Ankara Univ Vet Fak Derg, **68**, 321-328, 2021
DOI: 10.33988/auvfd.759964

The mandibles of the Honamli and Hair goat *(Capra hircus)*; a geometric morphometric study

Yasin DEMİRASLAN[1,a,✉], Özcan ÖZGEL[1,b], İftar GÜRBÜZ[1,c], Özlem ZÜMRE[2,d]

[1]Burdur Mehmet Akif Ersoy University, Faculty of Veterinary Medicine, Department of Anatomy; [2]Akdeniz University, Health Services Vocational School, Antalya, Turkey.
[a]ORCID: 0000-0003-3612-6142; [b]ORCID: 0000-0003-0394-5678; [c]ORCID: 0000-0001-9460-0645;
[d]ORCID: 0000-0003-4427-7442.

✉Corresponding author: yasindemiraslan@hotmail.com
Received date: 29.06.2020 - Accepted date: 11.11.2020

Abstract: The aim of the study was to analyze mandible of the Honamli and Hair goats according to the sex factor by geometric morphometric methods. A total of 36 adult goat mandibles including 9 males and 9 females for each breed, were used in the study. After the mandibles were photographed from the left lateral side, 10 homolog landmarks were marked. Generalized Procrustes, Relative Warp, and Principal Component Analysis were performed for the data of landmark coordinates. In the study, the first principal component explained 28.752% and 37.325% of the total shape difference in the Honamli and Hair goat, respectively. In the analysis made among goat breeds according to the sex factor, the first principal component explained 40.809% of the total shape difference in females and 30.486% of the total shape difference in males. Consequently, the Hair goat showed a significant sex difference compared to the Honamli goat. Besides, it was remarkable that male goats clustered clearly compared to female goats in terms of the breed factor.
Keywords: Geometric morphometry, Honamli goat, mandible, Principal Components Analysis.

Honamlı ve Kıl keçisi *(Capra hircus)* mandibula'sı; geometrik morfometrik bir çalışma

Özet: Çalışmada geometrik morfometrik metotlarla Honamlı ve Kıl Keçisi mandibula'sının cinsiyet faktörü ile birlikte analiz edilmesi amaçlandı. Çalışmada her ırk için 9'ar adet erkek ve dişi olmak üzere toplamda 36 adet ergin keçi mandibula'sı kullanıldı. Mandibula'lar sol lateral yönden fotoğraflandıktan sonra 10 adet homolog landmark işaretlendi. Landmark koordinat verileri General Procrustes, Relative Warp ve Temel Bileşenler analizine tabi tutuldu. Çalışmada Honamlı ve Kıl Keçisinde cinsiyetler arası yapılan karşılaştırmada birinci temel bileşen toplam şekil farklılığının sırasıyla %28,752 ve %37,325'ini açıkladı. Cinsiyet faktörüne göre keçi ırkları arasında yapılan analizde ise birinci temel bileşen dişilerde toplam şekil farklılığının %40,809'unu, erkeklerde %30,486'sını açıkladı. Sonuç olarak Kıl Keçilerinin Honamlı Keçilerine göre oldukça belirgin bir cinsiyet farklılığı göstermesi, ırk faktörü bakımından erkek keçilerin, dişi keçilere kıyasla net bir şekilde kümeleşmesi dikkat çekiciydi.
Anahtar sözcükler: Geometrik morfometri, Honamlı keçisi, mandibula, Temel Bileşenler Analizi.

Introduction

The domesticated goat, also known as *Capra Hircus*, is a species from the genus Capra belonging to the family *Bovidae* (2, 24). Being one of the first domesticated animal species along with sheep (37). Goat is an animal species that is commonly reared for its meat, milk, skin, and hair products from the first periods of mankind. This animal species can adapt to different environmental and breeding conditions and is resistant to many diseases; therefore, it is commonly reared (7, 19).

Honamli goat is a new goat species under protection that has been registered based on the communique of the Turkish Ministry of Agriculture and Forestry (34). The foreheads and legs of purebred Honamli goat reared in Taurus region are white or brown and their bodies are covered with black hairs (6). Being found in all the regions of Turkey, Hair goat is another goat breed commonly reared in the mountainous areas, forestry, and maquis shrublands like Taurus mountains (33).

Geometric morphometry is a shape analysis method that has been commonly used in recent years and is developed by subjecting geometric methods to the form difference analysis. Form is the geometric data obtained by removing variation differences from an object (38). Shape is the geometric properties which are steady based on environmental compatibility, location, and scale (31).

