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Research Article

Craniometrical Analysis of Wild Boar (*Sus scrofa*) from Northern Punjab, Pakistan

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Authors' Contributions
AI conducted the study, made the taxonomic identifiction and wrote the first draft of the paper. GS helped in craniometrical analysis. AMK designed and supervised the study. MTW helped in the discussion and made the illustration. RMA helped in sampling and contributed in discussion. MA contributed in introduction

Keywords
Craniometery, Evolution, Habitat fragmentation, Morphometry

Abstract | The current study reports the cranial morphology of *Sus scrofa*, with detailed comparison of different features of skull. The cranial morphology has been utilized as a tool to discriminate between the different species of wild and domesticated suids. The studied material comprises of the three skulls. The straighter snouts and slenderer crania manifests that specimens under study were wild while the sex of species was determined by the permanent canine teeth morphology, as in females the upper canines extend in ventrolateral directions and continue to grow in lateral direction while in males the upper canines extend out in anterolateral direction and curve dorsally. The estimation of suid's ages was based on third molar eruption. The fifty-one craniometric and twenty mandibular measurements were carried out on the adult male skull and data derived from analysis of our sample was compared with previously reported data of European and Japanese wild boar. As a result of comparison of the different craniometric and mandibular parameters it was inferred that the studied specimen has larger dimensions for various parameters than the European and Japanese wild boar. The smaller cranial and mandibular values in Eurasian and Japanese wild boar may be attributed to some evolutionary, climatic or hunting pressures.

Novelty Statement | This paper presents the first craniometrical report of the *Sus scrofa* from Northern Punjab, Pakistan. Furthermore, the current study provides the reference data for upcoming morphological and evolutionary studies of wild and domestic Suids in Pakistan.

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Introduction

The wild boar (*Sus scrofa*) belongs to superorder Cetartiodactyla and is a representative of family Suidae. This species has been considered as native of North Africa and Western Europe which extended its range to South East Asia including India, Pakistan, Java, Japan, Sri Lanka, Korea, Taiwan and Malaya (Beg, 1990).

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The wild boar successfully occupies various niches and has been reported from many different habitats with a large population size (Meriggi, 1992). In Asia, Europe and Africa, eight species of pigs are present. These species include *S. barbatus*, *S. bucculentus*, *S. cebifrons*, *S. celebensis*, *S. salvanius*, *S. scrofa*, *S. verrucosus* and *S. philippensis*. According to Nidup (2011), there are twenty-one subspecies of the wild boar (*Sus scrofa*). The sub-species *S. scrofa cristatus* exists in India and Pakistan (Khan, 1990). Its adaptability is enhancing by the large food availability and protection especially in highly disturbed environments (Caley, 1997; Goulding *et al.*, 2003).

Wild boars occupy a range of habitats including agricultural areas, shrub lands wooded forests and swamplands. In Pakistan. the wild boar distribution is a part of its ancestral range (Heptner *et al.*, 1966). They are most associated with Indus basin riverain tracts. They also have adapted perfectly to manmade irrigated forest plantations of the Punjab and Sindh provinces (Beg and Khan, 1982).

The changes in animals and taxonomic affiliation are indicated by the skull. The changes in the shape and proportion of skull bones affected by the genetic and environmental conditions are analyzed by the morphometric analysis thus, in osteological investigations craniometery has an important role (Bruenner *et al.*, 2002). Hardjasasmita (1987) distinguished various species of *Sus* in the Indonesian archipelago by using morphologic and craniometric features.

The rostral region of wild boar skull is elongate. Generally, the skull shape is triangular roughly in lateral, ventral and dorsal views. The skulls of wild pigs are sexually dimorphic as for many measurements the mandibles and crania are larger in males (Mayer and Brisbin, 1991). In both sexes of pigs 44, permanent teeth are present (Bahadur, 1942). The size and shape of tusks or permanent canines differ in both the sexes, as in females the upper canines extend in ventrolateral directions and continue to grow in lateral direction while in males the upper canines extend out in anterolateral direction and curve dorsally (Mayer and Brisbin, 1988).

Here all the craniometrical data measurements were applied for analysis to elucidate the size and shape variation among the wild boar of two regions. This data may assist in establishing the species status of wild boar in Pakistan.

Materials and Methods

The skulls of wild boar used for present research work were taken from the Zoological Museum University of the Punjab, Lahore. There were three skulls, with catalogue No. PUPC 181, PUPC 408 and PUPC 408A present in the museum. All the three skulls were studied for the craniometric analysis. In suids, the third molar develop completely usually at the age of four years, the individual with fully erupted third molars is considered as adult (Genov, 1999). Among the three skulls used for this study only one skull having catalogue No. PUPC 181 has fully erupted third molar. Hence, for further comparative analysis this adult male wild boar skull was used. After the fourth year, the size of the skull remains largely unchanged (Kozlo, 1975). The Craniometric measurements were taken for a total of 51 skull cranial features following the Von den Driesch (1976), for measurements of mandibular profile a total of 20 characters were considered following the features described by Endo *et al.* (2000).

