Evaluation of Mandibular Lingual Foramina Related to Dental Implant Treatment With Computerized Tomography: A Multicenter Clinical Study

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Background: *Bleeding can be one of the severe complications during implant placement or other surgeries. Presurgical assessment of the area should be performed precisely. Thus, we examined lingual vascular canals of the mandible using dental computerized tomography (CT); define the anatomical characteristics of canals and the relationship with mandibular bone.*

Methods: *One thousand sixty-one foramina in 639 patients, in 5 dental clinics, were included in this multicenter study. Distance between crest and lingual foramen, tooth apex and lingual foramen, distance from mandibular border, diameter of lingual foramen, canal type, anastomosis, and location of foramen were examined.*

Results: *Foramen was 18.33 ± 5.45 mm below the bony crest and 17.40 ± 7.52 mm from the mandibular border, with men showing larger measurements. The mean diameter of lingual foramina was 0.89 ± 0.40 mm; 76.8% canal type was mono; 51.8% patients presented with median lingual canal-foramen (MLC) and 21.1% with lateral lingual foramen. Diameter of MLC was statistically larger.*

Conclusions: *With a large sample group, results represented that lingual foramina could be visualized with dental CT, providing useful data for mandibular implant surgeries. Findings suggest that vascular canals and several anastomoses exist in the anterior mandible extending through premolar and molar regions as well. It is imperative to consider these vessels with the dental CT before and during the mandibular surgery to prevent threatening hemorrhage. (Implant Dent 2014;23:57–63)*

Key Words: dental implant, mandibula, anatomy, tomography, humans, surgery

Dental implant placement is a routine and predictable technique for the replacement of missing teeth. Interforaminal region is a good choice for the implant placement to support fixed partial dentures or overdentures. Symphysis is one of the autologous donor graft area in the oral cavity in need of excessive ridge augmentations.[1,2] Submental branch of the facial artery and sublingual branch of the lingual artery supplies this area, including the sublingual gland, mylohyoid, geniohyoid and genioglossus muscles, mucous membranes of the mouth floor, and the lingual gingiva.[3,4]

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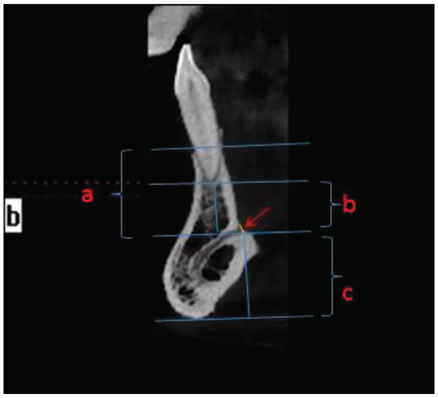

Fig. 1. Dimensional measurements on axial mandibular CT sections. **A**, Distance between crest and lingual foramen. **B**, Distance between tooth apex and lingual foramen. **C**, Vertical distance from the mandibular border to the lingual foramen. Arrow: diameter of lingual foramen.

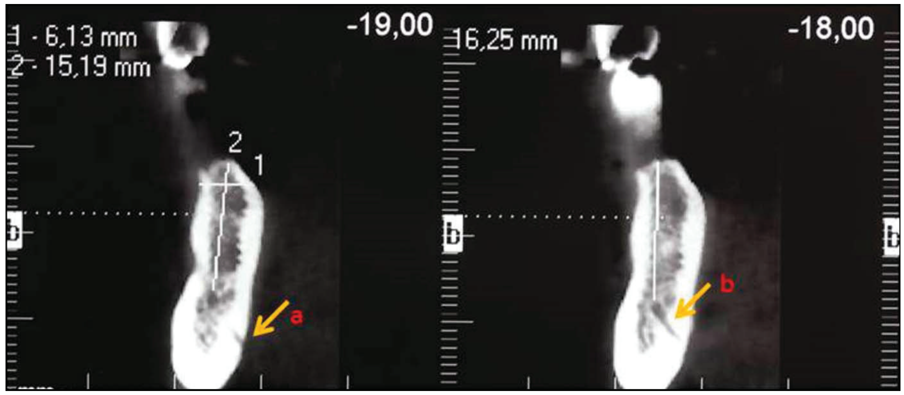

Fig. 3. Arrows: **A**, LLC, **B**, anastomosis between lingual and inferior alveolar artery.

