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Braca Kundalić[1], Slađana Ugrenović[1], Ivana Graovac[1], Vladimir Petrović[2], Jovana Čukuranović Kokoris[1], Vesna Stojanović[1], Branka Marković Ilić[3,♣]

Morphometric and morphological study of mandibular foramen and lingula in dry human mandibles

Морфометријска и морфолошка студија мандибуларног отвора и лингуле на доњим вилицама човека

[1]University of Niš, Faculty of Medicine, Department of Anatomy, Niš, Serbia;
[2]University of Niš, Faculty of Medicine, Department of Histology and Embryology, Niš, Serbia;
[3]University of Belgrade, Faculty of Sport and Physical Education, Belgrade, Serbia

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♣Correspondence to:
Branka MARKOVIĆ ILIĆ
Faculty of Sport and Physical Education, University of Belgrade, Blagoja Parovića 156, 11030 Belgrade, Serbia
e-mail: **branka.markovic@fsfv.bg.rs**

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SUMMARY

Introduction/Objective The mandibular foramen (MF) and lingula (ML) are key landmarks on the medial surface of mandibular ramus. Their position relative to ramus borders, dentition, and lingula morphology is clinically important for anesthesia and surgical procedures. The study aimed to assess the morphological and morphometric characteristics of MF and ML in relation to ramus borders, alveolar presence, and lingula shape in a Serbian population sample.

Methods The material comprised 50 human dry hemimandibles from the bone collection of the Department of Anatomy, Faculty of Medicine, University of Niš. Distances from MF and ML to the superior, anterior, and posterior ramus borders, temporal crest, and gonion were measured, along with MF diameter and ML height. Hemimandibles were classified by the number of alveoli present (0, 1–4, or 5–8). Lingulae were classified by shape. Measurements were obtained using a digital Vernier caliper, and mean values with standard deviations were analyzed by ANOVA. Statistical significance was deemed at $p<0.05$.

Results The MF–posterior border and ML–posterior border distances (14.49 and 16.03, respectively) were significantly larger in partially edentulous hemimandibles, compared with the dentulous subjects (11.97 and 13.95 mm, respectively). The triangular lingula was most prevalent (48%), followed by truncated (32%), nodular (16%), and assimilated (4%) forms. The ML–gonion distance was significantly greater in mandibles with a truncated *vs.* triangular lingula (33.37 *vs.* 27.99 mm).

Conclusion This study suggest considering the posterior ramus distance in partially edentulous patients and shape of ML to optimize MF localization for anesthesia and surgery.

Keywords: anatomic variation; mandible; morphometry; anesthesia; mandibular osteotomy

САЖЕТАК

Увод/Циљ Мандибуларни отвор (МО) и лингула (МЛ) представљају битне оријентире на унутрашњој страни гране мандибуле. Њихов положај у односу на ивице рамуса, дентицију и облик лингуле клинички су важни за анестетичке и хируршке процедуре. Циљ истраживања био је одредити морфолошке и морфометријске карактеристике МО и МЛ у односу на ивице гране мандибуле, присуство алвеола и облик лингуле у узорку српске популације.

Методе Материјал је чинило 50 полувилица човека из остеолошке колекције Катедре за анатомију Медицинског факултета Универзитета у Нишу. Мерена су растојања од МО и МЛ до горње, предње и задње ивице рамуса, слепоочног гребена и гониона, заједно са дијаметром МО и висином МЛ. Полувилице су класификоване по броју присутних алвеола (0, 1–4 и 5–8). Лингуле су подељене по облику на 4 групе. Мерења су вршена дигиталним нонијусом, а просечне вредности са стандардним девијацијама анализиране тестом АНОВА. Статистичка значајност је дефинисана као вредност $p < 0,05$.