Measurements were taken by digital Vernier caliper (accuracy ±0.01 mm), measuring band and calibrated ruler (accuracy ±1 mm).

Skull parameters

Dorsal view

Overall 16 skull measurements (Figure 1) of dorsal side were included in the analysis as under:

1. Skull length: Akrokranion - Prosthion- (Ak-P); 2. Length of Profile: Opisthocranion - Prosthion (Op-P); 3. Neurocranium dorsal length: Nasion- Akrokranion (N-AK); 4. Length of viscerocranium: Prosthion - Nasion (P-N); 5. Higher neurocranium length: Supraorbital-Akrokranion (Sp-Ak); 6. Length of face: Prosthion-Supraorbital (P-Sp); 7. Parietal bone length: Bregma -Akrokranion (Br-Ak); 8. Length of frontal bone: Nasion-Bregma (N-Br); 9. Nasal bone maximum length: Rhinion -Nasion (Rh-N); 10. Length of nasal bone (Minimum): -Nasion - Naso-incisive incision (N-Ini); 11. Entorbital-infraorbital hole length: Naso-incisive incision - Entorbital (Inf -Ent); 12. Infraorbital hole - prosthion length: - Prosthion-Naso-incisive incision (P-Inf); 13. Parietal bone width; 14. Frontal bone width: Ectorbital- Ectorbital (Ect-Ect); 15. Middle width of supraorbital holes; 16. The skull width: Zygion- Zygion (Zy-Zy)

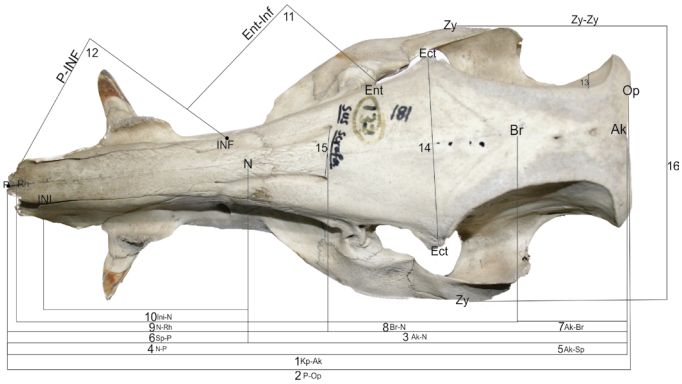

Figure 1: Dorsal view of the wild boar skull.

Ventral view

17. Condylo (Figure 2)- basal length: Prosthion - Occipital condyle (P-Condyl); 18. Length of base: Prosthion - Basion- (P-Ba); 19. Occipital bone -palatine incisive apophyses length: Premolar - Basion- (Pm-Ba); 20. Palatine apophyses of incisive bone length: Prosthion - Premolar (P-Pm); 21. Axis basi - facial length; basioccipital length Basion- Hornion (Ba-H); 22. Hornion- Prosthion (H-P); 23. Condyle - palatine length: Basion- Staphylion (Ba-St); 24. Length of palatine: Staphylion- Prosthion (St-P); 25. Length of upper dental arch: Postdental- Prosthion (Pd-P); 26. Canine recess - Molar 3 length; Canine recess-Molar 3- (C-M3); 27. Diastema length: Premolar 1 - Incisive 3- (P1-I3-); 28. Premolaromolar length: - Molar 3 - Premolar 1 (M3-P1); 29. Premolar2 - Molar 3 length: (P2-M3-); 30. Molar length; 31. Premolar length; 32. Length of upper canines; 33. Third molar length; 34. Third molar width; 35. Hard palate width (maximum).

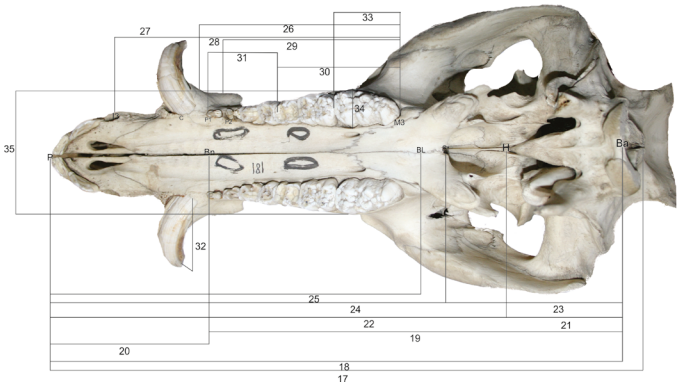

Figure 2: Ventral view of wild boar skull.

Lateral view

36. Length (Figure 3) of neurocranium (maximum): Basion- Nasion (Ba-N); 37. Lacrimal bones length; 38. Lacrimal bones height; 39. Lateral length of premaxilla: Nasointermaxillare- Prosthion (Ni-P); 40. Ectorbital-entorbital length: (Ect-Ent); 41. Length of mandible; 42. Height of mandible; 43. Length of lower canines.

