RESEARCH ARTICLE

Comparative Osteological Biometrics and Morphology of Skull of the Snow Leopard (*Panthera uncia*) and Leopard (*Panthera pardus*)

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Abstract

The study was aimed to analyze the morphological, osteometric and clinically significant landmarks in the skulls of snow leopards and leopards. Skulls were processed through cold water maceration for clean bones, and differentiation was based on morphology and biometrics. Parameters such as length, width, curved length, curved width and cephalic index were measured using scales, Vernier calipers and thread. Results showed that the nasal cavity of the snow leopard was larger than that of the leopard. The angular process in snow leopards was 0.2 cm longer. Leopards had a groove between the orbital rims, while their tympanic bullae were rounder and more distended compared to the snow leopard. The snow leopard's para-mastoid process formed a hook-like structure (0.5 cm long), and its supraorbital process was more pointed. This research provides species-specific characteristics useful for taxonomic classification, academic purposes, wildlife forensics and assisting wildlife veterinarians in handling clinical cases.

Key words: Biometrics, Leopard, Snow leopard, Skull.

Ind J Vet Sci and Biotech (2025): 10.48165/ijvsbt.21.5.04

Introduction

Snow leopard is often called "ounce" or "once." The term is believed to have its origins with the Greeks, who used "lynx" for every medium-sized cat species (Sunquist and Sunquist, 2017). The Snow leopard is the smallest member of the genus *Panthera* and is the sister species to the tiger (*Panthera tigris*) (Kitchener *et al*., 2016) and on the basis of morphology and behaviour it is placed alone in a separate genus. They are found in 12 countries across Central Asia (China, Bhutan, Nepal, India, Pakistan, Afghanistan, Tajikistan, Uzbekistan, Kyrgyzstan, Kazakhstan, Russia and Mongolia) (McCarthy and Chapron, 2003). According to *the IUCN red list of threatened species*, *2017* (McCarthy *et al.,* 2017), Snow leopard (*Uncina uncina*) / *Panthera uncia* is considered as vulnerable because the global population is estimated to number more than 2,500 but less than 10,000 mature individuals. According to Prater (1971), in India Snow leopard is known to occur above about 3200 m across the Himalayan regions of India, including the western states of Jammu and Kashmir, Himachal Pradesh, Uttar Pradesh and the eastern states of Sikkim and Arunachal Pradesh. Biometrics is a special field of mathematics concerned with the analysis of biological data. Here in this research, we have used biometrics to analyze the comparative morphology of skulls of snow leopard and leopard.

Materials And Methods

The study was carried out on the skulls of Snow leopard (*Panthera uncia*) and Leopard (*Panthera pardus*). One skull each of Snow leopard and Leopard was collected from Wildlife Taxidermy Center, Sanjay Gandhi National Park, Borivali, Mumbai (India). Both the skulls were processed by cold water maceration for about 5 days to obtain clean bones, as cold-water maceration is easy to perform and do not damage or shrink any bone as happens in other process. During cold water maceration of skull, we gradually changed the putrid water. After 5 days of soaking we took out the skulls ripped all the muscles, obtained all the bones, degreased with ammonia and then dried thoroughly and assembled them together with help of adhesive gum.

Biometrics was recorded with the help of scale, Vernier caliper and thread. The parameters like length, width, curved length, curved width and cephalic index for a whole skull were recorded. Height and width for Para mastoid process,

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How to cite this article: Sai Ram, N., Navya Sri, B., & Gaikwad, S. (2025). Comparative Osteological Biometrics and Morphology of Skull of the Snow Leopard (*Panthera uncia*) and Leopard (*Panthera pardus*). Ind J Vet Sci and Biotech, 21(5), 17-23.

