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Investigation of the Skull Basally in Honamli, Hair, Kilis and Saanen Goats Using Geometric Morphometric Methods

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Abstract: The study aimed to analyze the skulls of Honamli, Hair, Kilis, and Saanen goats from the basal aspect using the geometric morphometric method. In the study, 48 adult goat skulls were used for each breed in six males and females. After the skulls were photographed from the basal aspect, 11 homologous landmarks were marked. In the study, based on the breed, male and female Honamli, Hair, Kilis, and Saanen goat skulls were significantly separated from each other. The most prominent clusters were seen between female Kilis and Saanen's skulls and male Honamli and Kilis goats. As a result, it is thought that the information obtained could create a reference for the skull remains of ruminants obtained from archaeological excavations.
Keywords: *Geometric morphometric, Goat, Landmark, Principal component analysis.*

Honamli, Kıl, Kilis ve Saanen Keçilerinde Kafatasının Basal Yönden Geometrik Morfometrik Metot Kullanılarak İncelenmesi

Özet: Çalışmada geometrik morfometri yöntemi ile Honamli, Kıl, Kilis ve Saanen keçisine ait kafataslarının basal yönden analizi amaçlandı. Çalışmada her ırk için 6'şar adet erkek ve dişi olmak üzere toplamda 48 adet ergin keçi kafatası kullanıldı. Kafatasları basal yönden fotoğraflandıktan sonra 11 adet homolog landmark işaretlendi. Çalışmada ırk baz alındığında dişi ve erkek Honamli, Kıl, Kilis ve Saanen keçi kafatasları birbirinden önemli düzeyde ayrıldı. En belirgin kümelenmeler dişi Kilis ve Saanen, erkek Honamli ve Kilis keçisine ait kafatasları arasında görüldü. Sonuç olarak elde edilen bilgilerin arkeolojik kazılardan elde edilen geviş getirenlere ait kafatası kalıntıları için referans oluşturabileceği düşünülmektedir.
Anahtar Kelimeler; *Geometrik morfometri, Keçi, Landmark, Temel bileşenler analizi.*

Introduction

The domestic goat (Capra hircus) is a domesticated species of goat generally for livestock. The goat is a member of the Bovidae family (Ansell, 1972; Payne and Wilson, 1999). The hair goat is a combined productive goat breed resistant to Anatolia's challenging climate, can be evaluated for weak pastures, and raised in mountain villages (Gunlu and Alasahan, 2010; Sengonca and Kosum, 2005). Kilis goat is a crossbreed of Damascus goat with Hair goat and is a goat breed with a very high milk yield. Kilis goat is a goat breed widely cultivated in the Southeastern Anatolia region, especially around Hatay, Gaziantep, and Sanliurfa. These goats are a goat breed with durable body structure, long walking ability, high milk and reproductive efficiency (Gunlu and Alasahan, 2010; Kaymakcı and Askin, 1997; Sengonca and Kosum, 2005; Yalcin, 1986). The Honamli goats have been purely bred in the central and western Taurus by the Honamli Yoruks for centuries. According to Communiqué No. 2005/8503 on the Protection of Animal Genetic Resources, this species was included in the scope of protected native breeds in 2005 by the General Directorate of Agricultural Research and Policies (Karadağ and Soysal, 2018). Saanen goats are bred in Europe, in the Saanen valley of Switzerland. Since it is a goat breed with high fertility and milk yield, it has a widespread breeding area (Ceyhan and Karadag, 2009).

Geometric morphometry is a method that allows the detection of shape differences that cannot be detected with the naked eye through landmark coordinates. It, therefore, measures the amount of shape change by exploiting the differences in the position between the objects of the coordinates (Kimmerle et al., 2008; Viscosi and Cardini, 2011; Zelditch et al., 2012). This method allows the magnitude and direction of movement of coordinates between different populations or samples to be mapped and the result interpreted (Bigoni et al., 2010; Frost et al., 2003). In the literature, there are studies of small Ruminantia revealed by geometric morphometrics (Demiraslan et al., 2021; Demircioglu et al., 2021; Yalcin et al.,

2010). The literature review on goats shows a limited number of geometric morphometric method studies (Casanova and Miquel, 2015; Demiraslan et al., 2021; Haruda, 2017; Pares-Casanova and Domènech-Domènech, 2021). Therefore, the study aimed to analyze the skulls of four different goat breeds by geometric morphometric methods in the basal aspect.