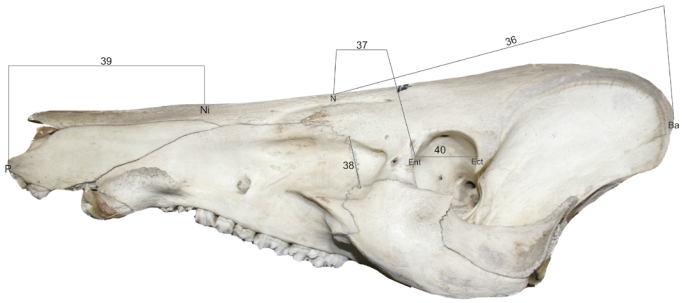

Figure 3: Lateral view of wild boar skull.

Aboral view

44. External (Figure 4) auditory canals distance: Otion- Otion (Ot-Ot); 45. Width of Occipital condyle; 46. Jugular apophysis width; 47. Occipital hole width; 48. Occipital hole height: Basion - Opisthion (Ba-O); 49. Nuchal crests width (maximum); 50. Nuchal crests width (minimum); 51. Aboral neurocranium height: Basion-Akrokranion (Ba-Ak).

Mandibular parameters

Regarding the mandible bone 20 measurements (Figure 5) were taken as;

1.Length of mandible from angle (LA); 2. Length of mandible from condyle (LC); 3. Vertical ramus aboral height (RAH); 4. Vertical ramus oral height (ROH); 5. Vertical ramus Middle height (RMH); 6. Height at m3 (Hm3); 7. Height at m1(Hm1); 8. Height at gnathion point (HG); 9. Symphysis length (SL); 10. Ramus length: angle - m3 (RL); 11. Canine alveolus length (CAL); 12. Breadth at posterior point of i3 (BI); 13. Breadth between canine alveori (BC); 14. Minimum breadth of the mandible (MBM); 15. Breadth of two mandibular halves at the lateral points of the two angle (BLP); 16. Breadth of the condyle processes between two halves (BCP); 17. Breadth of condyle process between medial and lateral points (BML); 18. Thickness of the condyle process between rostral and caudal points (TC); 19. At m1 breadth of mandible (Bm1); 20. Thickness of the mandible at middle point of m1(TM).

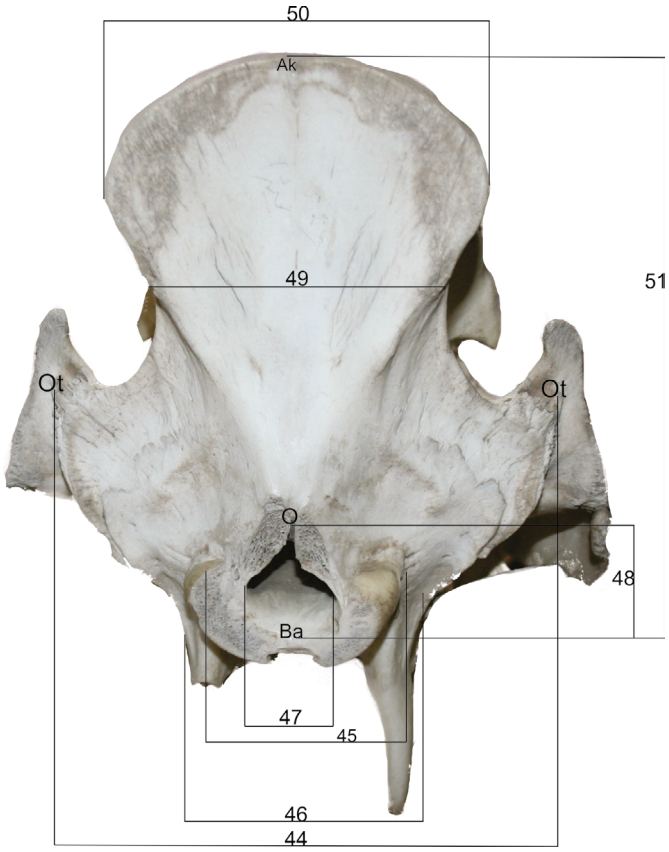

Figure 4: Aboral view of wild boar skull.

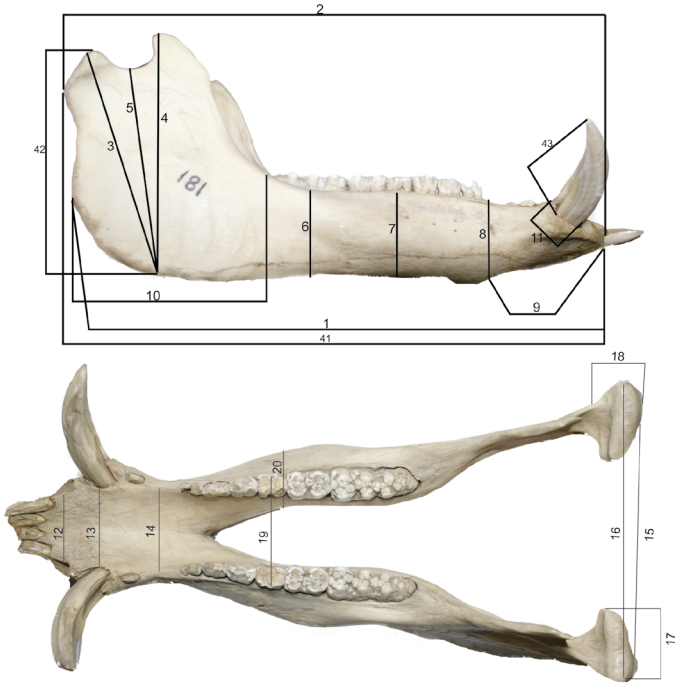

Figure 5: The measurement values of mandible. Upper: Lateral aspect. Lower: Dorsal aspect.