In geometric morphometry, homolog landmarks (LM) are used and the geometric structure of the samples are digitized at Cartesian coordinates (23). Thus, only the shape of sample is analyzed but not its form (20, 32). Slice (32) has reported that the geometric morphometry method offers more appropriate data for statistical analyses when compared to the traditional morphometric studies. There are studies in the literature using different types of geometric morphometry (8, 12, 13, 22, 36). However, there is no geometric morphometric study in Hair and Honamli goat breeds in the literature. For this reason, the aim of the study was to determine the shape differences in the mandibles of Hair and Honamli goat breeds in terms of sex factor using geometric morphometry method.

Materials and Methods

The study was approved by the Local Ethics Committee of Burdur Mehmet Akif Ersoy University (Approval number 2020/645). Mandibles of 36 (4 groups) adult Honamli and Hair goats, including 9 males and 9 females from each breed, were used in the study. The materials were removed from the skin and soft tissue and macerated by boiling.

Geometric morphometric analysis: The mandibles were photographed from a 30-cm distance on the left lateral side by focusing on the third premolar tooth (Canon EOS 650D, Japan). The images were saved in JPEG format in the computer. These images were converted into tps format using TpsUtil (Version 1.79) software (30). 10 homolog LMs (36) (Figure 1) were marked on the images through TpsDig2 (Version 2.31) (28) software so that the Cartesian coordinates of LMs were determined. Homolog LM confirmatory test was performed by using TpsSmall (Version 1.34) (27) software. Also, the slope and correlation values were determined as 0.999777 and 1.0 in Honamli goat, and 0.999694 and 1.0 in Hair goat, respectively.

As there were differences between the mandibles in terms of size, position and direction, Generalized Procrustes Analysis (superimposition-GPA) was performed (32). PAST (Version 4.02) (14) software was used for this analysis. Principal Components Analysis (PCA) was performed on the new coordinates obtained as a result of Procrustes Analysis. Thus, the degree of distinguishing the samples based on breed and sex was determined by applying Covariance Analysis between the factors (38). In addition, MorphoJ (16) software was used to indicate LM levels and directions where the shape differences were observed.

In the study, Relative Warp Analysis (RWA) was performed by TpsRelw (Version 1.70) (29) software and the consensus graphics of the groups were formed. The distribution of the groups on graphic was also tested by this analysis.

Statistical analysis: The statistical analysis of LM coordinate values based on the groups was performed by ANOVA test in PAST (Version 4.02) (14) software.

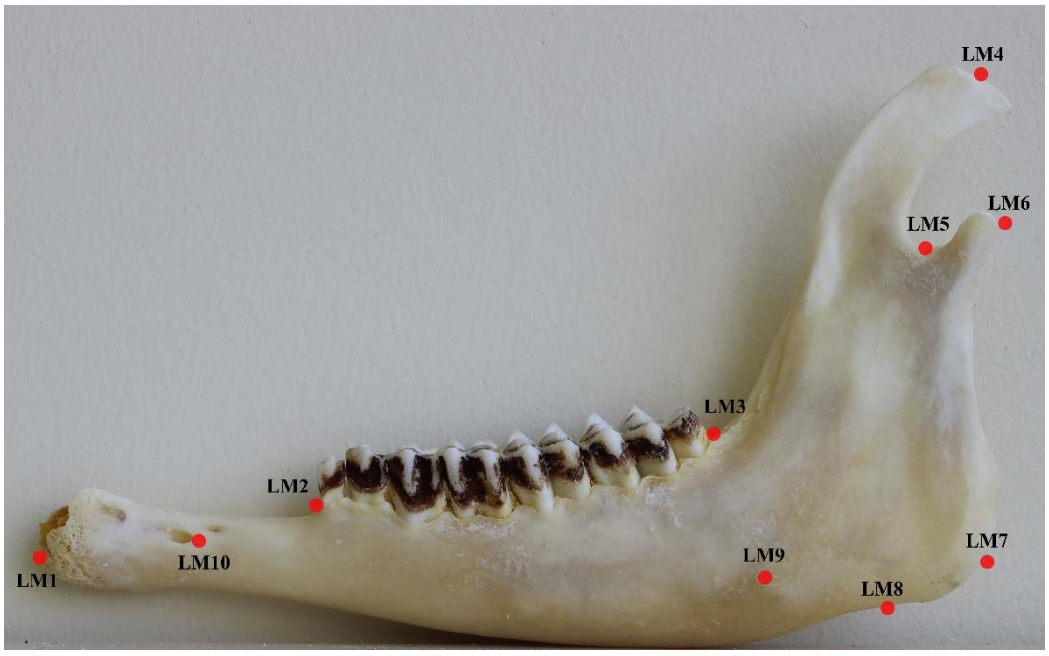

Figure 1. The view of Landmarks on mandible of the Honamli goat. LM1. Aboral cranioventral end point of alveoli dentales of I1, LM2. Cranioventral margin of P1, LM3. Caudoventral margin of M3, LM4. End-middle point of processus coronoideus, LM5. Medioventral point of incisura mandibula, LM6. Caudal end point of condylus mandibulae, LM7. Caudoventral corner of angulus mandibulae, LM8. Incisura vasorum facialium. LM9. Cranial junction point of the dorsal and ventral axes of fossa masseterica, LM10. Caudal margin of foramen mentale.