Source of support: Nil

Conflict of interest: None

Submitted 13/06/2025 **Accepted** 10/07/2025 **Published** 10/09/2025

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Table 1: Comparative osteological biometrics (cm) of skull of snow leopard and leopard

Parts	Biometrics	Snow leopard	Leopard
Skull	Length of skull	19.5	22.1
	Width of skull	12.7	13.1
	Height of skull	10.7	10.9
	Length of cranium	12.5	14.4
	Length of face	7	7.7
	Curved length	32.2	26.2
	Curved width	29.1	25.7
	Cephalic index (%)	65.12	59.27
Foramen magnum	Diameter (vertical)	1.7	1.5
	Diameter (horizontal)	2.0	1.9
	Minimum intercondylar distance C1-C2	2.1	2.8
	Maximum intercondylar distance (D1 to D2)	4.1	3.9
	Maximum medial inter-condylar distance (E1 to E2)	2.4	1.9
	External occipital crest	3.2	2.9
	Distance between foramen hypglossi	2.1	2.1
Tympanic bulla	Length	2.8	3.2
	Width	2.3	2.1
	Distance between Eustachian opening	3.7	3.9
	Distance between external carotid foramen	2.9	2.6
Para mastoid process	Width	0.7	1.1
	Height	0.9	0.6
	Width	0.8	1.1
	Height	0.4	0.5
	Inter orbital distance (at middle level)	4.9	4.2
Nasal aperture	Height	3.2	2.4(Medial) 2.8(Lateral)
	Maximum transverse width	3.4	3.1
Palate	Length	8.1	8.8
	Width between canines	3.1	3.6
	Width Between last molars	6.8	7.5
	Width at postnasal opening	1.1	1.9
	Distance between infraorbital foramina to orbit	1.0	0.8
	Distance between anterior palatine foramen	2.3	2.2
Nasal bone	Curved length at medial aspect	4.1	6.2
	Curved length at lateral aspect	5.7	7.1
	Circumference of nasal aperture	15.6	10.7
	Distance between infraorbital foramen and malar bone	1.1	0.8
	Distance between supraorbital process and zygomatic process of malar bone	1.9	1.2
Mandible	Mandible height (from base to the tip of canine tooth)	6.1	5.8
	Mandible length (from anterior alveolar end to the condyloid process)	12.4	12.7
	Mandible width (between two condyloid process)	10.5	10.9
	Mandible width at canine tooth	1.1	0.9
	Mandible height	5.1	5.8
Condyloid process	Condyloid process length (medial aspect)	1.4	1.1
	Condyloid process width	2.9	3.4
Angular process	Length	0.9	0.7
	Width	0.6	0.8
	Height	0.7	0.8
	Mandibular symphysis length	4.7	4.6
	Distance between angular process and lower mandibular border of anterior mental foramen	10.3	10.1
	Distance between condyle of mandible and apex of coronoid process	4.4	3.2

Orbital parameters like orbital length, orbital width, Orbital index and Orbital depth were measured. Height and width for supra-orbital process, inter orbital distance at middle level, condyloid process length (medial aspect), and width; Length, width and height for angular process and other biometrical parameters like mandibular symphysis length, were recorded. Distance between condyle of mandible and apex of coronoid process, distance between external occipital crest and distance between foramen hypglossi were also noted. Radiographs were made using computerized 500 mA X ray machine. Cephalic index of skull was derived with the formula: Cephalic index = 100 x width of skull / length of skull, (Schauenberg, 1969).

A comprehensive set of osteometric parameters was recorded to compare skull morphology between the Snow Leopard and Leopard, following established anatomical guidelines (Gundemir *et al.,* 2020; Saber and Gummow, 2015). These included linear and curved measurements of the skull, foramen magnum, tympanic bulla, palate, nasal aperture, nasal bone, and mandible (Sayed and Hamoda, 2021; Ozkan *et al.,* 2019). Curved dimensions were obtained using thread along anatomical contours to ensure precision and consistency. All measurements were standardized to facilitate reproducible and comparative morphometric analysis.