Results and Discussion

Results of the craniometric analysis are presented in

Table 1. The studied specimen of Wild Boar (*Sus scrofa*) collected from the Oriental region (The Punjab, Pakistan), is compared with reported data of Constantinescu *et al.* (2014) in which craniometeric profile of Eurasian Wild Boar has been described. Regarding the comparison and differences between the wild boar, the dorsal side skull length measurements, the graphical representation is shown in Figure 6. From the measured values, it is demonstrated that the skull length of the Oriental wild boar is 4.25 mm larger than the Eurasian. While Profile length of the Eurasian is 1.28mm larger than the Oriental boar. Minor or negligible variabilities are present in higher neurocranium length and parietal bone length (i.e. 0.38 and 0.48 mm variability respectively) which may be due to error in measurement and can be neglected. The high variability is present in neurocranium dorsal length, length of face, frontal bone length and length of nasal bone (minimum) the differences are 3.09, 3.25, 4.48 and 4.95mm respectively. The very high variability i.e. 6.26 and 7.02 mm are present in Entorbital-infraorbital hole length and infraorbital hole- prosthion length respectively. The highest variabilities on dorsal side are present in viscerocranium length and length of nasal bone (maximum) (i.e 18.89 and 16.4 mm respectively) the measurements of both these parameters are larger in the Eurasian wild boar as compared to the Oriental boar.

Ventral side skull length measurements and comparison are shown in the (Figure 7) from the data it is distinguished that the minor or negligible differences are present in the condylo–basal length, palatine apophyses of incisive bone length, molar 3- canine recess length and third molar length (0.97, 0.08, 0.19 and 0.58mm respectively, are the differences in measurements of both wild boar). The highly variable parameter in on ventral side are basal length, occipital bone - palatine incisive apophyses length, condyle palatine length, length of palatine, Premolaro- molar length, and molar length (3.1, 2.52, 3.7, 3.92, 3.48 and 2.72mm of difference is present respectively, in measurements of both species). The very high variability parameters include the basioccipital length, axis basi -facial length, diastema length and molar 3 – premolar length while the differences in both values is of 7.51, 5.21, 5.24 and 10.66 mm respectively. The highest variable indicator is the length of upper dental arch which is 14.8mm larger in measurement in Oriental wild boar than Eurasian boar.

