STUDIES ON CHARACTERISTIC FEATURES OF APPENDICULAR SKELETON OF LEOPARD AS AN AID IN WILDLIFE FORENSIC

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THESIS

In partial fulfilment of the requirements for
The Degree of

MASTER OF VETERINARY SCIENCE AND ANIMAL HUSBANDRY

In

WILDLIFE HEALTH AND MANAGEMENT

By

Devendra N. Podhade

Department of Wildlife Health and Management
Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur
College of Veterinary Science and Animal Husbandry,
Jabalpur (MP)

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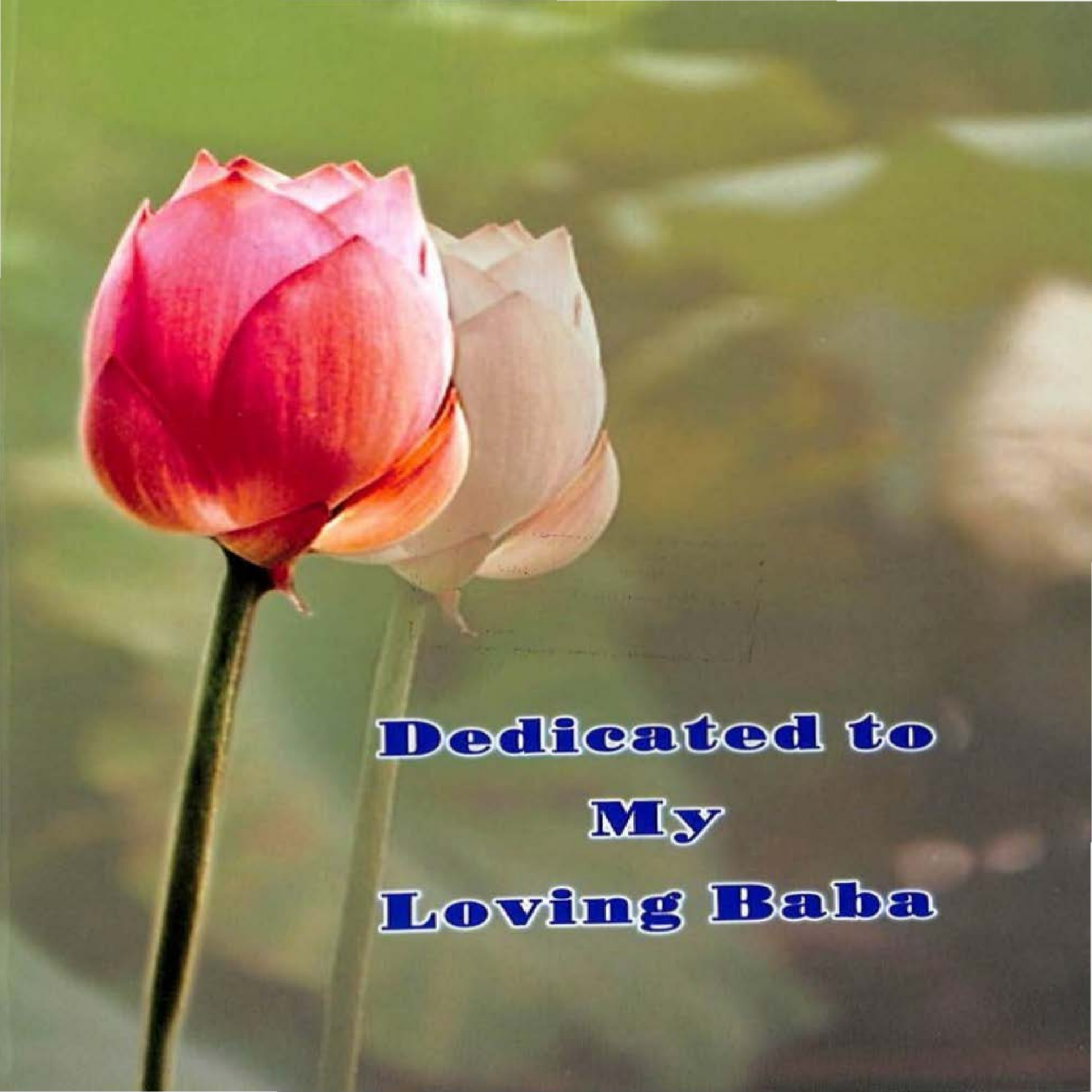
Dedicated to
My
Loving Baba