Резултати Растојања између задње ивице рамуса и МО, односно МЛ као оријентирâ, била су статистички значајно већа код делимично безубих полувилица (14,49 мм, односно 16,03 мм) у поређењу са полувилицама са зубима (11,97 мм и 13,95 мм, по датом редоследу). Најчешћи облик лингуле био је троугласти (48%), затим зарубљени (32%), нодуларни (16%) и асимиловани (4%). Растојање од МЛ до гониона било је статистички значајно веће код мандибула са зарубљеном лингулом (33,37 према 27,99 мм).

Закључак Резултати студије указују на значај разматрања удаљености задње ивице мандибуле код делимично безубих пацијената, као и облика лингуле, за потребе оптималне локализације МО у анестезији и хирургији.

Кључне речи: анатомска варијација; мандибула; морфометрија; анестезија; мандибуларна остеотомија

INTRODUCTION

The mandibular ramus features landmarks such as four borders, mandibular foramen, and mandibular lingula. Knowledge of their spatial relationship may have clinical implications in oral and maxillofacial surgery.

The mandibular foramen (MF), located on the medial surface of the mandibular ramus, is the entry point for the inferior alveolar neurovascular bundle into the mandibular canal and represents a critical landmark in dental anesthesia and ramus surgery [1, 2]. Even minor positional variations significantly affect the trajectory of inferior alveolar nerve (IAN) blocks and the safety of medial osteotomies, underscoring the importance of population and modality specific morphometric mapping [3, 4]. Studies on dry skulls and imaging reveal systematic differences in MF location influenced by age, sex, dentition, and ethnicity, explaining variable anesthetic success and complication rates [1, 4].

The mandibular lingula (ML) is a variable bony projection adjacent to the MF, serving as the sphenomandibular ligament attachment [4–6]. Its morphology is commonly classified into triangular, truncated, nodular, and assimilated types [5], with distribution varying between populations and between dry bone and CBCT studies [4, 6, 7]. The ML position (vertical height above, and anterior–posterior relation to the MF) affects its reliability as a surgical landmark [7]. The ML shape may be assessed differently in dry bone *vs.* CBCT studies, where the latter ones report a nodular shape more frequently than a triangular one, due to the rounder appearance at the imaging caused by soft tissue, periosteum, and volume averaging [8].

Incorrect estimation of the MF and/or ML positions contributes to IAN block failures and increases risks of vascular or neural injury [3]. A clinically significant asymmetry of the mandible was reported in 10-25% of individuals [8]. The data reported on sex-specific or ethnic differences in the distance from the lingula to the posterior border of ramus suggest that measurements on one side should not be extrapolated to the contralateral one, but assessed preoperatively [8]. In orthognathic surgery, such as sagittal split ramus osteotomy (SSRO) and intraoral vertical ramus osteotomy (IVRO), osteotomy placement must respect the MF–ML complex to avoid nerve injury or unfavorable fractures. Alveoli number may influence MF position [9], but no data was reported regarding the ML. The relationship between alveoli number and mandibular lingula morphology/position is underexplored but may be of clinical importance. Variations in diameters in partially or totally edentulous patients may influence anesthesia success and surgical safety, yet no available studies have addressed this relationship. Morphometric data thus provide essential guidance for anesthesia accuracy and surgical safety [7, 10].

The aim of this study was to investigate the morphological and morphometric characteristics of the mandibular foramen and lingula in relation to the borders of the ramus, the number of present alveoli, and the shape of the lingula.

METHODS

All the material is a part of the osteological collection of the Department of Anatomy, Faculty of Medicine, University of Niš, Serbia, where the study was conducted in accordance with the Declaration of Helsinki. Fifty dry human hemimandibles from twenty-five adult subjects were included in this study. Age and gender of the subjects were unknown. Inclusion criteria were mandibles with no signs of fractures and a presence of both the mandibular foramen and lingula. Exclusion criteria were deformed and fractured hemimandibles, and obstructed mandibular foramen.