The submental artery supplies the lymph nodes of the submandibular triangle, the anterior belly of the digastric muscle, and the mylohyoid muscle.[3,5] Important arterial anastomoses are formed between sublingual and submental arteries and between sublingual and incisive arteries through multiple accessory lingual foramina.[6] Mental artery, the branch of the inferior alveolar artery, was found to communicate with sublingual artery in the mental region of the internal mandible.[7] Although interforaminal region is a relatively safe area to place implants, perforation of the lingual cortex while placing dental implants can cause severe hemorrhage.[8–17] Additionally with the arterial wound, if drilling ruptures lingual periosteum, damage to anatomical structures in the sublingual space may enhance the bleeding, resulting in the hematoma of the floor of the mouth.[8] Besides the interforaminal region, the presence of lingual foramen in molar area has been reported as well.[18] Severe hemorrhage was reported during drilling in molar and premolar areas.[19,20]

Lingual vascular canals of the mandible have been investigated anatomically or by means of computerized tomography (CT).[21–35] Cadaver studies depicted that both submental and sublingual arteries perforate into the mandible through lingual foramen/foramina.[4,30] Longoni et al[34] examined the interforaminal area in 100 CTs of the Caucasian patients. They reported 61% vascular canals ranging in entrance diameters between 0.3 and 1.1 mm (mean, 0.6 ± 0.2 mm).[34] Katakami et al[18] reported the presence of arterial in the molar area and measured a mean diameter of 0.88 ± 0.2 mm. Position of the foramen was reported to be 7.06 mm from the border of the mandible.[18] Some authors classified the lingual foramina of the mandible as median lingual canal-foramen (MLC) and lateral lingual canal-foramen (LLC).[5,21,34,35] LLC diameters were found slightly lower than the midline values.[5,6,22]

After tooth extraction, bone loss is primarily horizontal from the labial side. This resorption pattern results in a lingually angulated trajectory of mandible. If atrophic inclined mandible is not considered well before implant placement, risk of lingual perforations may increase. Moreover, there is an existing osseous concavity, sublingual fossa, extending to the first premolar region. Dental CT is a well-known and frequently used imaging technique to depict bony architecture and surrounding anatomical structures. It is a valuable tool for ridge mapping and diagnosis of pathologies of the jaws, teeth, and maxillofacial

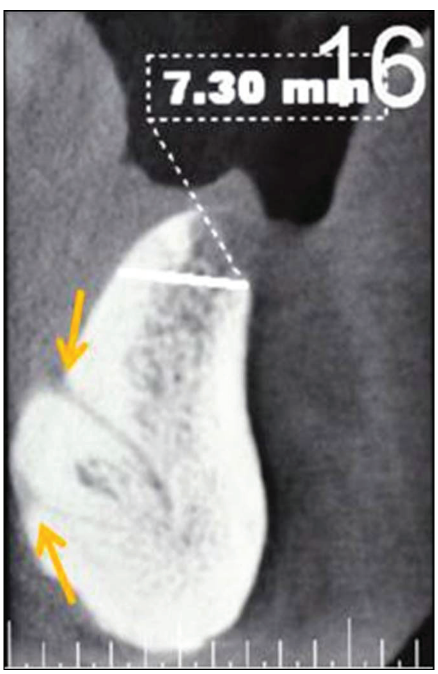

Fig. 2. Bifid lingual canal in the anterior mandible.

Table 1. Descriptive Statistics

	Women	Men	*P*	Total
Distance between crest and artery mm	17.64 ± 5.27	19.30 ± 5.57	0.000*	18.33 ± 5.45
Vertical distance from mandibular border mm	16.98 ± 8.35	17.97 ± 6.15	0.034*	17.40 ± 7.52
Distance between tooth apex and artery mm	9.44 ± 4.32	10.94 ± 4.33	0.000*	10.06 ± 4.38
Vertical size (diameter) of foramen mm	0.87 ± 0.42	0.91 ± 0.37	0.086	0.89 ± 0.40

One thousand sixty-one lingual foramen on axial mandibular CT sections were examined for the following measurements in Table 1. Statistically significant differences between men and women were detected in all parameters, except vertical size of the foramen.
$^*P < 0.05$.