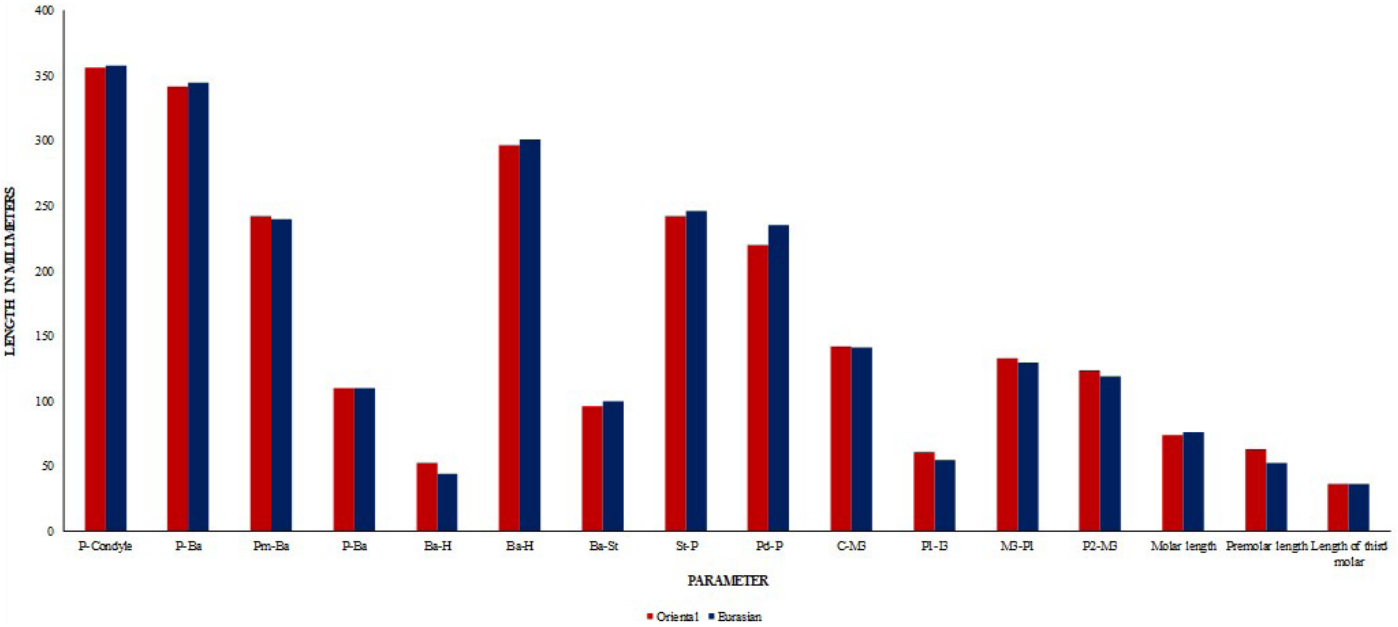

Figure 6: The graph showing the comparison of dorsal side skull length measurements of the oriental and the Eurasian Wild Boar.

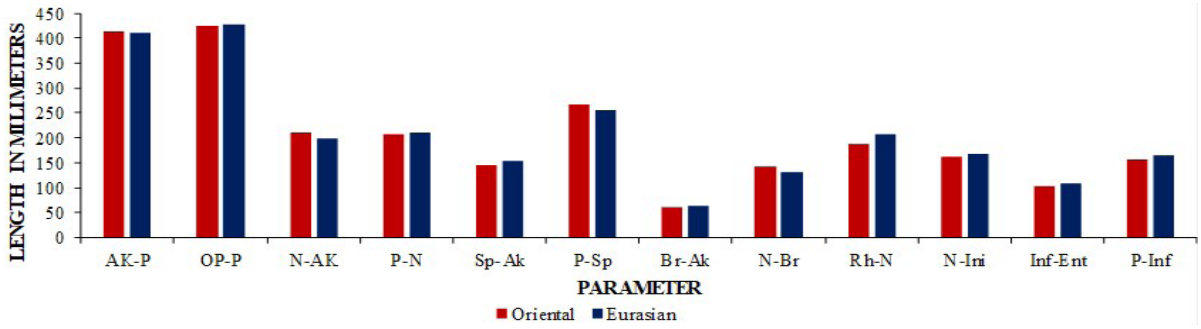

Figure 7: The graph showing the comparison of ventral side skull length measurements from the Oriental and the Eurasian Wild Boar.

Table 1: Comparison of craniometric features between the oriental wild boar and the Eurasian wild boar.

Parameter	Oriental wild boar	Eurasian wild boar*	D
1	414.05	409.8	4.25
2	425.02	426.3	-1.28
3	201.39	198.3	3.09
4	192.41	211.3	-18.89
5	154.92	155.3	-0.38
6	253.05	256.3	-3.25
7	62.28	62.76	-0.48
8	136.98	132.5	4.48
9	191.4	207.8	-16.4
10	163.35	168.3	-4.95
11	102.84	109.1	-6.26
12	157.28	164.3	-7.02
13	53.00	24.84	28.16
14	101.32	119.7	-18.38
15	29.88	34.13	-4.25
16	262.88	161.8	101.08
17	356.33	357.3	-0.97
18	341.20	344.3	-3.1
19	242.32	239.8	2.52
20	109.62	109.7	-0.08
21	51.27	43.76	7.51
22	296.09	301.3	-5.21
23	95.56	99.26	-3.7
24	241.88	245.8	-3.92
25	220	234.8	-14.8
26	141.01	141.2	-0.19
27	60.83	54.60	6.23
28	132.58	129.1	3.48
29	123.64	118.4	5.24
30	73.31	76.03	-2.72
31	62.90	52.23	10.67
32	56.13	79.30	-23.17
33	35.70	36.28	-0.58
34	20.69	28.88	-8.19
35	71.82	82.35	-10.53
36	312.88	251.3	61.58
37	60.56	58.05	2.51
38	23.41	31.94	-8.53
39	146.22	161.3	-15.08
40	36.49	42.72	-6.23
41	379.02	327.8	51.22
42	135.1	132.8	2.3
43	64.15	81.30	-17.15
44	123.24	130.6	-7.36
45	48.12	60.75	-12.63
46	81.02	82.61	-1.59
47	22.12	22.70	-0.58
48	34.28	35.97	-1.69
49	84.02	79.47	4.55
50	72.71	70.57	2.14
51	138.75	135.2	3.55

The lateral, mandibular and aboral side skull length measurements graphical representation is given in the (Figure 8) and difference in values are given in the (Table 1), it is demonstrated that a little difference is present in the length of lacrimal bone i.e. 2.51mm. In Eurasian wild boar, the lateral length of premaxilla, the length of upper canine and lower canines is (15.08, 23.17 and 17.51 mm respectively) larger in size than Oriental wild boar. While, a highest variability is present in the maximum length of neurocranium and length of mandible, both skull parameters are larger in the Oriental wild boar in values 0f 61.58 and 51.22 mm difference, respectively.

