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Three-dimensional reconstruction and morphometric analysis of mandible of Hamdani sheep: A computed tomography (CT) study

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Abstract: In this study, anatomical, morphometric and volumetric analyses of the mandible of Hamdani sheep were performed using computed tomography (CT) and three-dimensional (3D) software. For this purpose, 16 (eight males, eight females) Hamdani sheep heads were used. Images of these heads were taken on a 64-detector CT device applying 80 kV, 200 MA, 639 mGY, and 0.625 mm section thickness. Scan images of the mandible of each subject were converted into three-dimensional models using 3D software and reconstructed. Surface, volume and linear measurements (24) of the mandible were performed on the models. All the measurements were expressed as mean ± SD. The examinations determined that the mandible's volume and surface area values were more significant in males than females. Mandible length (GOC-ID) was 169.01±0.74 mm, and its height (GOV-CR) was 95.50±0.64 mm in males. In morphometric evaluations, statistically significant differences were observed between males and females in L2 (PC-ID), L6 (GOC-FMN), L14 (MTR-MH), L19(SI), Volume and Surface area measurement parameters (P<0.05). It is thought that the morphometric data obtained will be a reference in pathological conditions, taxonomy studies, and interventional surgical treatment applications to be performed on the site.

Keywords: *Computed tomography, Hamdani sheep, Mandible, Morphometry, Reconstruction.*

Hamdani koyununun mandibulasının üç boyutlu rekonstrüksiyonu ve morfometrik analizi: Bilgisayarlı tomografi (BT) çalışması

Özet: Bu çalışmada Hamdani koyunlarının mandibula'sının anatomik, morfometrik ve volümetrik özellikleri bilgisayarlı tomografi (BT) ve üç boyutlu (3D) yazılım programı kullanılarak tespit edildi. Bu amaçla 16 adet (8 erkek, 8 dişi) Hamdani koyunu kafası kullanıldı. Kafaların 64 dedektörlü BT cihazında 80 kv, 200 MA, 639 mGY ve 0.625 mm kesit kalınlığında görüntüleri alındı. Her bir deneğin mandibula'ya ait tarama görüntüleri özel bir 3D yazılım programı yardımıyla üç boyutlu modellere dönüştürülerek rekonstrükte edildi. Modeller üzerinde mandibula'nın yüzey, hacim ve doğrusal ölçüm (22 adet) analizleri yapıldı. İncelenen tüm özellikler ortalama ± SD olarak ifade edildi. Yapılan incelemelerde, erkeklerde mandibulanın hacim ve yüzey alanı değerlerinin dişilerden daha büyük olduğu tespit edildi. Erkeklerde mandibula uzunluğu (GOC-ID) 169.01±0.74 mm ve yüksekliği (GOV-CR) ise 95.50±0.64 mm olarak belirlendi. Morfometrik değerlendirmelerde dişi ve erkekler arasında L2(PC-ID), L6(GOC-FMN), L14(MTR-MH), L19(SI), hacim ve yüzey alanı ölçüm parametrelerinde istatistiksel olarak anlamlı farklar gözlendi (P<0.05). Elde edilen morfometrik verilerin, patolojik durumlar, taksonomi çalışmaları ve bölge üzerinde yapılacak girişimsel cerrahi tedavi uygulamalarında referans olacağı düşünülmektedir.

Anahtar Kelimeler*: Bilgisayarlı tomografi, Hamdani koyunu, Mandibula, Morfometri, Rekonstrüksiyon.*

Introduction

Hamdani sheep from the Rizaiye region of Iran are reared in eastern Turkey (Yalçın, 1979). This breed quickly adapts to harsh environmental conditions (Al-Barzinji and Abdul, 2007; Bingöl and Bingöl, 2015). The mandible of mammals mainly has a cortical bone structure and teeth (Tymczyna et al., 2012. The mandible or lower jaw is a pair of tabular bones connected via intermandibular symphysis (Dursun 2002). It is susceptible to bone loss due to aging, endocrine and metabolic disorders, drugs, or local factors. The mandible's anatomy is crucial for phylogenetic and biomechanical analyses (Szabelska et al., 2017; Yılmaz and Demircioğlu, 2019).