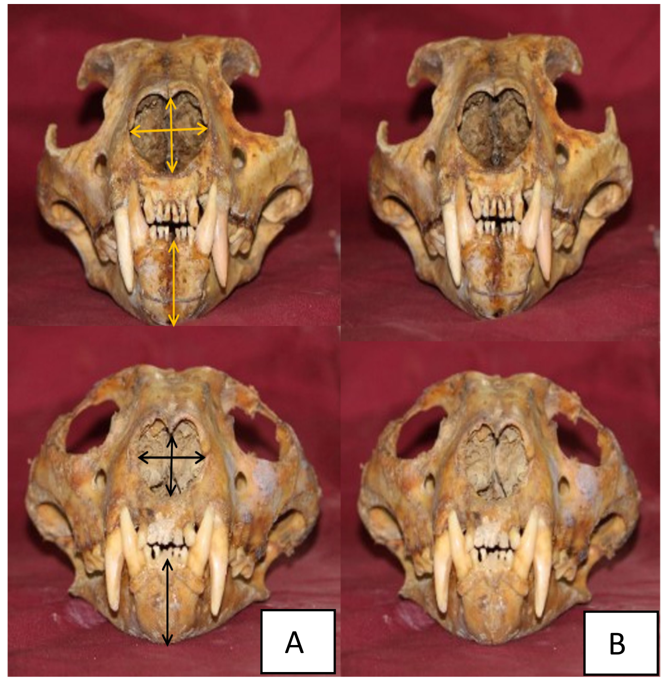

Fig. 2: Height and maximum transverse width of nasal aperture and length of mandibular symphysis (A), and circumference of nasal aperture (B)

Results and Discussion

The foramen magnum dimensions, including vertical and horizontal diameters, minimum and maximum intercondylar distances (C1-C2, D1-D2, E1-E2), and circumference were recorded first (Fig. 1). These measurements aid in understanding the differences in cranial base anatomy and spinal articulation between the two species. The nasal aperture was examined, where the snow leopard exhibited greater vertical height and transverse width compared to the leopard, reflecting its adaptation to cold environments. Additionally, the mandibular symphysis length was found to be slightly longer in the snow leopard (Fig. 2). The nasal cavity and its apertures as well as angular process of the mandible of snow leopard were larger than those of leopard (Table 1). Leopards have a little groove on skull between the two orbital rims in cranial aspect.

Palatine biometrics including palate length, transverse width, distance between canines, and between last molars recorded showed slight species-specific variation (Fig. 3). Additionally, the nasal bone curved lengths along the medial and lateral aspects were longer in leopards, indicating variation in nasal bone projection (Fig. 4). The angular process of the mandible was 0.2 cm longer in the snow leopard than in the leopard, and the distance between the angular process and the lower mandibular border of the anterior mental foramen was also greater in the snow leopard (Fig. 5).

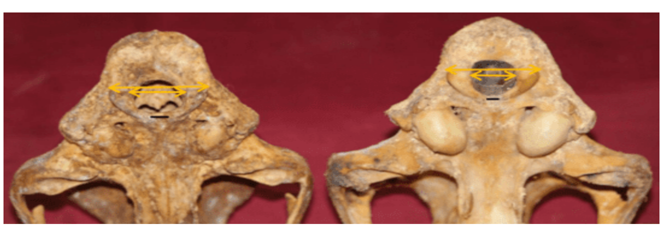

Fig. 1: Foramen magnum vertical and horizontal diameter, Minimum intercondylar distance C1-C2, Maximum intercondylar distance D1-D2, Maximum medial intercondylar distance E1-E2 and Circumference were noted.

The mandible measurement such as mandible height, length, width between condyloid processes and at canine tooth level showed subtle differences between the two felids in both robustness and shape (Fig. 6). A distinctive feature of the leopard was its enlarged and inflated entotympanic portion of the auditory bulla, which may enhance hearing capabilities (Fig. 7) (Table 1). According to Sims (2012), the flattened appearance of tympanic bullae in snow leopard is due to less inflated entotympanic and more inflated ectotympanic. The zygomatic arches were proportionally narrow in neofelis compared to the pantherines, but the difference was insignificant from the leopard and snow leopard (Christiansen, 2006).