Results

Table 1 shows the results of the PCA in the study. Accordingly, the first Principal Component (PC) accounted for 28.752% and 37.325% of the total shape difference in the sex-based comparison made in Honamli and Hair goat breeds, respectively. In the analysis performed between the goat breeds based on the sex factor, the first PC accounted for 40.809% of the total shape difference in females and 30.486% of the total shape difference in males.

Figure 2 shows the results of the first PC based on the breed and sex factors. Accordingly, the sexual dimorphism in terms of the first PC was more apparent in Hair goat compared to Honamli goat (Figure 2 a, d). Also, based on the first PC, the distinction of the male Honamli and Hair goats was more apparent compared to the female counterparts (Figure 2 b, c).

Table 1. Results of the PCA, S: sex, B: breed.

PC	Honamli goat (S)		Hair goat (S)		Female goat (B)		Male goat (B)	
	Eigenvalue	Variance %	Eigenvalue	Variance %	Eigenvalue	Variance %	Eigenvalue	Variance %
1	0.000588581	28.752	0.000749422	37.255	0.000836954	40.809	0.000598768	30.486
2	0.00047459	23.183	0.000421354	20.946	0.000480911	23.449	0.000400184	20.375
3	0.000316428	15.457	0.000210353	10.457	0.000199762	97.402	0.000335132	17.063
4	0.000248741	12.151	0.00018255	90.748	0.000161586	78.788	0.000180213	91.753
5	0.000151471	73.992	0.000131645	65.442	9.99E-01	48.717	0.000137439	69.976
6	8.51E+00	41.575	9.90E+00	49.232	7.73E+00	37.685	0.000109006	55.499
7	5.56E+00	27.172	7.88E+00	39.194	7.23E+00	3.525	6.07E-01	30.895
8	3.81E+00	18.624	4.70E+00	23.353	4.66E+00	22.714	4.74E+00	24.133
9	3.04E+00	14.864	3.54E+00	17.615	2.61E+00	12.712	3.36E+00	17.126
10	2.00E+00	0.97888	2.25E+00	11.163	1.59E+00	0.77733	2.64E+00	13.463
11	1.45E+00	0.70964	1.30E+00	0.64772	1.34E+00	0.6526	1.48E+00	0.75217
12	1.01E+00	0.49278	8.77E-01	0.43618	8.84E-01	0.431	1.40E-01	0.71142
13	7.84E-01	0.38304	6.49E-01	0.32281	5.14E-01	0.25051	4.02E-01	0.20489
14	3.37E-01	0.16467	3.60E-01	0.17875	4.02E-01	0.19613	1.73E-01	0.08831
15	1.94E-01	0.094936	1.19E-01	0.059029	1.34E-01	0.065548	6.40E-02	0.032603
16	1.86E-02	0.009079	4.55E-02	0.022642	8.27E-02	0.040322	5.22E-03	0.0026602
17	3.23E-03	0.0015775	1.03E-03	0.00051376	3.74E-03	0.0018216	1.76E-05	8.98E-02