There have been several technical advancements in anatomy instruction due to current technologies like computed tomography and medical imaging techniques, various software, and three-dimensional (3D) modeling methods (Brenton et al., 2007). People experience difficulty in imaging the spot through conventional two-dimensional (2D) radiography since its diagnostic accuracy is restricted. In imaging techniques, bony overlaps and structural distortions are seen due to the location of the condyle inside the cranial base. 2D and 3D computed tomography (CT) craniofacial imaging techniques are becoming increasingly popular (Ebner et al., 1990; Vitral and Telles, 2002; Vitral et al., 2004). 3D imaging is an effective method for estimating mandibular rotation and evaluating condylar and mandibular morphology (Miller et al., 2004; Cevidanes et al., 2005). Numerous software is used for 3D reconstruction. Some studies have revealed the software differences in measurements taken in the computer environment using this software (Güzel et al., 2022).

Morphometry is a research method that allows making numerical or graphical statistical analysis in width, length, or angle measurements between two specific points (Rolhf and Marcus 1993). Many studies have been conducted on 3D reconstruction and morphometry of the mandibles of different animal species and breeds. (Baygeldi et al.,2022; Demiraslan et al., 2014; Jashari et al., 2020; Yılmaz, 2020; Özkan et al..,2020; Yılmaz and Demircioğlu 2019; Yılmaz and Demircioğlu 2021; Hadžiomerović et al.,2022)

This study aims to determine the morphometric features of the mandible of the Hamdani sheep, which is reared in the Mesopotamian region, including Turkey, and to reveal data that will contribute to the taxonomy of these breeds as well as zooarchaeological studies and clinical sciences.