Measurements were obtained using a digital caliper with 0.01 mm accuracy. The presence and number of dental alveoli were noted. Shapes of ML were observed and classified, according to Tuli et al. [5], in four shapes. Morphometric landmarks were predetermined and the distances between them were measured in mm. (Figures 1 and 2). The MF point was the lowest point of the mandibular foramen. The ML point was the tip of the lingula. The AB point was the most concave point of the anterior border. The TC point was the most concave point of the temporal crest. The PB point was the most concave point of the posterior border. The MN point was the lowest point of the mandibular notch. The G point was the lowest point at the gonion. The diameter of the mandibular foramen was measured between the anterior and posterior borders of the MF. The height of lingula was measured as a distance from the tip of the lingula to the lowest point of the MF, along the line that was perpendicular to the plane parallel to the inferior border of the ramus. Two independent researchers cross-checked all measurements to reduce bias. Discrepancies > 10% prompted retake of measurements. The mean of two values was reported as final.

Dataset was analyzed using the SigmaStat 3.5 software. The normality distribution of the data was analyzed using Kolmogorov–Smirnov test. Levene's test was performed to determine the homogeneity of the variances. Morphometric measurements (the mean and standard deviation) were analyzed with the paired sample Student's t-test to check a symmetry between the hemimandibles, and with the one-way ANOVA to relate with the presence of alveoli and the lingula shape. The ANOVA was followed by the robust Holm–Šidák post-hoc test; in case of heteroscedastic data, the ANOVA on ranks was followed by the Dunn's post-hoc test for unequal variance group sizes. Statistical difference was considered significant at $p < 0.05$.

Ethics: The study was approved by the Ethics Committee of the Faculty of Medicine, University of Niš, Serbia (No. 12-13346-1/2-5, 28 October 2025).

RESULTS

The mean values and standard deviation of distances that describe the position of the MF and ML in relation to the bony landmarks on the hemimandible are given in mm and summarized in Table 1. There were no significant differences between the left and right hemimandibles. Distances from the MF towards anteriorly positioned landmarks (the temporal crest and the anterior border of the ramus) were larger on the left side (12.36 *vs.* 12.05 mm, and 16.85 *vs.* 16.62 mm, respectively), and a distance from the MF towards the posterior border was therefore shorter on the left side (13.36 *vs.* 13.59 mm). Both the distances from the MF to the mandibular notch and gonion were lower on the left side (21.85 *vs.* 22.12 mm, and 22.29 *vs.* 22.93 mm, respectively). The MF diameter was lower on the right side (3.59 *vs.* 3.76 mm). The height of the lingula was larger on the right side (8.34 *vs.* 7.28 mm).

Measured from the ML, the distances towards the anteriorly positioned points were larger too (11.41 *vs.* 10.97 mm to the TC landmark, and 17.41 *vs.* 16.32 mm to the AB point). The distances from the ML to the posterior border and mandibular notch were increased on the left ramus as well (15.31 *vs.* 14.81 mm, 15.37 *vs.* 15.00 mm, respectively) but decreased towards the gonion (28.75 *vs.* 31.13 mm).

Based on the number of present dental alveoli, all the hemimandibles were classified into three groups: with no alveoli, with 1–4, and with 5–8 alveoli present (Table 2). There were 21 hemimandibles, 15 hemimandibles, and 14 hemimandibles, respectively. The statistically significant difference was noted in the distances from both the MF and ML towards the posterior border in the subjects with 1–4 alveoli compared with those with 5–8 alveoli. In those with less alveoli, the MF–PB distance was significantly increased (14.49 *vs.* 11.97 mm, $p < 0.05$), as well as the ML–PB distance (16.03 *vs.* 13.95 mm, $p < 0.05$).

There were four shapes of lingula analyzed, and we found that there were 24 triangular (48%), 8 nodular (16%), 16 truncated (32%), and 2 assimilated (4%) lingulae (Table 3). All the morphometric measurements were then classified into four groups accordingly. It was the distance between the ML and gonion that was statistically significantly larger in the truncated lingula group compared with the triangular shape one (33.37 *vs.* 27.99 mm, $p < 0.05$).