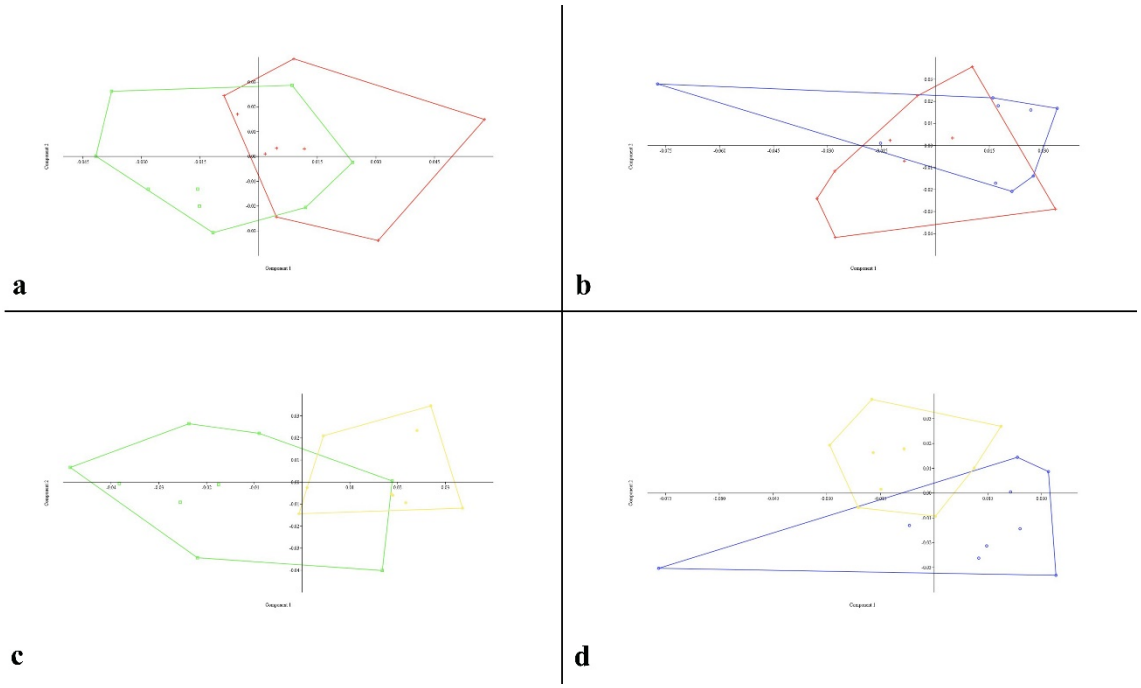

Figure 2. Graphic representation of the results obtained based on the first PC. a. Honamli goat (Sex), b. Female Honamli and Hair goat (Breed), c. Male Honamli and Hair goat (Breed), d. Hair goat (Sex).

Figure 3 shows the consensus graphics obtained as a result of RWA along with variation vectors in the study. Accordingly, vectoral variation density was determined at LM3, 4 and 9 levels in the female Honamli goat and at LM3, 4, 7, 8 and 9 levels in the male Honamli goat (Figure 3 a, c). The individual shape variation density was determined at LM1, 4, 7, 8, and 9 levels in the female Hair goat and at LM3 and 4 levels in the male Hair goat (Figure 3 b, d). Also, Figure 4 shows the graphics obtained as a result of the RWA made between the groups. According to the result of this analysis, it was remarkable that the sexual dimorphism was more apparent in Honamli goat than Hair goat (Honamli goat RWA1: 51.12%, RWA2: 26.68%, RWA3: 13.01%; Hair goat RWA1: 58.45%, RWA2: 19.11%, RWA3: 15.88%). It was observed in the breed distinction performed based on the sex factor by RWA that the male goat was diverged more apparently from the female goat (Male goat RWA1: 57.23%, RWA2: 22.18%, RWA3: 12.35%; Female goat RWA1: 53.81%, RWA2: 24.50%, RWA3: 13.72%).

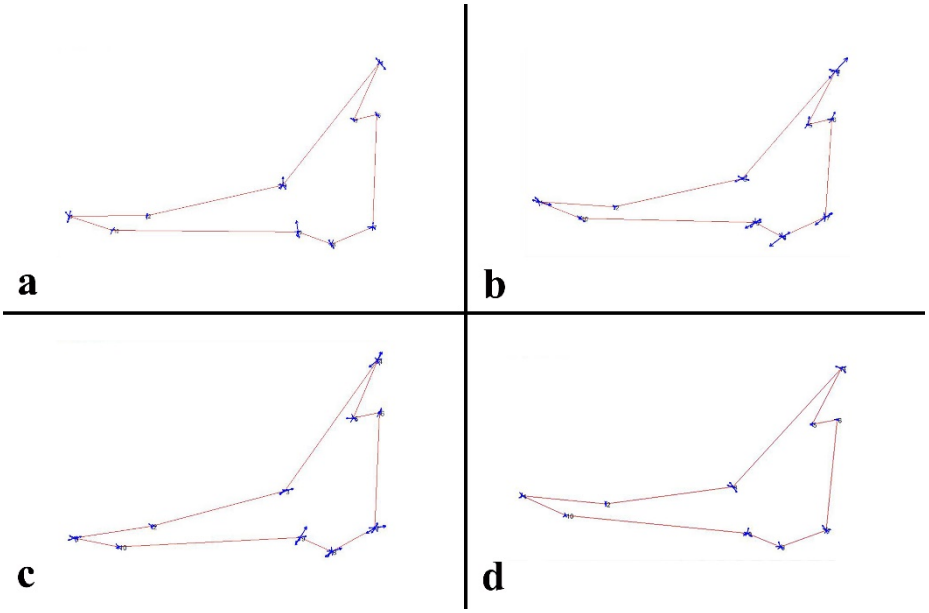

Figure 3. Consensus graphics based on groups, a. Female Honamli goat, b. Female Hair goat, c. Male Honamli goat, d. Male Hair goat.