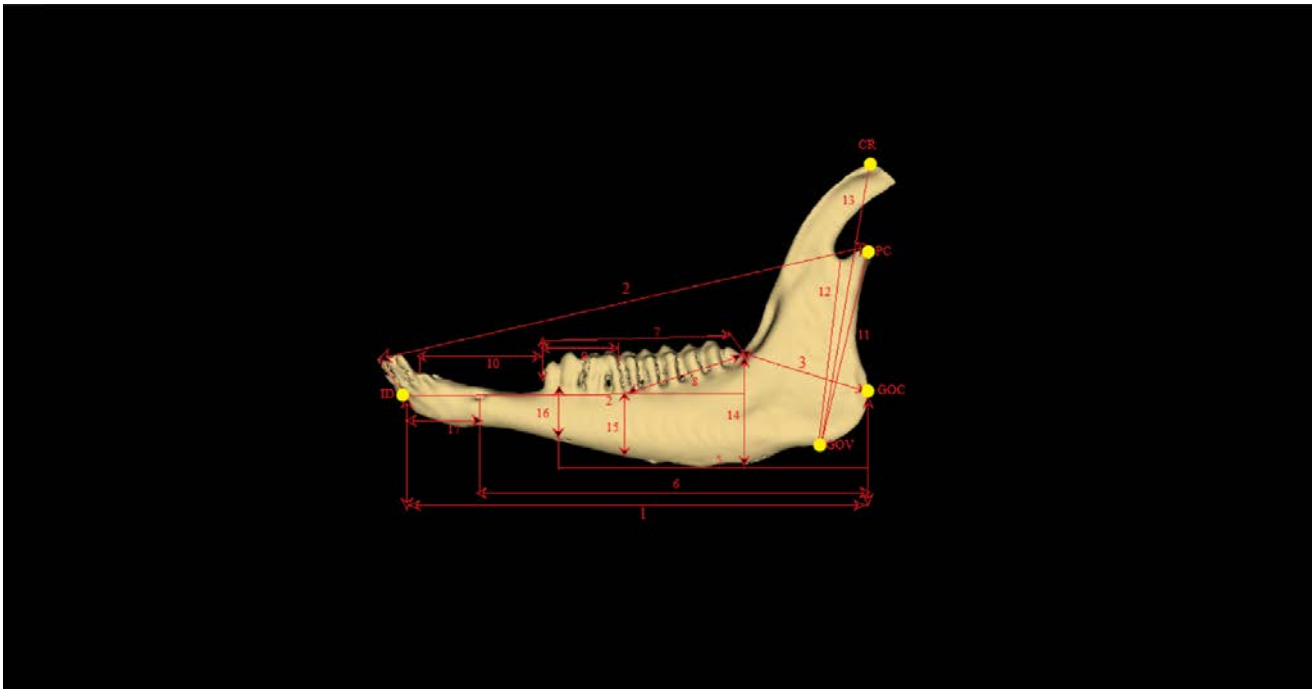

Figure 1: Morphometric measurement points of the mandible of Hamdani sheep (Lateral).
L1: Length between GOC-ID (GOC-ID), L2: Length between the aboral edge of proc. condylaris-ID (PC-ID), L3: Length between GOC- aboral alveolar edge of M_3 (GOC-MTR), L4: Length between the alveolar edge of M_3-ID (MTR-ID), L5: Length between GOC - oral alveolar edge of P_2 (GOC-PTW), L6: Length between GOC - aboral edge of for. mentale (GOC-FMN), L7: The total length of cheek tooth row (P_1-M_3) (PMU), L8: Molar row length (MDU), L9: Premolar row length (PDU), L10: Length of Diastema (DU), L11: Length between GOV-the highest point of proc. condylaris (GOV-PC), L12: Length between GOV-the deepest point of Inc mandibula (GOV-IMD), L13: Length between GOC-CR (GOV-CR), L14: Height of mandible in the plane of posterior alveolar edge of M_3 (MTR-MH), L15: Height of mandible in the plane of anterior alveolar edge of M_1 (MO-MH), L16: Height of the mandible in the plane of the anterior alveolar edge of P_2 (PTW-MH), L17: Length between the oral edge of for. mentale–ID (FMN-ID), L18: Length between CR and the highest point of proc. Condylaris (CR-PC).

Material and Methods

Mandible samples used in this study were collected from slaughterhouses operating in Şırnak, Turkey. Morphometric analyses were done on the mandibles of 16 adult Hamdani sheep heads (eight females and eight males). This study was performed with the permission of the Experimental Animals Local Ethics Committee in Harran University with 2022/002/05 approval number, dated 28/03/2022. The mandibles were scanned applying 80 kV, 200 MA, 639 mGY, and 0.625 mm section thickness on a 64-detector MDCT (General Electric Revolution) device after no deformation was determined on the mandible bones. Prokop (2003) was a reference in the scanning dose and protocol. CT scans of the mandibles were recorded in DICOM (Digital Imaging and Communications in Medicine) format. Reconstructions were made using 3D Slicer (5.0.2) software. Morphometric measurements were made once measurement points were determined. Measurement parameters (Table 1) were assessed according to von den Driesch (1976) and Avdic et al., (2013). Twenty-two osteometric measurements were taken from the mandible (Figure 1 and figure 2). Upon the completion of the morphometric measurements, the surface area and volume values of the mandible were determined. Mean±standard deviation (SD) values were calculated by performing statistical analyses. While the difference between males and females was examined using the indepen-dent t-test, Pearson correlation analysis was used to analyse the difference between measurements.

Results

Table 2 shows the mandible's osteometric measurements, volume, surface area mean value, and standard deviations. It was determined that there was a statistically significant difference between the sexes in terms of L2, L14, L19, and volume values ($P<0.01$). In addition, there was a statistically significant difference between the sexes in terms of L6 and surface area measurements ($P<0.05$). Table 3 shows the correlation analysis of the data. The results indicated that L15 had a positive correlation with L15, L16, L17, L18, L19, L20, L21 and L22 ($P<0.01$). Also, L16 showed a positive correlation with all parameters. ($P<0.01$).

Discussion and Conclusion

The mandibles of adult female and male Hamdani sheep were morphometrically analysed using the computed tomography imaging system in the present study. Mandible reconstruction is recognized as a necessary treatment for the reconstruction of mandible defects in a given situation (Yeter, 2021). Mandible reconstruction is used for treatment and surgery in many fields of medicine. The studies on different sheep breeds reported that the length of the mandible (GOC-ID) was 157.6±22.5 mm in Mehraban sheep (Karimi et al., 2012), 120±18.9 mm in West African dwarf goats, 142±0.98 mm in Black Bengal goats, 147.76±5.40 mm in tuj sheep (Demiraslan et al., 2014) and 152.43±7.47 mm in Morkaraman sheep (Demiraslan et al., 2014). In the study, the mandible length of Hamdani sheep was determined as