DISCUSSION

Understanding the morphometric relationships among the MF, the ML, and adjacent landmarks may help accurately localize these structures in clinical practice [6]. The precise location of the MF and its variations is critical for the success of IAN block anesthesia [11, 12]. A lack of anatomical knowledge and insufficient training to manage variations have been identified as major causes of block failure among dental students [13]. In routine practice, injections are often placed slightly anterior to the true position of the MF, which contributes to failure rates of up to 25% after the first attempt [14]. The absence of clear guidance on the appropriate depth and vertical level of needle penetration compounds this problem [9].

Endodontic therapy, extractions, and most mandibular treatments depend on block anesthesia rather than infiltration, since the dense cortical bone of the mandible prevents effective diffusion of anesthetic solutions. Because the MF is concealed by soft tissue, clinicians must inject as close as possible to its true location to avoid complications such as hemorrhage or persistent nerve injury, making reliable reference points indispensable [15]. Beyond anesthesia, the MF plays a central role in surgical planning, particularly in procedures aimed at functional or aesthetic correction of dentofacial deformities [9]. For mandibular surgeries, such as osteotomies, endodontic procedures, fracture management, and tumor resections, preoperative radiographic assessment and the use of additional anatomical guide points are recommended to minimize neurovascular injury [12].

Cone beam CT studies suggest that identifying the lingula first, and then the MF, improves the success of IAN blocks [16]. The lingula itself is widely used as a clinical marker to approximate the MF.

Knowledge of its morphometric relationships is particularly valuable in situations where the lingula is absent or indistinct, or in centers where advanced three-dimensional imaging is not readily available, as clinicians must rely on anatomical reference points to guide procedures [17]. In SSRO and IVRO, precise localization of the lingula and MF is critical to avoid injury to the inferior alveolar nerve and to ensure predictable osteotomy lines [4].

The results of our study showed no significant side differences in the positions of the MF and ML relative to the bony landmarks of the mandibular ramus. The distance between these target points and the posterior border of the ramus may vary significantly, depending on the number of alveoli. We identified four shapes of the lingulae, with the triangular shape being most common (48% of subjects), while the assimilated shape was the rarest, observed in only 4% of samples. The distance between the lingula and the gonion was significantly larger in the truncated group than in the triangular group.

The average distance between the MF and PB in the partially edentulous subjects (14.49 mm) in our study was larger than in the other two groups and significantly greater than in those with 5–8 alveoli (11.97 mm). These mean values fall within the reported literature range (9.23–17.69 mm) [12, 18, 19]. We observed the same significance in the mean ML–PB distance between the dentate and partially edentulous subjects (13.95 *vs.* 16.03 mm), which was within the reported range of average values (13.02–18.2 mm) [4, 6, 20].

Clinical assessments in patients without morphological anomalies indicate that the MF is positioned slightly posterior to the midpoint in the anteroposterior plane and aligned with, or just above, the occlusal plane in the vertical dimension [11]. Evidence from cadaveric dissections and dry mandible studies places the MF approximately 2.75 mm behind the midpoint of the ramus and about 19 mm below the coronoid notch [11]. Radiographic analyses using panoramic imaging, together with anatomical preparations, showed the inferior alveolar foramen situated nearer to the posterior border of the mandibular ramus [18]. A CBCT study results showed that males exhibited greater distance from the MF to the posterior border, suggesting that male patients may have a relatively larger safety margin for the osteotomy procedures [19]. The lingula has been described as lying further from the posterior border in males [7, 20], though Lupi et al. reported no sex-related variation [3]. Findings across studies are inconsistent: some note differences between the left and right sides, while others observe no asymmetry [20]. Population-based analysis also showed that the ML–PB distance did not distinguish Kenyans from Malays [10].