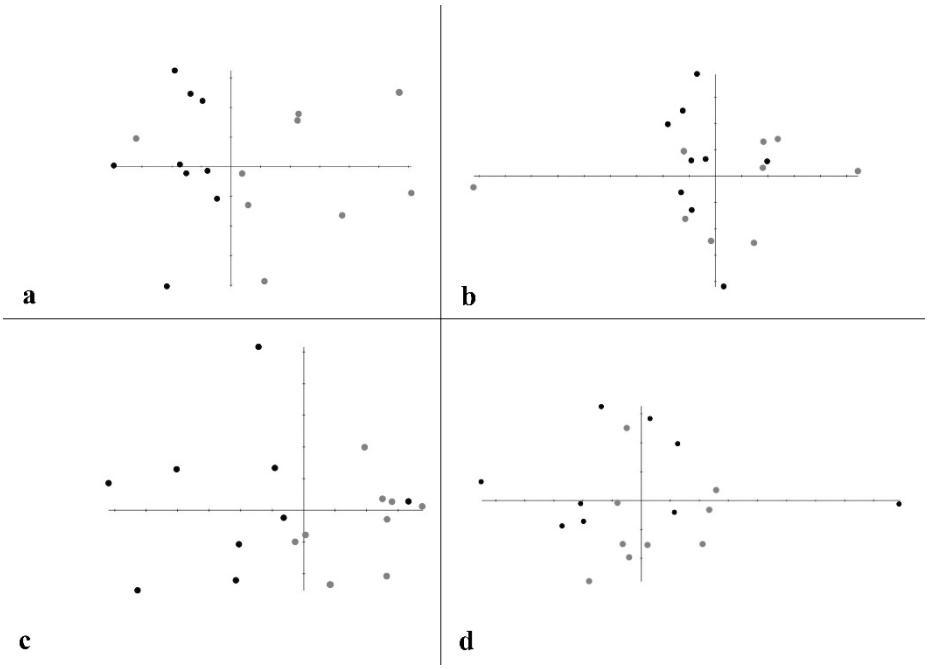

Figure 4. Graphic of RWA. a. The black points represent the female Honamli goat and the grey points represent the male Honamli goat, b. The black points represent the female Honamli goat and the grey points represent the female Hair goat, c. The black points represent the male Honamli goat and the grey points represent the male Hair goat, d. The black points represent the female Hair goat and the grey points represent the male Hair goat.

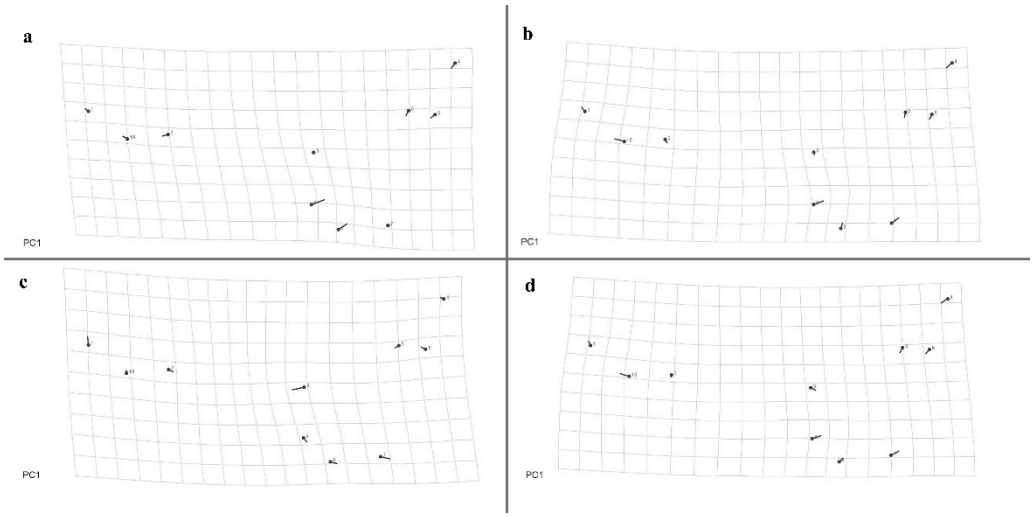

Figure 5. The lollipop representation of the shape differences occurred on the landmarks based on the first PC. a. Honamli goat (Sex), point represents female Honamli goat, b. Female Honamli and Hair goat (Breed), point represents female Honamli goat, c. Male Honamli and Hair goat (Breed), point represents male Honamli goat, d. Hair goat (Sex), point represents female Hair goat.

Table 2. Results of the statistical analysis of Landmark values.