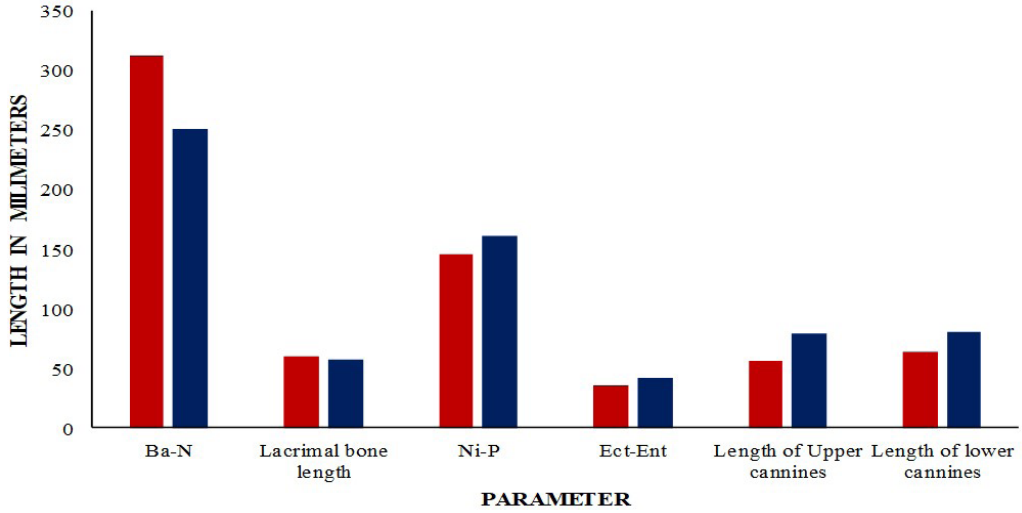

Figure 8: The graph showing the comparison of lateral, mandibular and aboral side skull length measurements from the Oriental and the Eurasian Wild Boar.

The graphical representation of values of skull width, (Figure 9) and difference in measurement (Table 1), represents that a negligible difference is present in width of jugular apophysis and occipital hole i.e. 1.59 and 0.59 mm respectively. The high variability is present in the values of maximum and minimum width of nuchal crests, the width is larger in Oriental wild boar in values of 4.55 and 2.14mm, than the Eurasian wild boar. While the width between the supra orbital whole is more in the Eurasian wild boar in value of 4.25mm than Oriental boar. The highly variable parameters include third molar width, width of hard plate (maximum) and external auditory canal distance, these are larger in size in the Eurasian wild boar than the Oriental in values of 8.91, 10.53 and 7.36mm respectively. The very high variability parameters are the width of parietal bone and width of frontal bone (i.e. 28.16 and 18.38mm respectively), the width of parietal bone is more in the Oriental boar while the width of frontal bone is more in the Eurasian boar. The highest variability is present in the width of skull as the width of the Oriental wild boar is 101.8mm larger than the Eurasian boar.

The comparative values of skull height, given in (Table 1) and graphical representation shown in (Figure 10) demonstrate that the little variability is present in the height of the occipital hole and in the height of mandible between the two boars the difference in values is 1.69 and 2.3 mm respectively. While in the height of lacrimal bone there is a high difference 0f 8.33mm, the height is more in the Eurasian wild boar as compared to the Oriental boar.

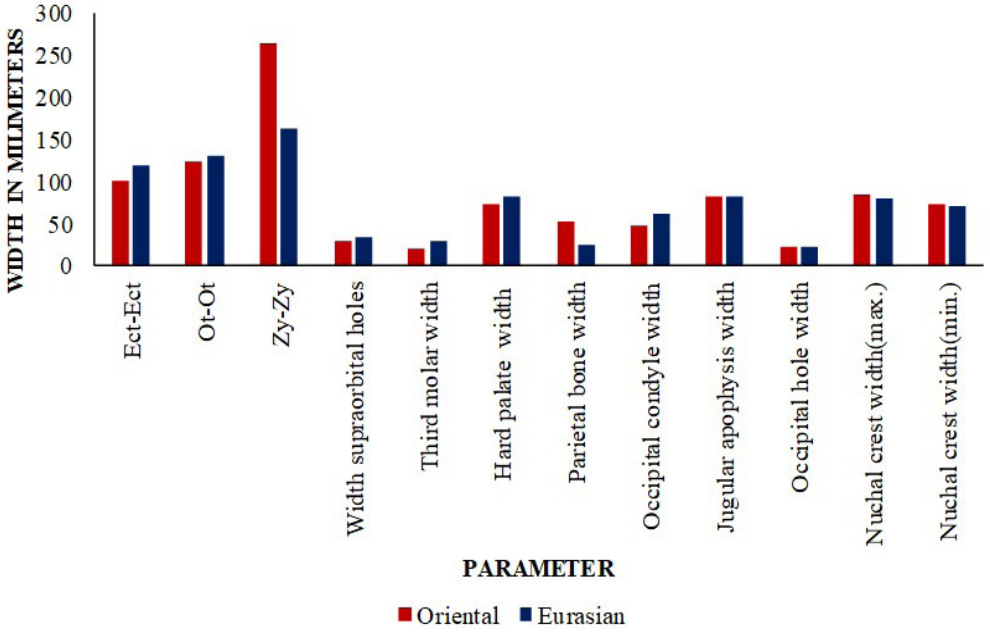

Figure 9: The graph showing the comparison of measurements of the width of skull parameters of the oriental and the Eurasian wild boar.