The skull of the snow leopard (*Panthera uncia*) exhibits a pointed supra-orbital process, which projects distinctly over the orbit (Fig. 8). This sharp and tapered structure is likely an adaptation linked to the species' cold habitat, offering enhanced protection to the eyes and possibly contributing to the characteristic facial expression. In contrast, the skull of the leopard (*Panthera pardus*) features a supra-orbital process with a broad base and a blunt apex (Fig. 9). This structure is less prominent and more rounded compared to that of the snow leopard, indicating interspecific variation in cranial morphology, whereas the leopard showed a broader, blunt-ended process (Fig. 10). These differences are indicative of distinct craniofacial morphologies suited to environmental adaptations.

The snow leopard's skull was notably short and wide, with a pronounced arch and a broad forehead. This structure accommodates a larger nasal cavity, an important adaptation that helps the animal survive in cold environments by warming incoming air. In contrast, the leopard's skull is slenderer and more elongated (Table 1; Fig. 11).

Fig. 3: Palatine biometrics like length, transverse width distance between canines, and distance between last molars

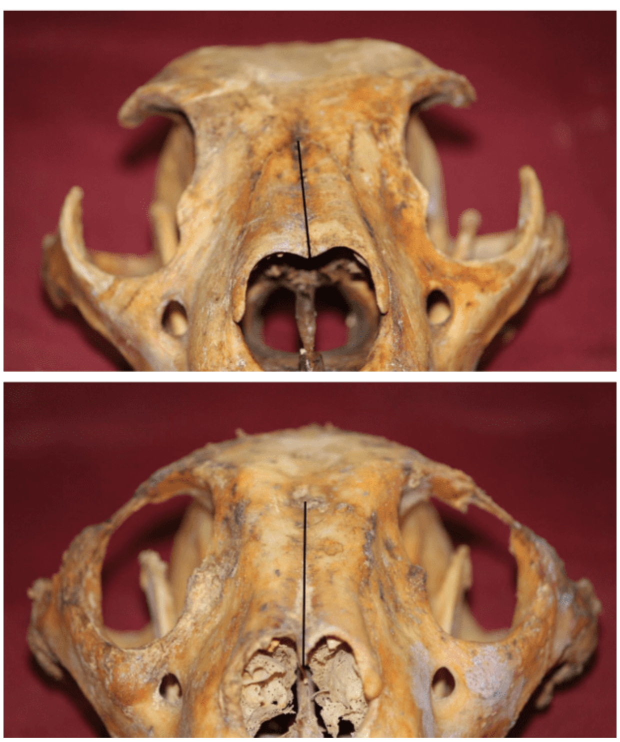

Fig. 4: For a nasal bone curved length at medial aspect and at lateral aspect

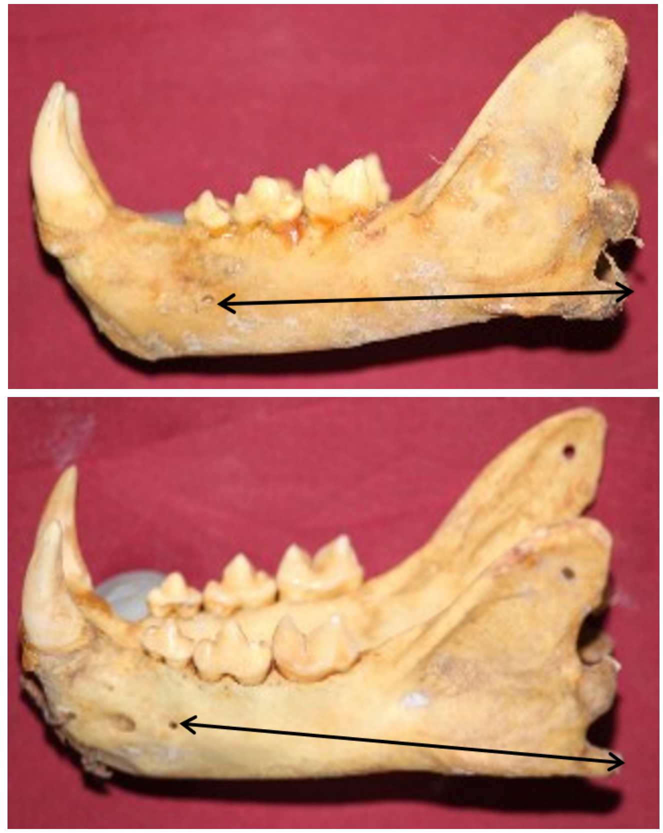

Fig. 5: Distance between angular process and lower mandibular border of anterior mental foramen

Fig. 6: Parameters for mandible: Mandible height (from base to the tip of canine tooth), Mandible length (from anterior alveolar end to the condyloid process), Mandible width (between two condyloid process), Mandible width at canine tooth and Mandible height

Fig. 7: Comparative analysis on tympanic bullae of snow leopard (left one) and leopard (right one), we can see that tympanic bullae of leopard are more rounded and elevated / distended as compared to that of snow leopard

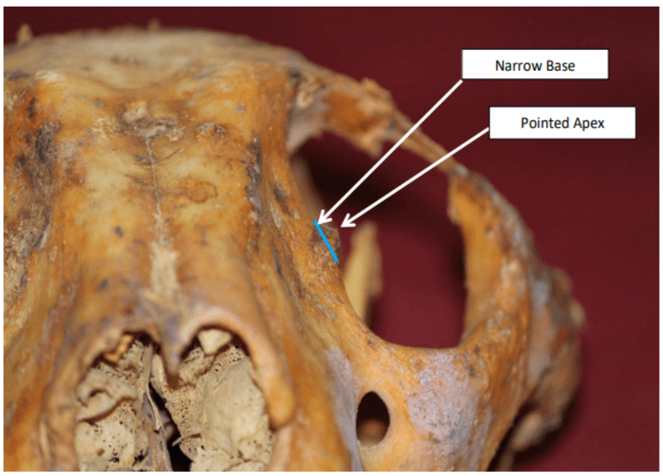

Fig. 8: Skull of snow leopard showing the pointed supra-orbital process

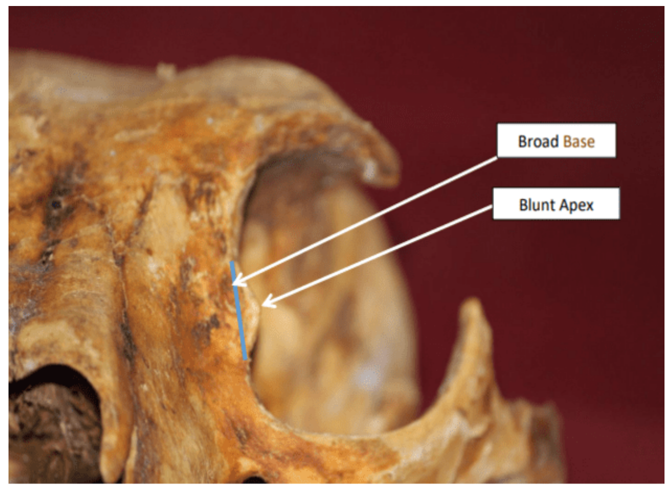

Fig. 9: Skull of leopard showeing the supra-orbital process having the broad base and nearly blunt apex