In a study that presented the same stratification as we did, a mean value of the MF–PB distance was found to be 14.66, 12.88, and 14.63 mm in the groups with no, 1–4, and 5–8 alveoli, respectively, with a significant difference between the latter two [9]. Opposite to us as well, Matveeva et al. [12] found that the PB was closer to the MF unilaterally in the edentate mandibles compared with the dentate group (9.23 *vs.* 10.69 mm on the right side). The authors attributed these differences to resorptive alterations in the ramus due to the longer period of tooth loss. On the other hand, Menditti et al. [21] observed a remodelling of the alveolar bone with preserved surrounding soft tissue in the edentulous mandible. It was accented with a claim that a loss of lower teeth resulted in severe bone resorption and the mandible's structure modification [22]. This may lead to a decrease in the muscle activity and masticatory forces, which consequently may result in loss of bone tissue, which they hypothesize to be more in the region of the body of the mandible, and not its ramus [22], thus affecting the traction of the foramen towards the alveoli and further from the posterior ramus. Although we found no comparable data for the ML–PB length, it is reasonable to suggest that the aforementioned changes may also affect the ML, given its close relationship with the MF.

The pioneer study on the lingual shapes in the Indian population named a triangular-shaped lingula for the most prevalent, followed by the truncated, nodular, and assimilated [5], which was the same arrangement we found in dry mandibles as well. The same prevalence was observed in Turkish and Brazilian populations, whereas the truncated lingula was more frequent among Thais, Southern Indians, and South Africans [10]. It is suggested that the triangular shape would be the most easily identifiable and detectable during SSRO [17]. A meta-analysis of 4694 subjects postulated that the frequency differences are small, so the pooled prevalences were 29.33% for the triangular type, 27.99% for the nodular type, 27.62% for the truncated shape, and 10.49% for the assimilated lingulae [6]. Recent studies have used CBCT imaging to assess the shape of the human lingula. While CBCT avoids the issues associated with the preparation and preservation of dry mandibles, the interpretation of these images can be affected by reduced sharpness during software processing. In CBCT studies, the nodular type was most frequently observed, followed by truncated, triangular, and assimilated forms. These variations may relate to factors such as age, race, dentition, skeletal type, and the preparation and preservation of mandibles [23].

In the present study, the distance from the ML to the gonion was significantly larger in the truncated group than in the triangular group (33.37 *vs.* 27.99 mm). A CBCT study reported the same distance in a range of 27.3–27.8 mm [24]. It was discussed that elongated and very pointed mandibular lingulae might be presented with greater distances [3]. The height of the truncated lingulae in our study was lower compared with the triangular lingulae. Still, the tip of the latter was pointing more posteriorly, thus being closer to the distally positioned gonion, which may explain why the ML–G distance was significantly higher in the truncated group.

This study presents several limitations. The absence of soft tissue and demographic details may overlook anatomical differences reported in studies utilizing CBCT as a rapidly advancing technology in clinical settings and contemporary morphometric and maxillofacial anatomical research. The relatively small sample size reduces the generalizability of the findings and highlights the need for larger datasets. Individual anatomical variability underscores the importance of pre-operative imaging, as dry bone data alone cannot fully guide surgical practice. Finally, validation through larger cadaveric studies, surgical trials, or correlation with imaging is required to confirm the applicability of these results in vivo.

CONCLUSION

The results of our study provide new information concerning the relationships of the mandibular foramen and lingula in the sample of Serbian population. The morphometric results suggest that the foramen and lingula are positioned more posteriorly in dentate mandibles compared with the partially edentulous ones. The most prevalent shape of the lingula we described is a triangular (48%), followed by the truncated (32%), nodular (16%), and assimilated (4%). Depending on the shape and height of the lingula, the ML–gonion distance may be larger in the presence of truncated lingula. The obtained data may be of use in planning and performing anesthetic blocks and surgical osteotomies.