Materials and Methods

This study is not subject to HADYEK permission by Article 8 (k) of the 'Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees.'

The study used six males and females for each breed, totaling 48 adult goat skulls. The skulls were collected from slaughterhouses in the Mediterranean, Middle, and Southeastern Anatolia regions. The materials were macerated first by boiling. After the maceration process, the skulls were photographed from the basal, from a distance of 30 cm, focusing on the sutura maxillopalatina. The photographs were converted to a Tps file using the TpsUtil (Version 1.79) program. We marked 11 homologous landmarks on the basal of the skulls using the TpsDig2 program (Version 2.31) (Figure 1). Thus, the Cartesian coordinates of the landmarks were determined. A homologous landmark verification test was performed with the TpsSmall (Version 1.34) program (Rohlf, 2017). Since there are differences in skulls, such as size, position, and direction, General Procrustes Analysis (superimposition) was performed on the skulls to eliminate these variables (Slice, 2005). PAST (Version 4.02) was used for this analysis (Hammer et al., 2001). Principal component analysis was performed with the same program on the new coordinates obtained as a result of superimposition. Thus, the degree of separation of the samples according to breed or sex was determined by using covariance analysis among the factors (Zelditch et al., 2004). In addition, the MorphoJ program was used to show which LMs and in which direction the shape difference is (Klingenberg, 2011). In the study, consensus graphs of the groups were created by performing Relative Warp Analysis with the TpsRelw (Version 1.70) program. The distribution of the groups on the graph was also tested with this analysis (Rohlf, 2017). Statistical analysis of LM coordinate values according to groups was performed with an ANOVA test in the PAST (Version 4.02) program.

Results

The results of the principal components analysis are shown in Table 1. Accordingly, the first principal

Table 1. Results of principal component analysis of the basal aspect of the skulls of male and female Honamli, Hair, Kilis and Saanen goats.

	Female		Male	
	PC Eigenvalue	**%Variance**	**PC Eigenvalue**	**%Variance**
1	0,00094486	30,319	0,000796745	28,164
2	0,000671452	21,546	0,000576305	20,371
3	0,000464533	14,906	0,00037422	13,228
4	0,000300546	9,6442	0,000317092	11,209
5	0,00021416	6,8721	0,000188696	6,6701
6	0,000131522	4,2204	0,000148862	5,262
7	0,000109768	3,5223	0,000112827	3,9883
8	9,10536E-05	2,9218	9,95847E-05	3,5202
9	5,02777E-05	1,6134	7,08039E-05	2,5028
10	4,47753E-05	1,4368	4,4781E-05	1,5829
11	3,22615E-05	1,0352	2,94083E-05	1,0395
12	2,47946E-05	0,79563	2,07973E-05	0,73515
13	1,35685E-05	0,4354	1,81443E-05	0,64137
14	9,39521E-06	0,30148	1,11181E-05	0,39301
15	7,19158E-06	0,23077	9,47571E-06	0,33495
16	4,64459E-06	0,14904	5,30567E-06	0,18755
17	9,23531E-07	0,029635	2,83117E-06	0,10008
18	5,22829E-07	0,016777	1,92067E-06	0,067893
19	1,00104E-07	0,0032122	6,11772E-08	0,0021625
20	7,33543E-17	2,3539E-12	4,66223E-17	1,648E-12
21	3,93401E-17	1,2624E-12	2,20207E-17	7,784E-13
22	5,34831E-18	1,7162E-13	1,57276E-18	5,5595E-14

component explained 30.319% and 28.164% of the total shape difference in female and male goat skulls, respectively.

The distribution graph of individuals according to the first principal component and Relative Warp analysis are shown in Figure 2. According to this, while significant differences were observed between breeds, the most significant separation among females was between Kilis and Saanen goats, and the most significant separation among males was between Honamli and Kilis goats.

The graph showing the points where the shape difference is concentrated in males and females according to PC1 is presented in Figure 3. Accordingly, LM1, LM9, and LM10 in females, LM5, LM6, LM7, and LM8 in males were the homologous points causing the most variation.

The level of LMs at which directional differences between individuals by breed and sex occurred are shown in Figures 4 and 5. Directional differences were observed in LM3 in all females, and in LM5 in all males.

Graphics of canonical variance analysis results are shown in figure 6. Accordingly, male goats were grouped more clearly than females in the breed.