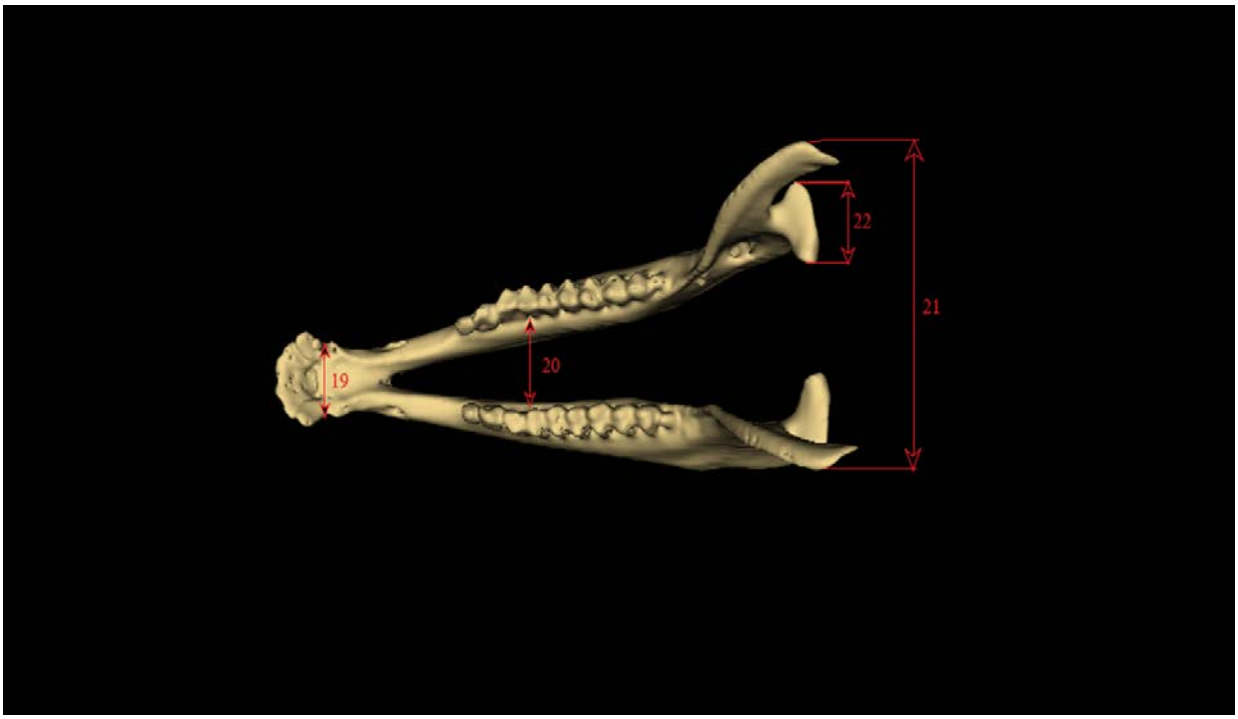

Figure 2: Morphometric measurement points of the mandible of Hamdani sheep (Dorsal view).
L19: Mandible width at last incisive tooth level (SI), L20: Width of the mandible at the level of the first molar (BM), L21: Width of mandibular space at the level of proc. coronoideus (MG), L22: Width of proc. condylaris (CG).

169.01±0.74 mm in males and 165.68±0.69 mm in females. The values demonstrated that the Hamdani sheep's mandible length was larger than the specified breeds.

Yılmaz and Demircioğlu (2020) reported in their study that the foramen mentale is one of the critical anesthesia sites of the mandible, and the FMN-ID parameter in gazelles was 15.33±2.27 mm in males and 14.70±2.90 mm in females. Karimi et al. (2012) found that the FMN-ID parameter was 20.7±4.5mm in Mehraban sheep, 15.6±2.2mm in WAD goats, and 21.1±1.7mm in Black Bengal goats. In the present study, the FMN-ID parameter was 33.60±0.40 mm in males and 31.16±0.24 mm in females.