Table 2. Vertical Size (Diameter) of Foramen

	Men				Women				Total			
	≤1 mm		>1 mm		≤1 mm		>1 mm		≤1 mm		>1 mm	
	n	%	n	%	n	%	n	%	n	%	n	%
Cyprus	23	27.1	62	72.9	23	26.4	64	73.6	46	26.7	126	73.3
Saudi Arabia	25	59.5	17	40.5	44	91.7	4	8.3	69	76.7	21	23.3
Spain	162	91.5	15	8.5	209	91.3	20	8.7	371	91.4	35	8.6
Lithuania	29	61.7	18	38.3	61	67	30	33	90	65.2	48	34.8
Turkey	85	88.5	11	11.5	141	88.7	18	11.3	226	88.6	29	11.4
Total	324	72.5	123	27.5	478	77.9	136	22.1	802	75.6	259	24.4

The distribution of diameters in 5 different countries was shown in this table. The diameter of foramina was classified as ≤1 and >1 mm to determine the risk of severe hemorrhage. Of the 1061 foramina, 75.6% were ≤1 mm and 24.4% were >1 mm.

Table 3. Artery Type According to Gender

	Mono (%)	Bifid (%)	Triple (%)
Male	78.1	18.7	3.2
Female	75.9	20.9	3.2
Total	76.8	20.0	3.2

About 43.34% of the patients have 1 lingual foramen and 56.65% have more than 1. The most prevalent artery type was monotype in men and women, in percentages of 78.1% and 75.9%, respectively. The least artery type was triple type in both the genders.

area.[36] Presurgical 3-dimensional assessment of the area is highly suggested to achieve favorable prosthetic angulations and avoid complications.[24,37]

Thus, we aimed to examine lingual vascular canals of the mandible using reformatted 3-dimensional axial CT sections and define the anatomical characteristics of the canals and their relationship with mandibular bone to provide useful preoperative information.

MATERIALS AND METHODS

A total of 639 partially dentulous and/or edentulous patients (266 men and 373 women, aged 18–83 years; mean 50 ± 14.18 years) scheduled for implant insertion in 5 dental clinics (185 CTs in Turkey, 173 CTs in Spain, 162 CTs in Cyprus-Turkey, 61 CTs in Lithuania, and 51 CTs in Saudi Arabia) were enrolled in this study. One thousand sixty-one lingual foramina of 639 patients were examined. One calibrated investigator (Y.D.Y., H.G.Y., M.V.-T., R.A.-S., and G.J.) at each center performed all the measurements. Spiral (Siemens AR-SP 40; Siemens, Munich, Germany) and cone-beam CT scans (Imaging Sciences International, Hatfield, PA) achieved in these centers were used in the present study. A detailed research protocol was discussed and agreed before initiation of the study. Measurements were clarified on schematic diagrams between the calibrated investigators (Y.D.Y., H.G.Y., M.V-T., R.A-S., and G.J.). CTs with low-quality imaging, such as scattering of the bony borders and pathology, were excluded. One thousand sixty-one lingual foramen on axial mandibular CT sections were examined for the following measurements (Figs. 1–3):

1. Distance between crest and lingual foramen.
2. Distance between tooth apex and lingual foramen if tooth is present at the location of foramen.
3. Vertical distance from the mandibular border.
4. Diameter (vertical size) of lingual foramen.

Lingual vascular canal type was classified as mono, bifid, and triples if the number of bony canal inside the mandible in an axial CT section is only 1, 2, or 3, respectively. If more than 1 canal is detected, the mean measurements were calculated and recorded as 1 measurement. Occurrence of lingual foramen on both the sides of mandible was noted as bilateral, if not, unilateral. Anastomoses with incisive artery, mental artery, and alveolar inferior artery were evaluated. Dentition status of mandibles and location of lingual foramen were recorded. Location of foramen was determined as the tooth number, observed at the region of that tooth.

In the literature, lingual canal located in or near midline is called MLC and that located in premolar regions is called LLC.[21] A recent study included the canine teeth into LLC.[21] Cadaver studies named the canal/foramen as "lateral" if it is not located at the midline.[28] In this study, the foramina of the whole mandible was examined rather than the interforaminal area.

Statistical Analyses

All statistical analyses were performed by the center at Hacettepe University with the SPSS for Windows 16.0 software (SPSS, Chicago, IL). Age and sex of the patients were recorded, and the measurements were analyzed according to the age and sex. Mean ± SDs and frequency, percentage were calculated for numerical and categorical variables, respectively. Independent samples *t* test was used to compare the differences between the gender groups.