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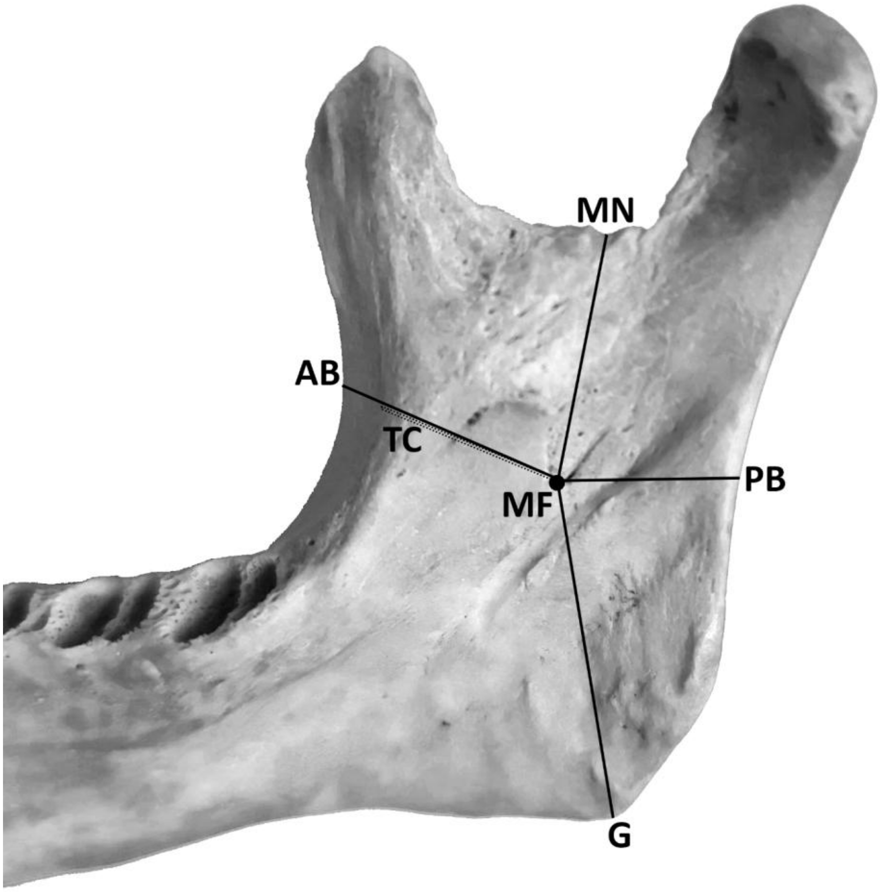

Figure 1. Distance measurements (full black line; MF–TC distance with the dotted line) and landmarks on the right hemimandible;

MF – mandibular foramen; TC – temporal crest; AB – anterior border of ramus; PB – posterior border of ramus; MN – mandibular notch; G – gonion