Orassi et al. (2021) reported the importance of the anatomical opening in the mandible, namely the diastema, in mandibular fracture surgery. Ozudogru et al. (2019) found a diastema length of 43.54±3.48 mm in Hasmer sheep. Ozkan et al. (2020) reported that this value was 45.98±3.87 mm and 48.50±6.13 mm in ewes and rams of Bardhoka domestic sheep. Jashari et al., (2021) stated that the length of

Table 1: Measurement points of the mandible of Hamdani sheep.

1	L1	GOC-ID	Length between GOC-ID
2	L2	PC-ID	Length between the aboral edge of proc. condylaris-ID
3	L3	GOC-MTR	Length between GOC- aboral alveolar edge of M_3
4	L4	MTR-ID	Length between the alveolar edge of M_3-ID
5	L5	GOC-PTW	Length between GOC - oral alveolar edge of P_2
6	L6	GOC-FMN	Length between GOC - aboral edge of for. mentale
7	L7	PMU	The total length of cheek tooth row (P_1-M_3)
8	L8	MDU	Molar row length
9	L9	PDU	Premolar row length
10	L10	DU	Length of Diastema
11	L11	GOV-PC	Length between GOV-the highest point of proc. condylaris
12	L12	GOV-IMD	Length between GOV-the deepest point of Inc mandibula
13	L13	GOV-CR	Length between GOC-CR
14	L14	MTR-MH	Height of mandible in the plane of posterior alveolar edge of M_3
15	L15	MO-MH	Height of mandible in the plane of anterior alveolar edge of M_1
16	L16	PTW-MH	Height of the mandible in the plane of the anterior alveolar edge of P_2
17	L17	FMN-ID	Length between the oral edge of for. mentale–ID
18	L18	CR-PC	Length between CR and the highest point of proc. condylaris
19	L19	SI	Mandible width at last incisive tooth level
20	L20	BM	Width of the mandible at the level of the first molar
21	L21	MG	Width of mandibular space at the level of proc. coronoideus
22	L22	CG	Width of proc. condylaris
23	V	VOLUME	Mandible volume
24	YA	SURFACE AREA	Mandible surface area

Table 2: Measurements of Hamdani's mandible by Sex (Independent Samples t-test).

	Sex	N	Mean(mm)	SD	P
L1(GOC-ID)	Male	8	169.01	0.74	0.766
	Female	8	165.68	0.69	
L2 (PC-ID)	Male	8	187.13	1.47	0.005
	Female	8	184.10	0.48	
L3(GOC-MTR)	Male	8	54.63	0.91	0.158
	Female	8	50.79	0.47	
L4(MTR-ID)	Male	8	119.16	1.34	0.358
	Female	8	114.54	0.67	
L5(GOC-PTW)	Male	8	112.32	0.61	0.510
	Female	8	110.01	0.38	
L6(GOC-FMN)	Male	8	138.36	0.31	0.025
	Female	8	135.05	0.79	
L7(PMU)	Male	8	68.81	0.37	0.416
	Female	8	65.27	0.61	
L8(MDU)	Male	8	61.89	0.41	0.367
	Female	8	57.72	0.47	
L9(PDU)	Male	8	18.16	0.34	0.064
	Female	8	16.02	0.21	
L10(DU)	Male	8	43.75	0.45	0.293
	Female	8	41.04	0.58	
L11(GOV-PC)	Male	8	69.26	0.50	0.102
	Female	8	65.28	0.28	
L12(GOV-IMD)	Male	8	62.45	0.35	0.072
	Female	8	60.48	0.85	
L13(GOV-CR)	Male	8	95.50	0.64	0.213
	Female	8	92.57	0.40	
L14(MTR-MH)	Male	8	38.28	0.54	0.003
	Female	8	35.88	0.27	
L15(MO-MH)	Male	8	21.08	0.42	0.360
	Female	8	17.88	0.47	
L16(PTW-MH)	Male	8	18.79	0.44	0.729
	Female	8	16.66	0.38	
L17(FMN-ID)	Male	8	33.60	0.40	0.07
	Female	8	31.16	0.24	
L18(CR-PC)	Male	8	25.72	0.51	0.226
	Female	8	25.08	0.66	
L19(SI)	Male	8	23.26	0.50	0.009
	Female	8	21.90	0.13	
L20(BM)	Male	8	28.71	0.17	0.107
	Female	8	26.19	0.52	
L21(MG)	Male	8	67.88	0.43	0.413
	Female	8	64.84	0.32	
L22(CG)	Male	8	19.43	0.34	0.673
	Female	8	16.73	0.31	
Volume(cm^3)	Male	8	45.79	1.33	0.002
	Female	8	44.03	0.18	
Surface area(mm^2)	Male	8	27802	1.109	0.046
	Female	8	24317	428.63	