CERTIFICATE - I

This is to certify that the thesis entitled "**Studies on Characteristic Features of Appendicular Skeleton of Leopard as an Aid in Wildlife Forensic**" *submitted in partial fulfillment of the requirement for the degree of* **MASTER OF VETERINARY SCIENCE AND ANIMAL HUSBANDRY** *in* **Wildlife Health and Management** *of Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is a record of the bonafide research work carried out by* **Mr. Devendra N. Podhade** *under my guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee and the Director of Instruction.*

No part of the thesis has been submitted for any other degree or diploma (Certificate awarded etc.) or has been published/published part has been fully acknowledged. All the assistance and help received during the course of the investigation has been acknowledged by him.

(Dr. Avadh Bihari Shrivastav)
Chairman of the Advisory committee

THESIS APPROVED BY THE STUDENT'S ADVISORY COMMITTEE

Chairman : Dr. A.B. Shrivastav 22.9.07

Member : Dr. M. L. Parmar 22.9.07

Member : Dr.(Mrs.) Madhu Swamy 22/9/07

Member : Dr.(Mrs.) Rakhi Vaish. 22/9/07

CERTIFICATE - II

The is to certify that the thesis entitled **"Studies on Characteristic Features of Appendicular Skeleton of Leopard as an Aid in Wildlife Forensic"** submitted by **Mr. Devendra N. Podhade** to the J.N. Krishi Vishwa Vidyalaya, Jabalpur in partial fulfillment of the requirements for the degree of **Master of Veterinary Science and Animal Husbandry** in the Department of **Wildlife Health and Management** has been, after evaluation, approved by the External Examiner and by the Student's Advisory Committee after an oral examination on the same.

Place: Jabalpur
Date: 4.1.2008

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Chairman : Dr. A.B. Shrivastav .....

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Head/Incharge of the Department : Dr. A.B. Shrivastav .....

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Director Instruction
J.N. Krishi Vishwa Vidyalaya
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(Devendra)

LIST OF CONTENTS

LIST OF TABLES

LIST OF PLATES

INTRODUCTION

INTRODUCTION

India is blessed with rich biodiversity with variety of fascinating wild flora and fauna. In recent years, India is now playing a pivotal role in the trade of wild animals and has become an exporter and a conduit for wildlife (Mennon and Kumar, 1999). Apart from various threats like loss of habitat, poisoning, accident and diseases facing wildlife today for its survival, poaching remains an important cause for wildlife extinction. Poaching of wild animals, particularly of leopard for bone trade has been increased recently and it is six to seven times greater than tigers (Mennon and Kumar, 1999). In Chinese Myth, bones are used to manufacture traditional medicine for treating various aliments. These are sold then clandestinely in Far East and many western countries. Due to this unfortunately, these species are at the verge of extinction and need immediate action against poachers.

The forensic science forms a vital part of the entire justice and regulatory system. Forensic scientists may be involved in all aspects of a poaching case, and the results of their work may serve either for the defense or for the prosecution. The forensic scientist's skill is to use all the information available to determine facts.

The trade of bones in wild animals is multi- million dollar business. From small-time poaching and hunting, it has grown into a well-organized, sophisticated network of racketeers across the world, which carry out a trade ring worth an estimated 6 to 20 billion dollars worldwide (MoEF, 1994). Sadly, as the international wildlife trade has increased and becomes more lucrative, wildlife-rich nations have been unable to control the trade of their wildlife. Although there are laws in place that prohibit the killing and trade of wild fauna.

Biological materials including bones of wild animals are sent routinely to State Diagnostic or Forensic Laboratories for identification of species. Due to lack of systemic studies Veterinarians by and large remain ignorant of such information. Moreover, lack of scientific documentation of characteristics, consequently the custodian of wild animals faces

embarrassment at many times, when some forensic cases require scientific record for legal proceedings against the poacher and trader.