Table 4. Regional Frequency of Lingual Foramen

	LLC						MLC				LLC						Total
Teeth	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	
%	0.3	0.1	1.1	4.4	6.9	6.3	5.0	26.9	24.5	3.9	7.3	7.7	3.8	1.4	0.3	0.2	100

Three hundred thirty-one patients presented with foramina only in median part of the mandible, 135 patients only in lateral sides, and 173 patients in both.

Table 5. Descriptive Statistics of MLC and LLC

	Median Lingual Foramen (MLC)			Lateral Lingual Foramen (LLC)			Total		
	Men	Women	*P*	Men	Women	*P*	MLC	LLC	*P*
Distance between crest and artery mm	19.42 ± 5.98	17.45 ± 5.46	0.000*	19.16 ± 5.04	17.03 ± 5.03	0.008*	18.24 ± 5.75	18.43 ± 5.07	0.575
Vertical distance from mandibular border mm	18.44 ± 5.98	17.18 ± 9.93	0.086	17.46 ± 6.30	16.60 ± 5.79	0.123	17.69 ± 8.58	16.99 ± 6.04	0.136
Distance between tooth apex and artery mm	11.62 ± 4.13	9.41 ± 3.81	0.000*	9.96 ± 4.42	9.62 ± 5.10	0.508	10.30 ± 4.09	9.77 ± 4.81	0.075
Vertical size (diameter) of foramen mm	0.95 ± 0.40	0.90 ± 0.47	0.187	0.87 ± 0.32	0.82 ± 0.35	0.113	0.92 ± 0.44	0.84 ± 0.34	0.002*

The only significant difference between MLC and LLC was detected in diameter of foramen; MLC was significantly larger than LLC.
*$P < 0.05$.

The correlations between numerical variables were analyzed with Pearson correlation coefficient. $P < 0.05$ was considered statistically significant.

RESULTS

From the 639 mandibular CTs examined, 1061 mandibular lingual foramina were detected. About 20.5% of the mandible was dentate, 10.2% was full edentate, and 69.3% was partially edentate. Foramen was found at a mean distance of 18.33 ± 5.45 mm below the bony crest and 17.40 ± 7.52 mm from the mandibular border. The differences were statistically significant for men and women ($P = 0.000$ and $P = 0.034$, respectively). Distance between tooth apex and lingual artery was 10.06 ± 4.38 mm; the distance was significantly higher in men than women ($P = 0.000$). The mean diameter of lingual foramina was 0.89 ± 0.40 mm (Table 1).

We classified the diameter of foramina as ≤1 and >1 mm to determine the risk of severe hemorrhage. Of the 1061 foramina, 802 were ≤1 mm and 259 were >1 mm and these numbers corresponds to the 75.6% and 24.4% of whole foramina, respectively, where 72.5% of male patients presented with ≤1 mm foramina and 27.5% were >1 mm. It was 77.9% and 22.1%, respectively, in women. The distribution of diameters in 5 different countries was shown in Table 2.

The most prevalent lingual vascular canal type was mono (1 canal), determined in 76.8% of the canals. Approximately 20% was bifid and 3.2% of canals were triple. All the canals detected as bifid and triple were at the midline area. Distributions according to genders were listed in Table 3. About 277 (43.34%) patients have 1 lingual foramen and 362 (56.65%) have more than 1. About 362 patients having multiple foramina presented with the foramina mostly on both the right and the left sides of mandible (60.77% bilaterally and 39.22% unilaterally).

Vascular anastomoses were detected on CT sections in 38.1% of the arteries examined. The frequency of anastomoses, which could be seen with mental foramen, anterior loop, incisive canal, and mandibular canal were as follows: 2%, 4.5%, 3.7%, and 27.9%, respectively.

Three hundred thirty-one patients (51.8%) presented with foramina only in median part of the mandible, 135 patients (21.1%) only in lateral sides, and 173 patients (27.1%) in both. Regional frequency of lingual foramina was shown in Table 4. The measurements were examined for MLC and LLC separately (Table 5). Diameters of foramen were statistically larger in MLC ($P = 0.002$, $P = 0.000$, respectively). When MLC and LLC were examined according to gender, lingual foramina were found closer to alveolar crest and tooth apex in women on the median part of mandible ($P = 0.000$ for both distance between crest and artery, apex to artery). On the lateral part of the mandible, only distance between crest and artery was larger in men ($P = 0.008$).