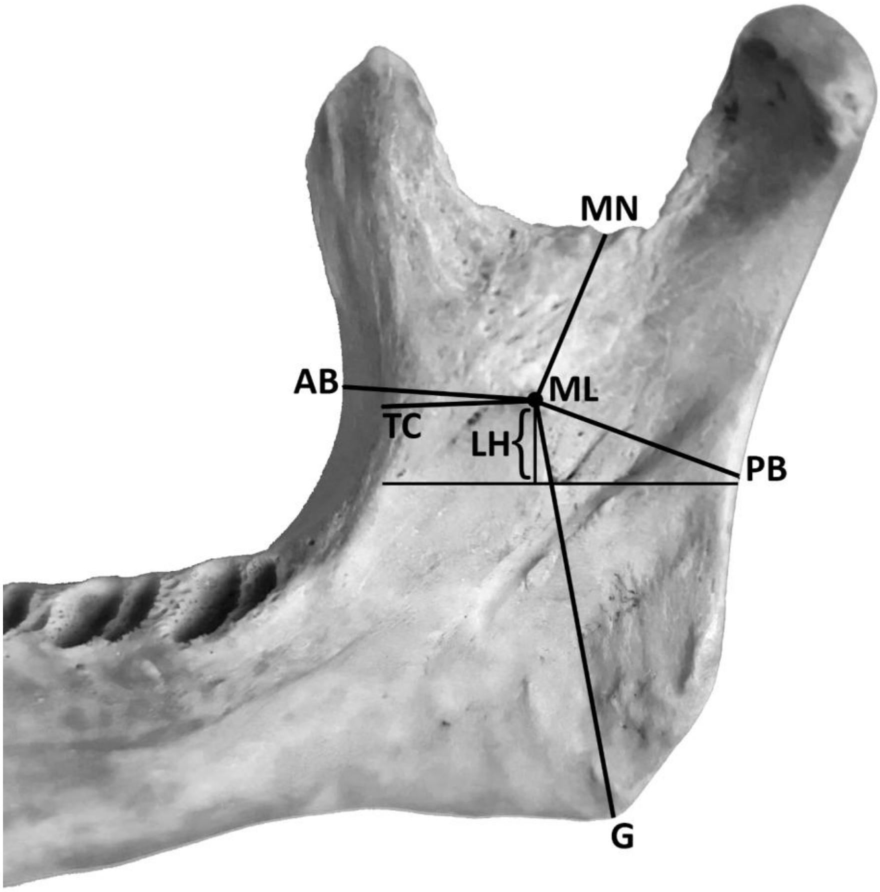

Figure 2. Distance measurements (full black line) and landmarks on the right hemimandible;

ML – lingula; TC – temporal crest; AB – anterior border of ramus; PB – posterior border of ramus; MN – mandibular notch; G – gonion; LH – height of lingula;

LH is depicted as a vertical line drawn perpendicular to the horizontal plane passing through the inferior border of the mandibular foramen, and oriented parallel to the inferior border of the ramus

Table 1. Morphometric characteristics of the mandibular foramen and lingula according to side, in mm

Side	N		MF–TC	MF–AB	MF–PB	MF–MN	MF–G	MFD	MLH	ML–TC	ML–AB	ML–PB	ML–MN	ML–G
Left (L)	25	Mean	12.36	16.85	13.36	21.85	22.29	3.76	7.28	11.41	17.41	15.31	15.37	28.75
		SD	2.18	2.12	2.24	3.27	4.20	0.71	2.02	2.63	3.02	2.21	2.36	5.23
Right (R)	25	Mean	12.05	16.62	13.59	22.12	22.93	3.59	8.34	10.97	16.32	14.81	15	31.13
		SD	1.99	2.26	3.35	3.34	4.73	0.95	2.15	2.11	2.41	2.15	2.69	6.11
Total	50	Mean	12.21	16.74	13.47	21.99	22.61	3.67	7.81	11.19	16.86	15.06	15.19	29.94
		SD	2.07	2.18	2.82	3.27	4.44	0.83	2.13	2.37	2.76	2.17	2.51	5.76
L *vs.* R (p-value)			0.60	0.72	0.78	0.78	0.61	0.49	0.08	0.51	0.17	0.43	0.61	0.15

N – number of hemimandibles; SD – standard deviation; MF–TC – distance between mandibular foramen and temporal crest; MF–AB – distance between mandibular foramen and anterior border of ramus; MF–PB – distance between mandibular foramen and posterior border of ramus; MF–MN – distance between mandibular foramen and mandibular notch; MF–G – distance between mandibular foramen and gonion; MFD – diameter of mandibular foramen; MLH – height of mandibular lingula; ML–TC – distance between mandibular lingula and temporal crest; ML–AB – distance between mandibular lingula and anterior border of ramus; ML–PB – distance between mandibular lingula and posterior border of ramus; ML–MN – distance between mandibular lingula and mandibular notch; ML–G – distance between mandibular lingula and gonion

Table 2. Morphometric characteristics of the mandibular foramen and lingula according to number of present dental alveoli, in mm