Information on bones of leopard is meager. Therefore, the identification of seized bones becomes extremely difficult. Due to lack of information, identification of bones of leopard has been bottleneck in convictions of poachers. Thus, there is an urgent need for the systematic and scientific studies on gross morphological bone structure of leopard. Hence, it is proposed to document the morphology of bones with the following objective

OBJECTIVES

To study gross morphological features and osteological parameters of the appendicular skeleton of the leopard.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Scapula:

Raghvan (1964) observed scapula of dog and found that the spine presents above the acrominon process, a small curved plate like metacromion process.

Sisson (1977) stated that scapula of dog was relatively long and narrow. The spine divided the lateral surface into two nearly equal fossae. The cranial border was thin, strongly convex and sinuous. The caudal border was straight and thick. The dorsal border was convex and thick and bore a band of scapular cartilage.

Evans and Christensen (1979) studied on scapula of dog and noticed that supraspinous fossa was widest in the middle because the cranial border of scapula extent in an arc from the scapular notch to the cranial angle. The whole thin plate of the bone which formed the supraspinous fossa was sinuous possessing of its greatest undulation a lateral projection involving the middle of the fossa. They also observed that the caudal border was thickest of the three borders and bore, just dorsal to the ventral angle, the infraglenoid tubercle observed. The cranial border was thin except at its extremities. Distally, it formed a concavity known as scapular notch. The cranial angle imperceptibly united the thin, convex cranial border to the rough, convex, thick vertebral border. The caudal border was obtuse as it united the adjacent thick caudal border with the thinner, rougher, gently convex vertebral border.

Pandit (1994) made observation on scapula of tiger and reported that it was wide, flat bone, almost oval in shape, with straight caudal border, which was thicker than the semicircular cranial border. The vertebral border was thicker than cranial and caudal border. The free border of the spine was slightly convex, rough and thick in its upper 2/3 part and became sharp at the lower end where the border showed a projection pointing backwards. The costal surface was wide nearly flat area and presented rough surface at the cranial angle. From the cranial angle, a slightly convex vertical line extended to the lower angle. On the cranial side of the line two more vertical lines were visible making cranial part of the costal surface of the scapula uneven.

horse (45.86), nilgai (45.45) and goat (43.62). The ratio of supraspinous fossa and infraspinous fossa for carnivorous animals ranged between 1:1 or 1:2 and for herbivorous animals, the range was 1:2.5 to 1:3.

Taluja *et al.* (2001) made osteometry of scapula in tiger and recorded mean maximum width of supraspinous and infraspinous. The scapular spine was thick and rough dorsally, thin ventrally and bent caudally. The distance between acromion and lateral aspect of the rim of the glenoid cavity was 3.20 cm. The cranial border was thin and strongly convex and measured 25.50 cm. The caudal border was shorter (20.12cm), straight and thick. The dorsal border measured 14.75 cm in length and was thick and convex and bore a band of cartilage.

Du Toit *et al.* (2002) compared proximal scapulohumeral osteological features in leopard (*Panthera pardus)* and cheetah (*Acinonyx jubatus)* and found that the length of scapular spine and width of the glenoid notch were greater in leopard than cheetah. Humeral head circumference was also greater in leopard than cheetah.

Panday *et al.* (2004) made study on the scapula of five Asiatic Lion (*Panthera leo persica*) and observed that scapular spine divides lateral surface into two equal fossae. The maximum height of the spine was 2.69±0.11 cm. The maximum width of supraspinous fossa was 5.38±0.06 cm, while that of infraspinous fossa was 6.45±0.18 cm. The ratio between supraspinous and infraspinous fossa was 1:1. The medial surface was rough for muscular attachments. The subscapular fossa was very deep near glenoid cavity.

Humerus:

Sisson (1977) stated that humerus of dog was relatively very long,was rather slender and had a light spiral twist. The radial and olecranon fossae often communicated through a large supratrochlear foramen.

Pandit (1994) reported that humerus of tiger was an irregularly cylindrical bone slightly curved to hook like a letter 'S'. The shaft of the humerus was more or less triangular in proximal 1/3 and cylindrical in distal 2/3. In the distal extremity, the lateral area was small and articulated with radius while a wider medial area called as trochlea which was far from the ulna. There was no

communication between coranoid and olecranon fossa in tiger but the medial epicondylar space known as interossoeous space may be performing similar function.