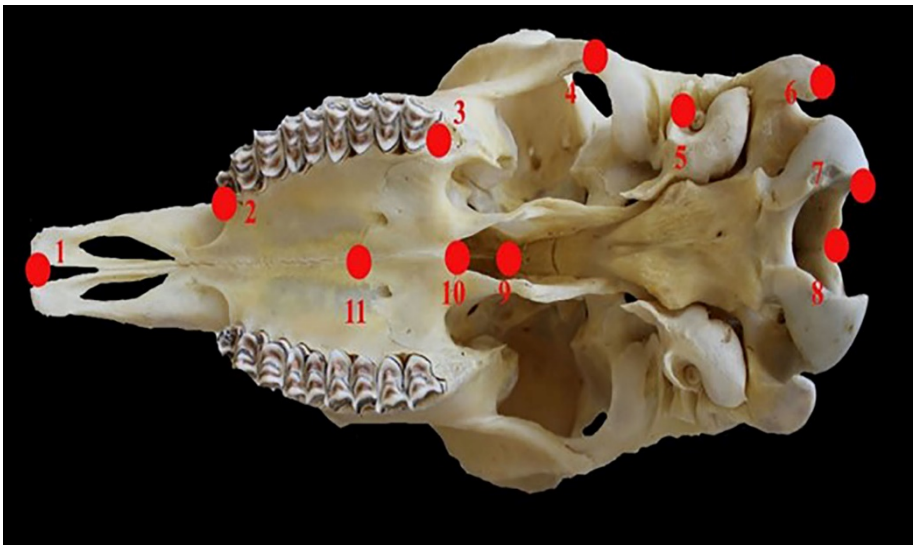

Figure 1. Landmarks marked from basal on the skulls of female Hair.

1. The most rostral of the fissura interincisiva, 2. rostro-oral corner of the margo alveolaris of II. premolar tooth, 3. caudo-oral corner of the margo alveolaris of III. molar tooth, 4. midpoint of the arcus zygomaticus, 5. meatus acusticus externus, 6. Processus jugularis, 7. Condylus occipitalis 8. Caudo-median point of foramen magnum, 9. Caudal of vomer, 10. Base of choana, 11. Median point of sutura maxillopalatina).

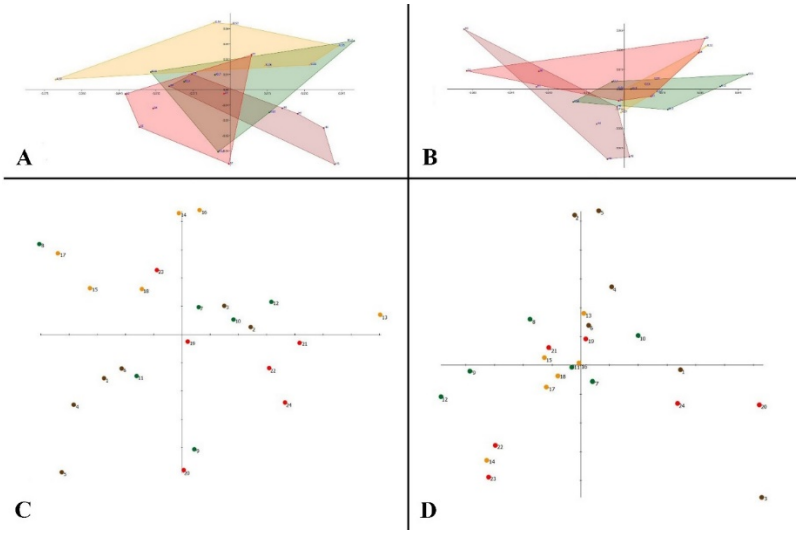

Figure 2. The Scatter plots of principal component (PCA) and relative warp analysis (RWA) of male and female Honamli, Hair, Kilis and Saanen goats.

A. PCA plot for female, B. PCA plot for male, C. RWA plot for female, D. RWA plot for male. 1-6 or brown: Honamli, 7-12 or green: Hair, 13-18 or orange: Kilis, 19-24 or red: Saanen.