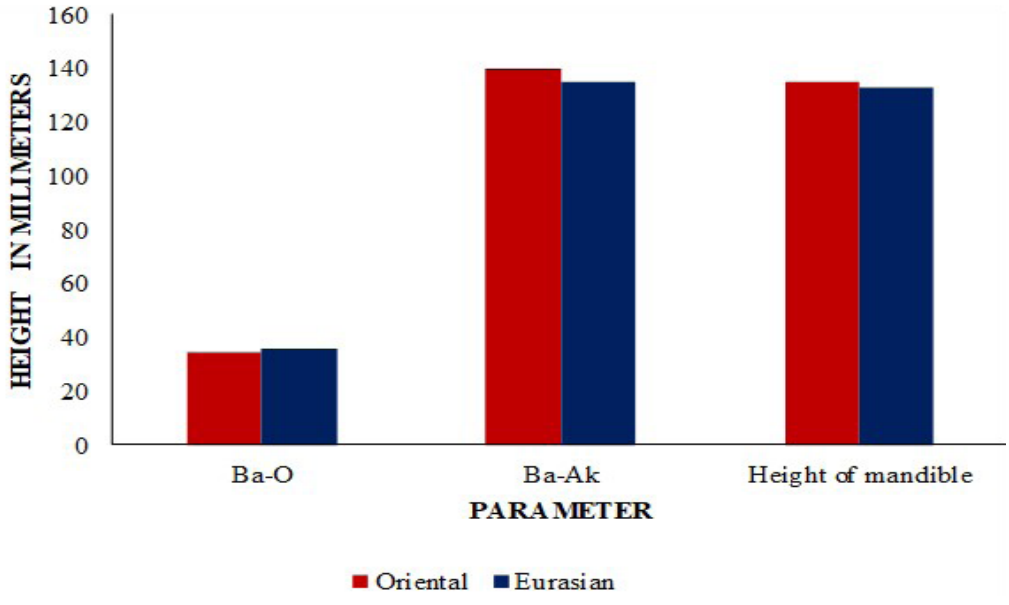

Figure 10: The graph showing the comparison of measurements of the height of skull parameters of the oriental and the Eurasian wild boar.

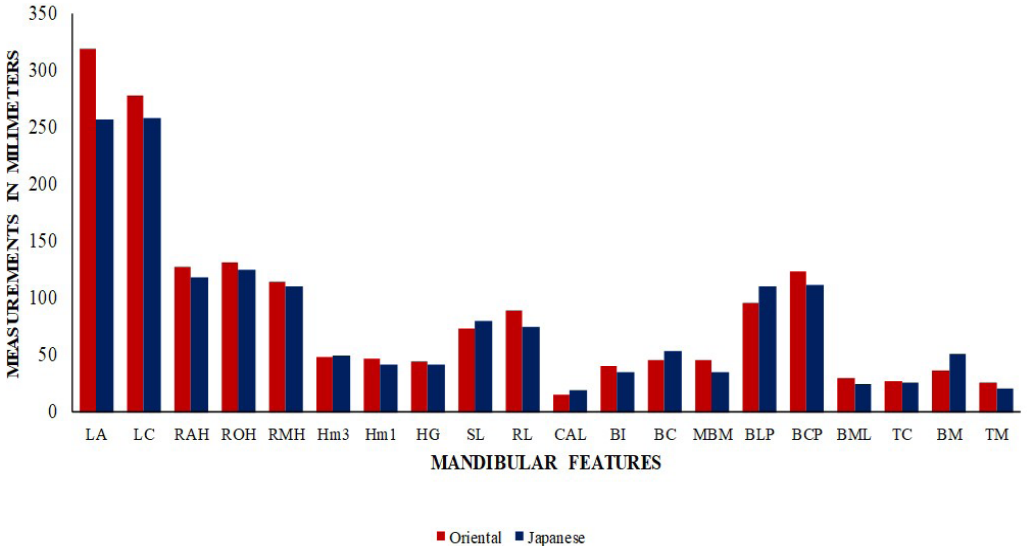

Figure 11: The graph showing the comparison of the measurements of the mandible of the oriental region wild boar and the Japanese wild pig.