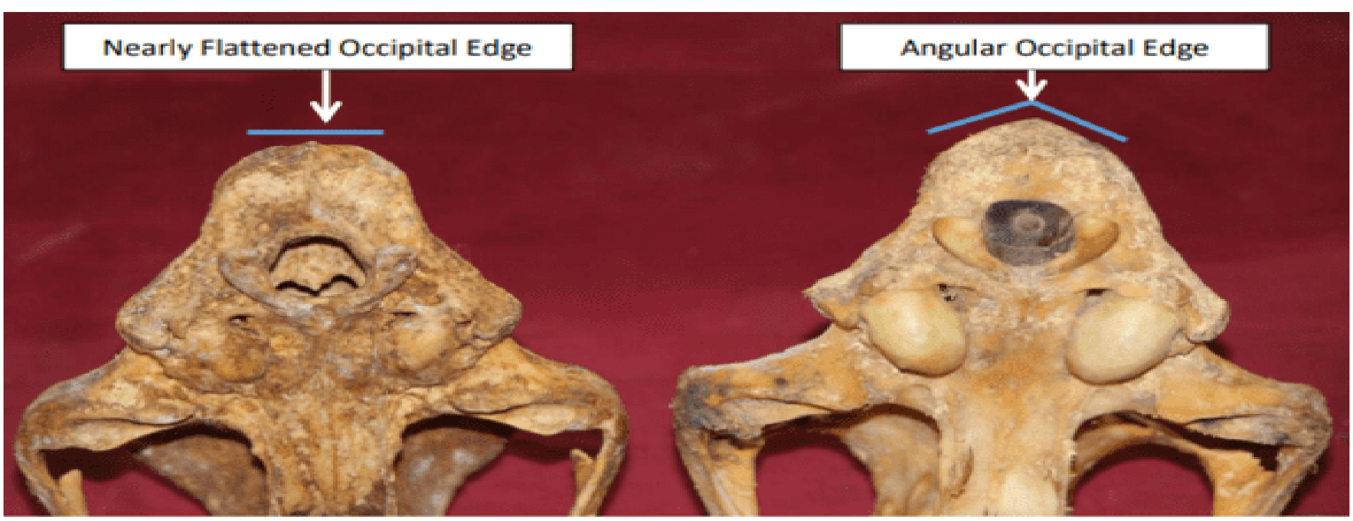

Fig. 10: Left side skull of snow leoard showing flat/straight occipital edge, right skull of leopard having angular occipital edge

Fig. 11: Left side skull of leoard showing a broad forehead, right side skull of snow leopard having narrow fore head

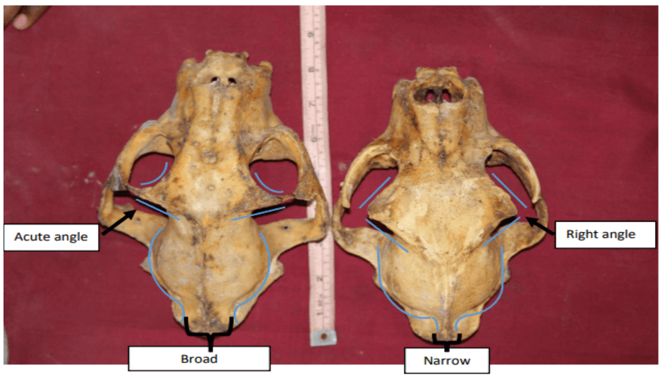

Fig. 12: Cranial view highlighting morphological difference in skulls: Right side snow leopard and left side leopardnarrow forehead