The older the patients were, the shorter the vertical distance from mandibular border and distance between crest and foramen (r = –0.178, $P = 0.000$; r = –0.242, $P = 0.000$, respectively). Age was also negatively correlated with diameter of foramen (r = –0.188, $P = 0.000$). Vertical distance from mandibular border and distance between crest and foramen were positively correlated to each other (r = 0.702, $P = 0.000$). The distance from tooth apex to foramen was positively correlated with both vertical distance from mandibular border and distance between crest and foramen (r = 0.340, $P = 0.000$; r = 0.559, $P = 0.000$, respectively).

DISCUSSION

Several case reports have pointed out the life-threatening hematoma in the floor of the mouth because of injury of mandibular lingual vessels mainly occurred in the interforaminal region.[8–14,16] Profuse bleeding was reported in the premolar and molar region in some case reports but not well examined yet.[19,20] In this study, we examined the whole lingual foramina with a large group of patients (639 patients with 1061 foramina) by means of dental CT.

The distance to the foramen from the alveolar bone crest was found to be 18.33 ± 5.45 mm, ranging between 1 and 31 mm (MLC, 18.24 ± 5.75 mm; LLC,

18.43 ± 5.07 mm). Mardinger et al[38] found this range to be 2 to 26 mm in an anatomical study. The present results were consistent with this study. They dissected 12 hemimandibles, and in 10 of the mandibles, arteries were found in mental area, 9 in second molars, and 12 in canine area; 2 mm distance was measured in mental and molar areas. Because mandibular resorption was unclassified in this study, it can be assumed that in cases of atrophic edentulous ridges, it should be even shorter.

The mean distance from the mandibular border to the foramen was measured to be 17.40 ± 7.52 mm ranging from 1 to 31.2 mm in this study. Several CT studies gave different results.[18,21,26,30,35] Katakami et al[18] found a mean distance of 7.06 mm ranging between 0.75 and 15.28 mm on 181 patients. Other CT studies reported the mean results for median and LLCs separately. Tagaya et al[30] showed a range from 1.1 to 18.4 mm in the medial part and 7.7 mm (2.2–13.7 mm) mean distance from the mandibular border on the lateral side of 200 patients. Gültekin et al[35] found a mean distance of 11.6 ± 3 mm for MLCs and 6 ± 1.3 mm for LLC in 26 patients. Kilic et al[29] gave a range of 1 to 19 mm (median, 13 mm) for MLC and 2 to 35 mm (median, 7 mm) for LLC. The mean values were 10.2 ± 5.5 mm and 5.4 ± 3.8 mm for MLC and LLC, respectively, in another study of 32 patients.[21] In this study, the mean values were detected to be 17.69 ± 8.58 mm for MLC and 16.99 ± 6.04 mm for LLC. This higher distance could be because of the complex ethnicity of the study samples (5 different countries), and in our knowledge, this is the first study with such high sample group.

We measured the distance between tooth apex and artery in this study. Immediate implantation into carefully selected extraction sockets shortens the time of therapy. About 3- to 5-mm bone beyond the apex is supportive for primary stability in immediate implantation procedures. The mean distance was measured as 10.06 ± 4.38 mm in this study. Thus, study results reveal that there is enough space for immediate procedures and it is safe with regard to the lingual vessels. However, Froum et al[39] performed risk assessment in CT scans before extraction in the mandibular premolar and molar areas for immediate implant placement. For immediate implant placement, they determined that the amount of necessary bone in apical area should be 6 mm (4 mm for apical anchorage and 2 mm for safety zone). According to their results, 53% to 73% of mandibular premolars and molars presented with high risk when immediate implant treatment was considered. Therefore, one should suggest that presurgery CT scan evaluation is an obligation in this area when planning immediate implant placement treatment.