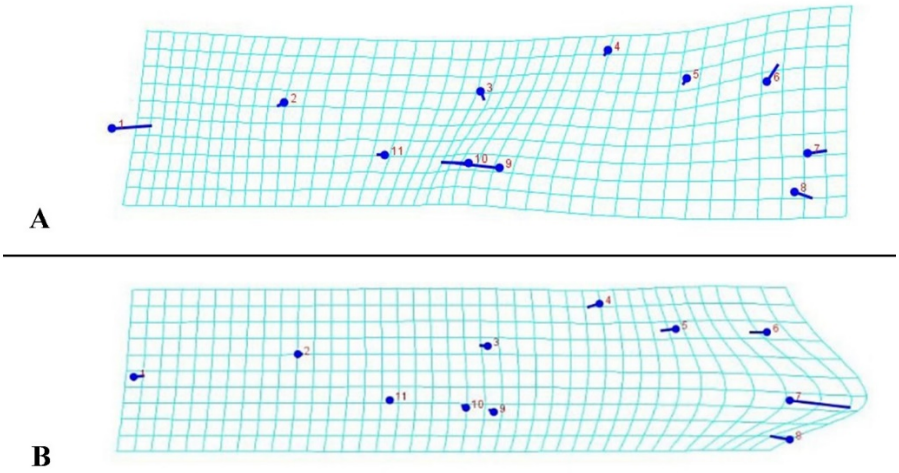

Figure 3. Transformation grid model of Honamli, Hair, Kilis and Saanen goat skulls according to the PC1. A. female, B: male

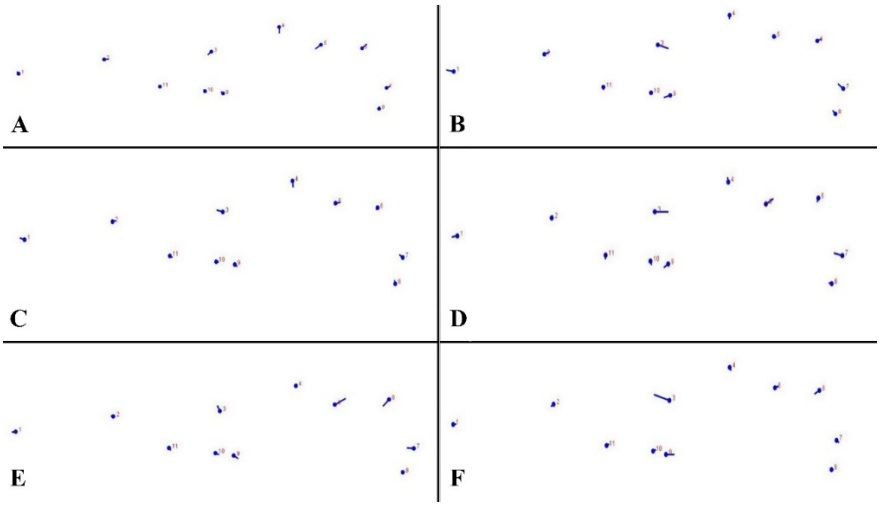

Figure 4. Graphs of discriminant function analysis of shape variation according to breed for female goats. A. Hair-Honamli, B. Hair-Kilis, C. Hair-Saanen, D. Honamli-Kilis, E. Honamli-Saanen, F. Kilis-Saanen.

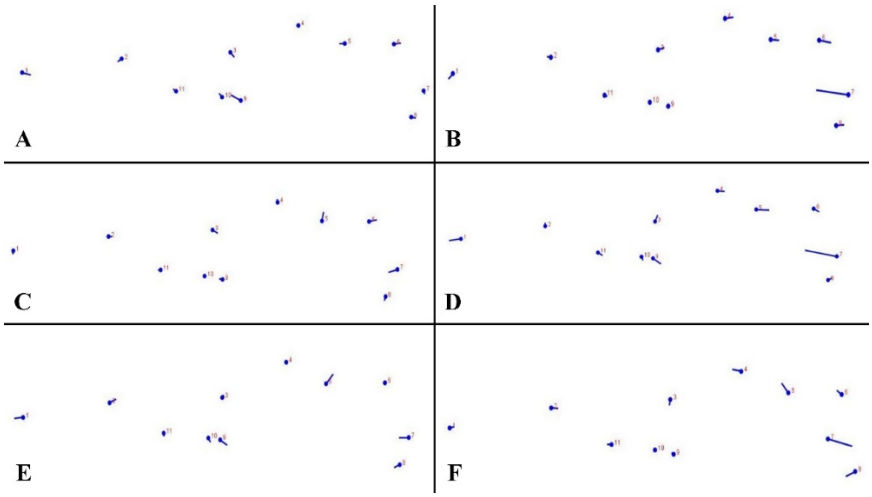

Figure 5. Graphs of discriminant function analysis of shape variation according to breed for male goats. A. Hair-Honamli, B. Hair-Kilis, C. Hair-Saanen, D. Honamli-Kilis, E. Honamli-Saanen, F. Kilis-Saanen.