Landmarks	Coordinates	Significant	F	P-value
	X	NS	1.777	0.17
LM1	Y	AB	8.37	0.00038
	X	C	3.961	0.01636
LM2	Y	B	9.921	0.00012
	X	C	3.103	0.03872
LM3	Y	NS	1.534	0.2245
	X	NS	0.8482	0.4822
LM4	Y	NS	1.854	0.1559
	X	NS	2.067	0.1242
LM5	Y	NS	4.979	0.0057
	X	A	4.39	0.01008
LM6	Y	NS	1.262	0.3036
	X	B	3.932	0.01597
LM7	Y	NS	2.265	0.09833
	X	A	2.937	0.04858
LM8	Y	NS	1.073	0.3737
	X	NS	0.9657	0.4198
LM9	Y	NS	1.002	0.4069
	X	NS	0.4384	0.74
LM10	Y	NS	1.186	0.3338

NS. Non-significant (P>0.05), **A.** Significant statistical difference between the male and female Honamli goat (P<0.05), **B.** Significant statistical difference between the male Honamli and Hair goat (P<0.05), **C.** Significant statistical difference between the male and female Hair goat (P<0.05).

Figure 5 shows the LM levels where shape differences occurred. Accordingly, there was a cranioventral shape difference at LM4, 5 and 6 and a caudodorsal shape difference at LM8 and 9 (Figure 5 a) in Honamli goat. Similar but less apparent shape differences were determined in Hair goat (Figure 5 d). In the comparison of breeds in terms of the sex factor, a craniodorsal shape difference at LM1, a point shape difference at LM3, an cranioventral shape difference at LM4, 5 and 6, a caudodorsal shape difference at LM7, 8, and 9 and a cranial shape difference at LM10 were observed in the female goats (Figure 5 b). A dorsal shape difference at LM1, a cranioventral shape difference at LM3 and 5, a craniodorsal shape difference at LM4 and 6, a caudoventral shape difference at LM7, 8 and 9, and a dorsal shape difference at LM10 were determined in the male goats (Figure 5 c).

Table 2 shows the data obtained as a result of the comparison of LM x and y coordinate values between the groups. Accordingly, a statistically significant difference was observed at LM1, 6 and 8 in Honamli goat and at LM2 and 3 in Hair goat (P<0.05). No statistical difference was

determined at LMs in the female goats (P>0.05). But there was a statistical difference at LM1, 2 and 7 in the male goats (P<0.05).

Discussion and Conclusion

In the study, the mandibles of two native goat breeds of Anatolia were analyzed by using geometric morphometric methods in terms of sexual dimorphism. In the literature, no study analyzing goat mandible in terms of breed and sex factors by using the geometric morphometric method was found. This is the first attempt to investigate both goat species and goat breeds. This is the most apparent limitation of this study.

Native goat breeds are a superior gene source with their high adaptation skills for the local conditions (9). Considering that goats have been a part of human life for a very long time, it is quite possible to find native animal breed bones in archaeological excavations. The data obtained from the archaeological bone material are important for fauna determination, the comparison with other historical processes, and estimation of the morphological characteristics of animals (5, 11, 21). The morphological data to be obtained in the skull and mandible of the living mammals by using geometric morphometric method may be used to reveal the phylogenetic relationships (17). Landmark-based geometric morphometry method analyzes shapes without linear deterioration by keeping their integrity (1, 25). For this reason, the data of the present study are important to provide principal formal information on the small ruminant mandible remains uncovered in the archaeological excavations in the Western Mediterranean region with high archaeological value.

Researchers commonly use the phenotypical and morphological characteristics in the distinction of animal breeds (3). Geometric morphometric analysis provides to determine shape differences which cannot be determined visually on LM coordinates. Therefore, it measures the shape change amount using the location differences of coordinates between objects (15, 35, 39). Superimposition (GPA), which is a geometric morphometric procedure, eliminates all the variations such as the location, direction, and scale of objects, which are not related to shape, by aligning coordinates according to weighted scaling factors for each "sample" (18, 26, 38). The size and direction of the movement of coordinates among different populations or samples are mapped and thus the results are interpreted (4, 10). In the present study, the shape difference between the mandibles of two native goat breeds was analyzed by using the geometric morphometric method. Based on the first PC, it was observed that the distinction of the male Honamli and Hair goats was quite apparent compared to the female counterparts. This was thought to be associated with that the male goats were preferred for breeding due to the phenotypical factors.

In their study, Yalcin et al. (36) stated that the first degree shape differences were located at LM1, 3, 8, 9, and 10. They reported an anterioventral shape difference at LM3 and 9 in Akkaraman sheep and a posteriodorsal shape difference in Wild sheep. In the same study, they stated that LM8 was posterior in Akkaraman sheep and anterior in Wild sheep. Also, they reported a posteriodorsal direction difference at LM1 and 10 in Akkaraman sheep and a anterioventral direction difference in Wild sheep (36). In the present study, the first-degree shape differences were observed at LM4, 8 and 9 in Honamli goat and at LM4, 7, 9 and 10, in Hair goat respectively. LM4 was cranioventral and LM8 and 9 were caudodorsal in Honamli goat. LM4 was cranioventral, LM7 and 9 were caudodorsal and LM10 was craniodorsal in Hair goat. This information obviously indicated the mandible differences in terms of species and breeds.