In accordance with the literature,[21,25,35] vertical size of foramen was 0.89 ± 0.40 mm in this study. Similarly, Katakami et al[18] reported a mean diameter of 0.88 ± 0.2 mm. They examined the lingual vascular canals of whole mandible similar to this study. A cadaver dissection study gave a mean diameter of 0.8 mm for perforating cortical branches of sublingual artery.[23] Another anatomical study with dry skull mandibles gave a mean diameter of foramen on the lingual side of mandible as 0.8 ± 0.4 mm.[28] Rosano et al[22] detected 0.8 to 0.9 mm diameter of genial foramen in the anatomical assessment of anterior mandible. The present study results obtained with CT sections are consistent with the anatomy.

Vertical size of foramen was mostly reported for MLC and LLC in the literature in CT examinations or just reported for median part of the mandible. The present study results for MLC and LLC were 0.92 ± 0.44 mm and 0.84 ± 0.34 mm, respectively. Consistent with the previous reports, diameter of MLC was statistically higher than LLC in this study.[21,35] Gültekin et al[35] reported a mean value of 0.8 ± 0.2 mm for MLC and 0.6 ± 0.1 mm for LLC with 26 patients. Kilic et al[29] reported 1.05 and 0.92 mm, respectively, in a study of 200 cases. These results were in accordance with each other. Gahleitner et al[21] reported slightly smaller diameter, 0.7 ± 0.3 mm for MLC and 0.6 ± 0.3 mm for LLC.

We classified the foramen diameters as ≤1 and >1 mm to give an idea about the risk of severe hemorrhage. Of the lingual foramen, 75.6% were ≤1 mm. Lustig et al[40] identified the lingual artery in the anterior mandible, width, and blood flow by ultrasound/doppler measurement. Average size was reported to be 1.41 ± 0.34 mm and blood flow was 2.92 ± 3.19 mL/min. It was concluded that the artery is of sufficient size to give rise to hemorrhage in implant placement and procedures related to symphysis. Moreover, 25.9% arteries traveling in the sublingual space were located between the sublingual gland and the mandible.[4] In this pattern of course, blood vessels run parallel to the occlusal plane and assumed that the vessels lying perpendicular to the drill bit are at a greater risk for arterial injury.[4] Mylohyoid muscle separates the mouth floor like a diaphragm. In dentate mandibles, artery traveling above the muscle is more prone to cause hemorrhage, whereas in edentulous, one runs below the mylohyoid muscle.[4] Morphology of the mandible of the implant patient should be observed well because perforation of the lingual cortical plate may lead to the violation of sublingual/submandibular area.

Several anastomoses of arteries take place in the body and oral cavity. Anastomosis of inferior alveolar artery and its branches, mental and incisive arteries, were found either with anatomical dissection or CT imaging.[7,18,27] Using a contrast medium, association between superior genial spinal foramen and incisive canal was examined in dry skulls. The association was seen in 41%, but the authors stated that leakage of the medium outside canals could not be totally prevented.[41] The observation of the anastomosis was reported; however, the frequency of this formation was given in only 1 study.[18] In this study, anastomoses of lingual artery with inferior alveolar artery and its branches could be detected with 38.1% of 1061 artery, whereas Katakami et al[18] showed 31 arterial anastomoses with 154 (20.12%) lingual artery, none was between intercanine area. We observed 3.7% anastomoses with incisive canal. The difference could be because of high number of samples investigated.

Gender differences had an influence on examined parameters, except diameter of the foramen. But, number of foramen >1 mm diameter was higher in men. Distances between crest and

foramen, tooth apex and foramen, and distance from the mandibular border were higher in men. Because the literature did not mention an evaluation about gender, on the parameters listed above, we cannot make a direct comparison. In a previous study, about tooth and dental arch dimensions, men had significantly larger dimensions.[42] Additionally, we observed gender differences in anatomical features of another bony canal and environmental bone of the jaws.[43]

According to Lee et al,[44] one may suggest that by using the cone-beam CT and a laser intraoral scanner in virtual dental implant surgery, dentist may perform safer and successful implant surgeries and treatments.

Conclusions

Within the limitation of this study, lingual foramina of the mandible could be visualized with dental CT and provided useful data for mandibular implant surgeries. Findings suggest that vascular canals and several anastomoses exist in the anterior mandible extending through premolar and molar region as well. Size and prevalence of the arteria should not be underestimated. They are sufficient to enhance the risk of severe bleeding in many cases. It is imperative to consider these vessels, using the dental CT, before and during the mandibular surgery to prevent threatening hemorrhage.

Disclosures

The authors claim to have no financial interest, either directly or indirectly, in the products or information listed in the article.

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