Ray *et al.* (1997) made studies on humerus of adult leopard and reported that it was 21 cm long, slender and less spirally twisted. The circumference of shaft was 6 cm. The supracondylar foramen instead of olecranon fossa was present above the medial epicondyle. The caudal surface was flat and smooth. At the distal extremity, it was rough and wider. The characteristic absence of supracondyloid fossa in the shaft but presence of tuberositae supracondylaris lateralis as a almost identical with observation in carnivores and pigs.

Radius and ulna:

Radius:

Sisson (1977) reported that radius of dog was flattened craniocaudally and it increased in size distally. The dorsal surface was convex in both directions and was marked in its distal half by a groove. The caudal surface presented a nutrient foramen in its proximal third. The head was relatively small and was supported by distinct neck. The radial tuberosity was small, proximal to it was a large lateral eminence and distal to this a rough eminence. The distal extremity was much wider, forming trochlea. It had extensive concave articular surface for carpal bones. Its medial border projected distally, forming the styloid process. Laterally, there was a facet for ulna.

Pandit (1994) reported that in tiger, radius was smaller than ulna. The proximal extremity was smaller of the two and was slightly compressed cranio-caudally. At the proximal side of this extremity, there was a concave articular fossa which was oval in shape except for a notch on cranial side. On the lateral edge of the bone was a very prominent vertically elongated rough protuberance. The shaft was half cylindrical, convex medio-cranio-lateral surface and a flat caudal surface. The cranial surface was slightly convex vertically and on medial side of this convex edge the surface was slightly depressed and rough, with some rough lines at the junction of middle and lower 1/3. The lateral border between the cranial and caudal

surfaces was rough in its upper 2/3 part. The distal extremity was much larger than the proximal and was compressed cranio-caudally. On the medial side of the distal extremity, there was a pointed projection named as styloid process.

Ulna:

Pandit (1994) reported that ulna of tiger was longer than the radius. The proximal extremity was formed by a strong mediao-laterally flattened olecranon. The proximal end of olecranon was very thick caudally and had a vertical groove on its cranial aspects separating two tuberosities, medial being thicker and shorter than lateral. The trochlear notch articulated with the trochlear articular area of humerus and the articular circumference of the radius. The shaft was flattened mediao-laterllay in the proximal third, triangular in the middle and somewhat cylindrical in lower third. The lateral surface presented a smooth area in the proximal part, representing the interosseous space between the radius and ulna. The caudal surface was narrow and triangular. The distal extremity consisted of a protuberance on the cranial side which had wide a semicircular articular facet for articulation with the corresponding facet on the distal extremity of radius. The styloid process was measured 2 cm long but extends only to the level of styloid process of radius and not further as in other carnivorous animals.

Carpals:

Sisson (1977) recorded 7 carpals in the dog. Numerical reduction in the proximal row was apparently due to the fusion of the radial and intermediate, constituting a large bone, the intermedioradial, which articulated with almost all of the distal surface of the radius and with the bones of the distal row. Ulnar carpal articulated with the radius and ulna bone proximally, and accessory carpal palmarly articulated distally fourth carpal and was prolonged distally, to articulated with fifth metacarpal also. Accessory carpal was cylindrical, and was constricted in its middle. The dorsal extremity articulated with the ulna bone and ulnar carpal. He also reported that first carpal was smallest in the distal row and articulated with the second carpal laterally, and the first metacarpal distally. Second carpal was wedge shaped, the base being palmar. Its proximal surface was convex whereas distal

surface was concave and rested on the second metacarpal. The distal surface of third carpal was concave and articulated chiefly with the third metacarpal. Fourth carpal was the largest of the distal row, it articulated with the fourth and fifth metacarpals.