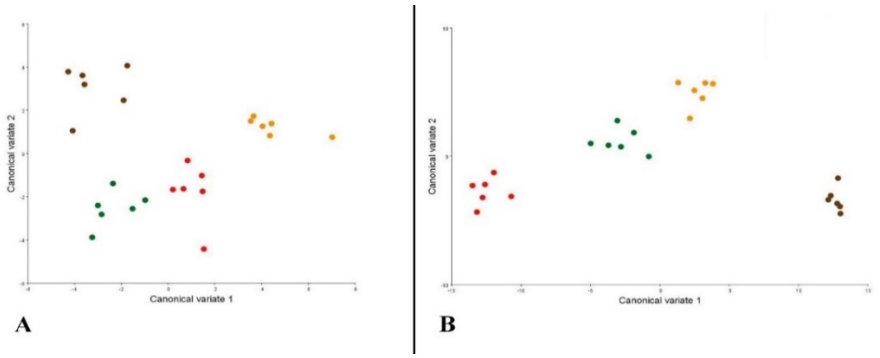

Figure 6. Graphical distribution of individuals according canonical variance analysis. A.Female, B. Male. Brown: Honamli, Green: Hair, Orange: Kilis, Red: Saanen.

Discussion

In this study, the skulls of Honamli, Hair, Kilis, and Saanen goats were analyzed by a geometric morphometric method based on the basal- to- breed factor. Few studies have been found in the literature on goat skulls using the geometric morphometric method. This situation constituted the most apparent limitation of the study as it largely prevented the discussion of the findings.

It has been reported that critical macro-anatomical changes occurred in the morphology of the cranial bones, as well as some general morphological features of sheep and goats, with domestication (Schaffer and Reed, 1972). Our study examined goats' skulls living in different geographical regions, whose breed was registered, by basal geometric morphometric methods. The study' overarching goal was to determine whether racial dimorphism in general body appearance or body part is also reflected in the basal skull. The first findings in this study, which we conducted with a limited number of materials, point to racial and morphological dimorphism in the basal of the goat skull.

Casanova and Miquel (2015) reported that in the geometric morphometric examination of the dorsal skulls of White Rasquera goats, sex discrimination could be made, and the sagittal points

of the viscerocranium provided the greatest contribution to this distinction. In our study, the skulls of Hair, Honamli, Kilis, and Saanen goats were analyzed geometric morphometrically, and it was found that it was possible to distinguish between goat breeds. The most important points where the shape variation was evident were caudo-oral corner of the margo alveolaris of molar tooth III in females and the meatus acusticus externus in males. It is thought that the caudo-oral corner of the margo alveolaris of molar tooth III in females may be distinctive due to differences in feeding habits. The fact that the meatus acusticus externus is distinctive in males suggests that it may be due to the variability of auricle lengths according to breeds.

Demiraslan et al. (2021), in their geometric morphometric study on the mandible of Honamli and Hair goats, reported that Hair goats showed a very distinct sex difference compared to Honamli goats and that male goats were clustered compared to female goats in terms of breed factor. In our study, the basal of the skull was distinctly separated according to goat breeds.

In conclusion, in this study, using geometric morphometric methods, Honamli, Hair, Kilis, and Saanen goat skulls were analyzed for the first time in basal racial dimorphism. The study provides the first inference that racial distinction between goats can be possible from the basal skull. It can be suggested that the study' findings should be elaborated with more material and by including different breeds of goats. Thus, the geometric morphometric findings obtained from the skull base can have a prominent place in the taxonomy of the goat breed. Despite all these, it is thought that the data presented in this study will contribute to morphometric studies on the skull of Ruminantia.

Conflict of Interest

We did not have any real, potential or perceived conflict of interest.

Ethical Approval

This study is not subject to HADYEK permission in accordance with Article 8 (k) of the "Regulation on Working Procedures and Principles of Animal Experiments Ethics Committees".

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Similarity Rate

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Author Contributions

Motivation / Concept: AY, YD
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Control/Supervision: YD, ÖÖ
Data Collection and / or Processing: AY, YD
Analysis and / or Interpretation: AY, YD
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Writing the Article: AY, YD
Critical Review: YD, ÖÖ

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