis and interpretation: N.T.
Writing manuscript: A.B., A.E.E., N.T., Ü.C.Ş., Ö.E.B.
Critical revision of manuscript: A.B., A.E.E., N.T., Ü.C.Ş., Ö.E.B.
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