Fig. 13: Radiographic demonstration of dentition of leopard

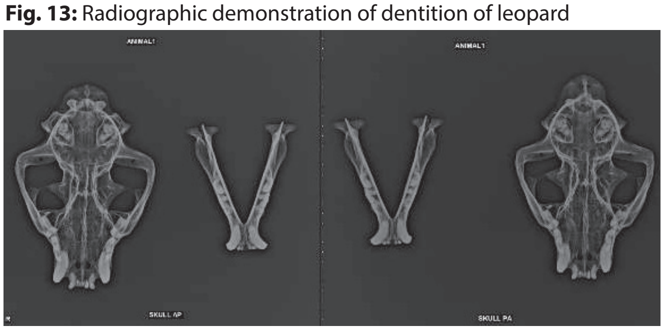

Fig. 14: Radiographic anterio-posterior view of leopard skull

Fig. 15: Radiographic anterio-posterior view of snow leopard skull

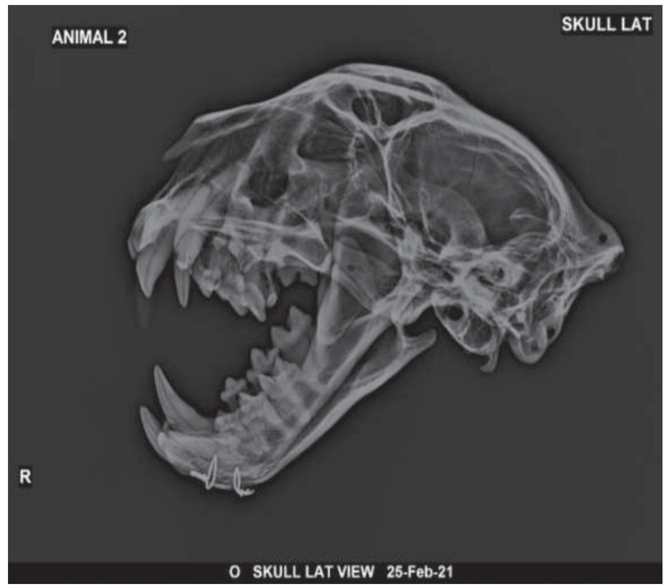

Fig. 16: skull of leopard showing dentition in a lateral view

There was a significant morphological difference in both the skulls of snow leopard and leopard, as shown in the Figure 12 when the skulls were observed from the cranial aspect, the dorsal rim of the orbits of snow leopard appeared curved, whereas in leopards they were almost straight and the cranium of both the animals had their own distinct shape, in snow leopard the cranium was more rounded and formed broader occipital crest as compared to leopard.

The cephalic index was higher in snow leopards (65.12%) compared to leopards (59.27%) (Table 1). The interorbital distance, nasal aperture, and external occipital crest were all larger in the snow leopard, reinforcing morphological adaptations for altitude and climate. According to Hemmer (1972) skull of snow leopard is short and broad highly vaulted with a broader forehead. This morphology supports an enlarged nasal cavity which is an adaptation to cold climate. Leopard skull was slim and elongated, entotympanic of the auditory bulle is large and inflated (Sims, 2012). The large nasal cavity probably allows for efficient countercurrent warming of inhaled air and cooling of exhaled air when breathing. Schauenberg's index (Schauenberg, 1969); greatest length of skull/cranial volume) suggests that *P. uncia* has relatively large brain as compared to the other *Panthera* species, *viz., Puma concolor, Acinonyx jubatus*, and *Lynx lynx* amongst 38 species of felids that were investigated by Kitchener *et al. (*2016).

Radiographic Observations

Radiographic analysis further clarified internal features and dentition. Snow leopards showed broader occipital crests and rounded cranial outlines (Figs. 13-16). The dentition pattern was consistent with species-specific carnivorous adaptations.

Conclusion

The current study evaluated comparative osteological and biometric aspects of snow leopard and leopard skulls. The information obtained is important for taxonomic affiliation, academic information, wildlife forensic, and will be helpful for the wildlife veterinarians to handle and manage the clinical cases related to head of these species. This information could be used for the identification of skull and mandible of snow leopard and leopard. Morphological features such as tympanic bullae, cephalic index, orbital and nasal configurations serve as key distinguishing markers.

Acknowledgement

The authors thank the Wildlife Taxidermy Center, Sanjay Gandhi National Park, Borivali, Mumbai for providing the necessary samples required for analyzing the results.

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