Yalcin et al. (36) reported that the difference at LM9 level was quite apparent and this may be associated with the differences such as environmental conditions and feeding habits as well as adaptation to domestication process. Also, in the present study, it was observed that the most apparent differences were at LM9 level, which is compatible with above-mentioned finding.

Yalcin et al. (36) reported that sexual dimorphism was not observed in mandible of Anatolia Wild sheep. In the present study, goat mandible was analyzed by using geometric morphometric method for the first time in terms of sexual dimorphism based on breed factor. In the study, sexual dimorphism was observed in both breeds. However, the sexual dimorphism of Hair goat in terms of the first PC was more apparent compared to Honamli goat.

Consequently, in the present study, mandibles of domesticated goats were analyzed using geometric morphometric methods based on breed and sex factors for the first time. It was remarkable that the Hair goat had quite apparent sexual dimorphism compared to the Honamli goat. Also, one of the most remarkable results of the study was that the male goats clustered clearly compared to the female goat in terms of breed factor. It is considered that the data obtained in this study would contribute to the other ruminant mandible studies by using geometric morphometric method. Also, we think that the data would be used in the distinction of the mandible remains uncovered in zooarchaeological excavations and especially considered as ovicapri (sheep-goat).

Ethical Statement

The study was approved by the Local Ethics Committee of Burdur Mehmet Akif Ersoy University (approval number 2020/645).

Conflict of Interest

The authors declared that there is no conflict of interest.

Finacial Support

This research received no grant from any funding agency/sector.