diastema in Sharri sheep was 46.48±3.46 mm in ewes and 44.20±4.04 mm in rams. In the study by Evcim (2020), it was reported that the length of diastema was 54.67±5.00 mm in sheep and 58.73±7.78mm in goats. Demiraslan et al. (2014) expressed the diastema length as 36.44±2.5mm in Tuj sheep and 37.16±1.88mm in Morkaraman sheep. It was determined in the present study that the diastema length of Hamdani sheep was 41.04±0.58 mm in ewes and 43.75±0.45 mm in rams. It is thought that these differences between the breeds may be due to the nutritional changes associated with the differences in the environments where the animals are reared.

Demiraslan et al. (2014) reported the PC-ID measurement parameter as 160.43±7.24 mm in Morkaraman sheep and 155.59±5.28 mm in Tuj sheep, while Özkan et al. (2020) determined this value as 194.21±8.87mm in ewes of Bardhoka sheep and 198.01±12.35mm in their rams. In the present study, the PC-ID measurement parameter of Hamdani sheep was 187.13±1.47mm in rams

Table 3: Correlation between measurements of Hamdani sheep

	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10	L11	L12	L13	L14	L15	L16	L17	L18	L19	L20	L21	L22
L1	1																					
L2	,785(**)	1																				
L3	,830(**)	,742(**)	1																			
L4	,876(**)	,788(**)	,823(**)	1																		
L5	,795(**)	,700(**)	,902(**)	,864(**)	1																	
L6	,903(**)	,769(**)	,891(**)	,854(**)	,843(**)	1																
L7	,872(**)	,830(**)	,954(**)	,904(**)	,915(**)	,889(**)	1															
L8	,903(**)	,802(**)	,932(**)	,911(**)	,917(**)	,896(**)	,961(**)	1														
L9	,912(**)	,790(**)	,894(**)	,835(**)	,894(**)	,922(**)	,924(**)	,937(**)	1													
L10	,886(**)	,723(**)	,909(**)	,811(**)	,912(**)	,888(**)	,909(**)	,924(**)	,936(**)	1												
L11	,914(**)	,789(**)	,963(**)	,899(**)	,906(**)	,949(**)	,964(**)	,952(**)	,950(**)	,925(**)	1											
L12	,753(**)	,736(**)	,828(**)	,823(**)	,735(**)	,864(**)	,832(**)	,827(**)	,813(**)	,701(**)	,872(**)	1										
L13	,884(**)	,835(**)	,852(**)	,892(**)	,817(**)	,898(**)	,922(**)	,930(**)	,934(**)	,851(**)	,913(**)	,887(**)	1									
L14	,910(**)	,832(**)	,914(**)	,824(**)	,850(**)	,918(**)	,931(**)	,944(**)	,930(**)	,889(**)	,935(**)	,847(**)	,915(**)	1								
L15	,877(**)	,775(**)	,950(**)	,874(**)	,881(**)	,903(**)	,944(**)	,984(**)	,914(**)	,904(**)	,945(**)	,842(**)	,912(**)	,930(**)	1							
L16	,888(**)	,728(**)	,904(**)	,808(**)	,829(**)	,904(**)	,869(**)	,924(**)	,902(**)	,890(**)	,908(**)	,774(**)	,867(**)	,909(**)	,952(**)	1						
L17	,907(**)	,774(**)	,939(**)	,904(**)	,902(**)	,941(**)	,958(**)	,941(**)	,939(**)	,903(**)	,989(**)	,845(**)	,899(**)	,915(**)	,923(**)	,867(**)	1					
L18	0,455	,531(*)	,569(*)	0,443	0,36	0,467	,538(*)	,536(*)	0,416	0,404	0,459	,517(*)	,550(*)	,539(*)	,636(**)	,632(**)	0,396	1				
L19	,783(**)	,803(**)	,921(**)	,726(**)	,835(**)	,874(**)	,867(**)	,868(**)	,859(**)	,826(**)	,882(**)	,798(**)	,791(**)	,905(**)	,903(**)	,902(**)	,845(**)	,639(**)	1			
L20	,937(**)	,785(**)	,892(**)	,884(**)	,875(**)	,930(**)	,878(**)	,931(**)	,919(**)	,907(**)	,949(**)	,797(**)	,875(**)	,914(**)	,915(**)	,930(**)	,933(**)	0,427	,855(**)	1		
L21	,890(**)	,786(**)	,929(**)	,900(**)	,930(**)	,935(**)	,927(**)	,947(**)	,914(**)	,936(**)	,957(**)	,785(**)	,870(**)	,907(**)	,941(**)	,941(**)	,938(**)	0,483	,889(**)	,964(**)	1	
L22	,913(**)	,778(**)	,936(**)	,854(**)	,908(**)	,913(**)	,934(**)	,949(**)	,956(**)	,944(**)	,972(**)	,761(**)	,875(**)	,918(**)	,931(**)	,915(**)	,969(**)	0,398	,868(**)	,962(**)	,959(**)	1