Alveoli	N		MF–TC	MF–AB	MF–PB	MF–MN	MF–G	MFD	MLH	ML–TC	ML–AB	ML–PB	ML–MN	ML–G
0	21	Mean	11.99	16.71	13.75	21.91	22.67	3.86	7.93	11.6	17.06	15.11	14.66	30.55
		SD	1.42	1.72	2.05	3.91	3.53	0.81	2.51	2.21	2.21	1.29	2.73	4.53
1–4	15	Mean	12.26	16.99	**14.49**[a]	21.37	22.74	3.44	7.55	11.37	17.13	**16.03**[b]	15.41	27.67
		SD	1.76	2.66	3.4	2.35	4.25	0.88	1.83	2.81	3.84	2.45	2.32	5.79
5–8	14	Mean	12.11	16.50	**11.97**[a]	22.28	22.66	3.65	7.9	11.04	16.29	**13.95**[b]	15.81	31.47
		SD	2.99	2.35	2.72	3.20	5.87	0.81	1.92	2.51	2.18	2.51	2.47	6.94

N: number of hemimandibles; SD: standard deviation; MF–TC: distance between mandibular foramen and temporal crest; MF–AB: distance between mandibular foramen and anterior border of ramus; MF–PB: distance between mandibular foramen and posterior border of ramus; MF–MN: distance between mandibular foramen and mandibular notch; MF–G: distance between mandibular foramen and gonion; MFD: diameter of mandibular foramen; MLH: height of mandibular lingula; ML–TC: distance between mandibular lingula and temporal crest; ML–AB: distance between mandibular lingula and anterior border of ramus; ML–PB: distance between mandibular lingula and posterior border of ramus; ML–MN: distance between mandibular lingula and mandibular notch; ML–G: distance between mandibular lingula and gonion;

[a]one-way ANOVA, Holm–Šidák post-hoc test; $p < 0.05$;

[b]one-way ANOVA, Dunn's post-hoc test; $p < 0.05$

Table 3. Morphometric characteristics of the mandibular foramen and lingula according to shape of lingula (ML), in mm

ML shape	N		MF–TC	MF–AB	MF–PB	MF–MN	MF–G	MFD	MLH	ML–TC	ML–AB	ML–PB	ML–MN	ML–G
Triangular	24	Mean	11.54	16.21	13.51	21.77	21.25	3.53	7.98	11.03	16.78	14.64	15.56	**27.99**[a]
		SD	1.87	2.08	2.72	3.24	4.34	0.83	1.63	2.71	2.40	2.28	2.64	5.18
Nodular	8	Mean	12.66	16.89	14.7	23.58	22.17	4.02	8.71	11.98	17.40	15.36	15.48	29.21
		SD	1.24	1.45	3.61	1.73	4.44	1.01	1.96	2.41	2.54	1.75	1.59	5.88
Truncated	16	Mean	12.87	17.58	13.12	21.42	25.45	3.61	7.22	11.57	16.84	15.78	14.85	**33.37**[a]
		SD	2.36	2.51	2.22	3.66	3.42	0.68	2.45	2.13	3.48	2.04	2.44	5.5
Assimilated	2	Mean	10.57	15.69	10.88	19.32	19.92	4.6	6.87	11.55	16.03	13.18	12.72	28.89
		SD	0.87	1.56	5.33	4.31	3.67	0.77	5.40	2.91	3.08	2.64	5.46	5

N – number of lingulae; SD – standard deviation; MF–TC – distance between mandibular foramen and temporal crest; MF–AB – distance between mandibular foramen and anterior border of ramus; MF–PB – distance between mandibular foramen and posterior border of ramus; MF–MN – distance between mandibular foramen and mandibular notch; MF–G – distance between mandibular foramen and gonion; MFD – diameter of mandibular foramen; MLH – height of mandibular lingula; ML–TC – distance between mandibular lingula and temporal crest; ML–AB – distance between mandibular lingula and anterior border of ramus; ML–PB – distance between mandibular lingula and posterior border of ramus; ML–MN – distance between mandibular lingula and mandibular notch; ML–G – distance between mandibular lingula and gonion;

[a]one-way ANOVA, Holm–Šidák post-hoc test, $p < 0.05$