References

1. **Adams DC, Rohlf FJ, Slice DE** (2013): *A field comes of age: Geometric morphometrics in the 21st century.* Hystrix, **24,** 7-14.
2. **Ansell WFH** (1972): Order Artiodactyla. In The mammals of Africa. An identification manual Smithsonian Institution Press, Washington.
3. **Batubara A, Noor RR, Farajallah A, et al** (2011): *Morphometric and phylogenic analysis of six population Indonesian local goat.* J Ani Sci Tech, **34,** 165-74.
4. **Bigoni L, Velemínská J, Brůžek J** (2010): *Three-dimensional geometric morphometric analysis of cranio-facial sexual dimorphism in a Central European sample of known sex.* Homo, **61**, 16-32.
5. **Clark KM** (1995): *The later prehistoric and protohistoric dog: the emergence of canine diversity.* Archaeozoologia, **7,** 9-32.
6. **Elmaz Ö, Saatçi M, Mamak N, et al** (2012): *The determination of some morphological characteristics of Honamli goat and kids, defined as a new indigenous goat breed of Turkey.* Kafkas Univ Vet Fak Derg, **18**, 481-5.
7. **Ensminger ME, Parker RO** (1986): Sheep and goat Science, Fifth Edition. Danville, Illinois: The Interstate Printers and Publishers Inc.
8. **Figueirido B, Serrano-Alarcón SJ, Palmqvist P** (2012): *Geometric morphometrics shows differences and similarities in skull shape between the red and giant pandas.* J Zool, **286,** 293-302.
9. **Food and Agriculture Organization; FAO** (2007): Global Plan of Action for Animal Genetic resources and Interlaken Declaration on Animal Genetic Resources, Rome, Italy.
10. **Frost SR, Marcus LF, Bookstein FL, et al** (2003): *Cranial allometry, phylogeography, and systematics of largebodied papionins (primates: Cercopithecinae) inferred from geometric morphometric analysis of landmark data.* Anat Rec A Discov Mol Cell Evol Biol, **275,** 1048-1072.
11. **Guintard C, Lallemand M** (2003): *Osteometric study of metapodial bones in sheep (Ovis aries, L. 1758).* Ann Anat, **185,** 573-583.
12. **Gündemir O, Özkan E, Dayan MO, et al** (2020): *Sexual analysis in turkey (Meleagris gallopavo) neurocranium using geometric morphometric methods.* Turk J Vet Anim Sci, **44**, 681-687.
13. **Gürbüz İ, Aytek Aİ, Demiraslan Y, et al** (2020): *Geometric morphometric analysis of cranium of wolf (Canis lupus) and German shepherd dog (Canis lupus familiaris).* Kafkas Univ Vet Fak Derg, **26**, 525-532.
14. **Hammer Q, Harper DAT, Ryan PD** (2001): *PAST: Paleontological Statistics Software Package for Education and Data Analysis*. Palaeontol Electron, **4,** 9.
15. **Kimmerle EH, Ross A, Slice D** (2008): *Sexual dimorphism in America: geometric morphometric analysis of the craniofacial region.* J Forensic Sci, **53,** 54-57.
16. **Klingenberg CP** (2011): *MorphoJ: an integrated software package for geometric Morphometrics*. Mol Ecol Resour, **11**, 353-357.
17. **Marcus LF, Hingst-Zaher E, Zaher H** (2000): *Application of landmark morphometrics to skulls representing the orders of living mammals.* Hystrix, **11,** 27-47.
18. **Mitteroecker P, Gunz P** (2009): *Advances in Geometric Morphometrics.* Evol Biol, **36,** 235-247.
19. **Naderi S, Rezaei HR, Pompanon F, et al** (2008): *The goat domestication process inferred from large-scale mitochondrial DNA analysis of wild and domestic individuals.* Proc Natl Acad Sci, **105,** 17659-17664.
20. **O'Higgins P** (2000): *The study of morphological variation in the hominid fossil record: biology, landmarks and geometry.* J Anat, **197,** 103-120.
21. **Onar V, Belli O** (2005): *Estimation of shoulder height from long bone measurements on dogs unearthed from the Van-Yoncatepe early Iron Age necropolis in Eastern Anatolia.* Rev Med Vet, **156,** 53-60.
22. **Önel A** (2010): Comparison of hares (Lepus europaeus Pallas, 1778) from Elazığ and Malatya by using geometric morphometrics techniques. Doktora Tezi. Fırat Üniversitesi Fen Bilimleri Enstitüsü, Elazığ.
23. **Özden B** (2008): İran küçük bal arısı (Apis florea Fabricius) populasyonlarında geometrik morfometrik analizi. Bilim Uzmanlığı Tezi, Karaelmas Üniversitesi Fen Bilimleri Enstitüsü, Zonguldak.
24. **Payne WJA, Wilson RT** (1999): An introduction to Animal Husbandry in the tropics. Blackwell Publishing Company: Oxford, UK.
25. **Rohlf FJ, Bookstein FL** (1990): Proceedings of the Michigan Morphometrics Workshop; Proceedings Michigan Morphometrics Work. University of Michigan Museum of Zoology: Ann Arbor, MI, USA.
26. **Rohlf FJ, Slice DE** (1990): *Extensions of the Procrustes method for the optimal superimposition of landmarks.* Syst Zool, **39,** 40-59.
27. **Rohlf FJ** (2017): TpsSmall Version 1.34, Ecology & Evolution. SUNY at Stone Brook, USA.
28. **Rohlf FJ** (2018): TpsDig Version 2.31, Ecology & Evolution. SUNY at Stone Brook, USA.
29. **Rohlf FJ** (2019): TpsRelw Version 1.70, Ecology & Evolution. SUNY at Stone Brook, USA.
30. **Rohlf FJ** (2019): TpsUtil program Version 1.79, Ecology & Evolution. SUNY at Stone Brook, USA.
31. **Slice DE** (2005): Modern Morphometrics. In: Physical Anthropology, Kluwer Acad./Plenum, New York.
32. **Slice DE** (2007): *Geometric morphometrics.* Annu Rev Anthropol, **36**, 261-281.
33. **Tekin ME, Öğeç M** (2017): *Konya Bölgesinde Halk Elinde Yetiştirilen Kıl Keçisi Oğlaklarının Büyüme ve Yaşama Gücü.* Lalahan Hay Araşt Enst Derg, **57**, 93-98.
34. **The Official Gazette of Turkish Republic** (2015): Communication on Supporting Principles of Animal Husbandry Practices, No: 2015/43, Num: 29535.

35. **Viscosi V, Cardini A** (2011): *Leaf Morphology, Taxonomy and Geometric Morphometrics: A Simplified Protocol for Beginners.* PLoS One, **6,** e25630.
36. **Yalcin H, Kaya MA, Arslan A** (2010): *Comparative Geometrical Morphometries on the Mandibles of Anatolian Wild Sheep (Ovis gmelini anatolica) and Akkaraman Sheep (Ovis aries).* Kafkas Univ Vet Fak Derg, **16**, 55-61.
37. **Zeder MA, Hesse B** (2000): *The Initial Domestication of goat (Capra hircus) in the Zagros Mountains 10,000 Years Ago*. Science Journal, **287**, 2254-2257.
38. **Zelditch ML, Swiderski DL, Sheets HD, et al** (2004): Geometric Morphometrics For Biologists: A Primer, Academic Press, Cambridge.
39. **Zelditch ML, Swiderski DL, Sheets HD** (2012): Geometric Morphometrics for Biologists: A Primer, Academic Press, Amsterdam.