and 184.10±0.10mm in ewes, which was statistically significant (P<0.01).

Özkan et al. (2020) determined the GOC-FMN parameter of Bardhoka domestic sheep as 149.43±7.55 mm in ewes and 152.14±10.58 mm in rams. Also, Karimi et al. (2012) reported this parameter as 137.4±18 mm in Mehraban sheep, 99.6±16.7 mm in WAD goats, and 116.9±4 mm in Black Bengal goats. Demiraslan et al. (2014) found that the GOC-FMN measurement point was 118.85 ± 2.52 in Tuj sheep and 122.29 ± 5.19 in Morkaraman sheep, while Sundaram et al., (2019) reported that the GOC-FMN measurement point of Madras Kizil sheep was 123.0±4.6 mm in males and 115.3±1.4 mm in females. In the present study, the GOC-FMN parameter in Hamdani sheep was 138.36±0.31mm in males and 135.05±0.79mm in females, which was statistically significant (P<0.05).

Demiraslan et al. (2014) reported a positive correlation between L1 and L6 in their correlation analysis of mandible measurements of Tuj and Morkaraman sheep. Özudoğru et al., (2019) determined a positive correlation between L1-L3, L1-L12, and L3-L6. The correlation analysis conducted in the present study indicated a positive correlation between L1-L6, L1-L3, L1-L12, and L3-L6, which was compatible with the studies (P<0.01).

Yılmaz and Demircioğlu (2019) reported that the mandible volume was 40.36±6.03cm^3 in males and 37.98±4.69cm^3 in females, and the surface area was 251.6±33.6mm^2 in males and 212.6±26.7mm^2 in females, in their reconstruction study on the mandible of gazelles. In the present study, the volume of the mandible of Hamdani sheep was 45.79±1.33cm^3 in males and 44.03±0.18cm^3 in females, which was statistically significant (P<0.01). Also, the surface area was 278.02±32.05 mm^2 in males and 243.17±22.63 mm^2 in females, which was statistically significant (P<0.05). The mandible of Hamdani sheep was larger in volume and surface area than the mandible of gazelle.

Consequently, no morphometric and reconstructive study has been conducted on the mandible of Hamdani sheep. This study is believed to shed light on anatomical and taxonomic studies determining morphometric parameters and to contribute to diagnostic imaging and surgical procedures in clinical settings.

Conflict of Interest

The authors stated that they did not have anyreal, potential or perceived conflict of interest.

Ethical Approval

This study was performed with the permission of the Experimental Animals Local Ethics Committee in Harran University with 2022/002/05 dated 28/03/2022 approval number.

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Similarity Rate

We declare that the similarity rate of the article is 13% as stated in the report uploaded to the system.

Author Contributions

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Control/Audit: İD
Data Collection and/or Processing: BCG
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Literature Review: BCG, NGİ
Posted By: İD, BCG
Critical Review: BCG

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