The mandible measurements of Oriental Wild boar (*Sus scrofa*) are compared with reported data of Endo *et al*. (2000) the Japanese wild pig (*S. scrofa leucomystax*). The comparative values and difference in both values is given in the (Table 2) and graphical representation is shown in the (Figure 11) from these values it is demonstrated that the negligible variability is present in height of mandible at m3(Hm3) and thickness of the condyle process between the rostral and caudal points (TC) values i.e. 1.48 and0.62 mm respectively. The high variability is present in the vertical ramus middle height of (RMH), height of mandible at m1 (Hm3) , height of mandible at gnathion (HG), canine alveolus length (CAL), breadth at posterior point of I3 (BI), breadth of condyle process between the medial and lateral points (BML) and thickness of mandible at middle point of M1 (TM) the difference in the values is 5.07, 5.29, 2.74, 3.91, 5.36, 5.5 and 4.39 mm respectively, the value of canine alveolus length(CAL) is smaller in Oriental wild boar as compared to the Japanese pig .The high variability is present in the mandibular indicators of ramus length between the angle and m3 (LR), minimum breadth of mandible (MBM), ramus aboral height (ROH) , ramus oral height (ROH) and breadth of the condyle process between the two halves (BCP) the difference in the values are 14.11, 11.17, 9.31, 6.07 and 11.53mm respectively these indicators are larger in size in the Oriental wild boar. While the symphysis length (SL), breadth at canine alveori (BC), breadth of two mandibular halves at the lateral points of the two angles (BLP), breadth at m1(Bm1) is more in the Japanese pig (in values of 7.22, 7.1, 14.94 and14.84mm respectively) than the Oriental wild boar. The highest variability is present in the length from the angle (LA) the Oriental wild boar is 61.35 mm larger in size than the Japanese wild pig.

Table 2: Comparison of the mandibular features between the Oriental Wild Boar and the Japanese wild pig.

Sr. No.	Mandibular features	Oriental region wild boar	Japanese wild pig*	D
1	LA	318.4	257.0	61.4
2	LC	278.4	258.0	20.4
3	RAH	127.3	118.0	9.3
4	ROH	131.0	125.0	6.0
5	RMH	115.0	110.0	5.0
6	Hm3	48.5	50.0	-1.5
7	Hm1	47.3	42.0	5.3
8	HG	44.7	42.0	2.7
9	SL	72.8	80.0	-7.2
10	RL	89.1	75.0	14.1
11	CAL	15.0	19.0	-4.0
12	BI	40.4	35.0	5.4
13	BC	45.9	53.0	-7.1
14	MBM	46.3	35.1	11.2
15	BLP	95.7	110.7	-15.0
16	BCP	123.5	112.0	11.5
17	BML	30.5	25.0	5.5
18	TC	26.6	26.0	0.6
19	BM	36.2	51.0	-14.8
20	TM	25.4	21.0	4.4

Conclusion

In the present study, the craniometric parameters of the wild boar *Sus scrofa* are reported and compared in order to establish the sub specific status of wild boar in Pakistan. Our results indicate that the *Sus scrofa* is larger in size in many craniometric features than the Eurasian

wild boar such as width of skull, length of parietal bone (minimum), length of upper dental arch, length of premolar, length of neurocranium (maximum) and length of mandible. However, the present sample is not sufficient enough to establish the hypothesis or it may be considered as sampling bias which need further studies with a larger sample size.

By this study we can suggest the possible reasons of differential craniometrics features of wild boar belonging to different zoogeographic regions may include;

1. In the Pleistocene time span, Wild boars of Eurasian region and many from ISEA (Island South East Asia) experienced strong bottleneck resulting in small genetically stressed populations (Groenen *et al*., 2012; Frantz *et al*., 2013). Moreover, twenty (20) thousand years ago during the last glacial maximum, the population size of many species particularly *S. scrofa* reduced to minimum (Groenen *et al*., 2012) due to drastic climatic change which resulted in reduction of overall temperature. The smaller cranial values in Eurasian wild boar may be due to some evolutionary changes as the Southeast Asia seems the place of origin of *S. scrofa* (Larson *et al*., 2005) as in Southeast Asia a great diversification of this genus is found (Lucchini *et al*., 2005; Groves, 1981). At first, it disperses to India and then into the East Asia, with a final, progressive spread across Eurasia into Western Europe (Larson *et al*., 2005). All these factors resulted in much lower diversity of European wild boar compared to Asian wild boar (Groenen *et al*., 2012).
2. As stated by the Keuling *et al*. (2013) and Jedrzejewski *et al*. (2000), the predators and hunters affected considerably thus declining the population of wild boar.

While the comparison of mandible size of Oriental *Sus scrofa* and the Japanese wild pig documents that the length from angle and length from condyle is more in Oriental species as compared to Japanese. Thus, we may suggest that the size of Oriental species is larger than the Japanese. It may also be due to evolutionary changes as the *Sus scrofa* extended its range from western Europe to Japan.

Due to all these stress factors imposed on the pigs, we suggest that the cranial growth of the Eurasian species could not reached to the optimum as in Oriental and Japanese wild boar while bottleneck effect further enhanced this character. The smaller data size in this study is due to religious and community restrictions which made the collection of sample a very difficult task. Anyhow, a more comprehensive approach is necessary to establish the status of wild boar in Pakistan.

Conflict of interest

The authors have declared no conflict of interest.

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