Evans and Christensen (1979) studied carpal bones of the dog reported that radial carpal represented the fusion of the primitive radial, central and intermediate carpal bones. The proximal surface of the radial carpal bone was extensively articular for the distal end of the radius. The distal surface of the radial carpal bone articulated with all four distal carpal bones. Laterally, it articulated extensively with ulnar carpal. Its transverse dimension was about twice its width. ulnar carpal articulated proximally with the ulna and radius, distally with the fourth carpal and the fifth metacarpal, medially with the radial carpal, and palmar side with the accessory carpal. It possessed a small lateral process and a larger palmar one for articulation with the accessory carpal and metacarpal V. This lateral process was separated from the main part of the bone on the lateral side by a concave articular area for articulation with the styloid process of the ulna. Accessory carpal was truncated rod shaped bone located on the palmar side of the ulnar carpal. Both ends of this bone were enlarged. The basal enlargement bore saddle shaped articular surface for the ulnar carpal which was separated by an acute angle from a smaller, transversely concave,, proximally directed articular area for the styloid process of the ulna. He also observed that first carpal was a smallest carpal bone. It was somewhat flattened as it articulated with palmaromedial surfaces of the second carpal and the base of metacarpal II. It articulated proximally with the radial carpal and distally with metacarpal I. Second carpal was small, wedge shaped, proximodistally compressed bone which articulated proximally with the radial carpal, distally with metacarpal II, laterally with the third carpal and medially with the first carpal. Third carpal was larger than the second carpal. It had larger palmar projection, which articulated with the three metacarpal bones. It articulated medially with the second carpal, laterally with the fourth, proximally with radial carpal and distally with metacarpal III. Fourth carpal was the largest bone in the distal row. It presented a caudal enlargement and was wedge-shaped in both

cranial and proximal views. It articulated distally with metacarpal IV and V, medially with the third carpal, and proximomedially with the radial carpal.

Pandit (1994) studied carpals in tiger. He gave separate description of radial carpal bone. It was the largest among all the carpals. It was an irregularly shaped, short bone compressed dorso-ventrally. The proximal face showed articular area for lower extremity of the radius. On the lateral face of the radial carpal, there was articular area for the ulnar carpal. The distal surface of the radial carpal had extensive articular area for articulations with carpal bones of the distal row. Ulnar carpal was very irregular shaped bone with articular facets on the proximal, medial and distal surfaces. Proximally, it articulated with the radius and ulna and distally with the IV carpal and the V metacarpal bones. Medial surface had an elongated articular area for the radial carpal bone. Accessory carpal was a small rod which carried one larger articular area for the ulnar carpal, on the cranial side and a small concave articular area in the lateral face for articulation with the styloid process of the ulna. First carpal was the medial most bone of the distal row of the carpus and was the smallest bone. It was a flat, thick platelike bone with articular facets on the proximal, distal and lateral sides for articulations with radial carpal, first metacarpal and the second carpal bones respectively. Second was slightly compressed cranio-caudally. This wedge shaped bone had articular facets on proximal, distal, medial and lateral surfaces for articulation with radial carpal, second metacarpal, first carpal and third carpal respectively. Non- articular surfaces were rough due to attachments of ligaments. Third carpal was intermediate in size between second and fourth carpal. It had articular facets on the proximal surface for radial carpal, distally with third metacarpal, medially with second carpal and laterally with fourth carpal. He also reported that fourth carpal was a large bone somewhat compressed dorso-ventrally. Its proximal surface had articular area for radial carpal, distal surface articulated with fourth and fifth metacarpal bones and the medial articular surface articulated with the third carpal bone.

Metacarpals:

Sisson (1977) stated that the first metacarpal bone of dog was much smaller and was round in shape. Second metacarpal was three sided

whereas third and fourth metacarpals were four sided. Fifth metacarpal was widest at the proximal end and was slightly shorter than the second.

Evans and Christensen (1979) made study on metacarpals. He reported that first metacarpal was shortest and most slender of the metacarpal bones in the dog. It articulated proximally with the second metacarpal. Distally, the trochlea articulated with proximal phalanx. Second metacarpal was shorter than III and IV and were four sided. Third metacarpal was more triangular proximally. Distally, it diverged, forming the intermetacarpal space. The trochlea possessed roller like cranial parts which were undivided and were separated from the bodies dorsally by sesamoid fossae. Sesamoid impressions were present between trochlea and body of metacarpal bone. The caudal part of the head possessed prominent, sharp edged sagittal crest. Fourth metacarpal was similar to that of III metacarpal. Fifth metacarpal was four sided particularly at proximal end.

Pandit (1994) reported that it was the most medial and shortest among metacarpal bones in the tiger. Both the extremities were very thick and shaft was short and three sided. The three borders separated the three surfaces of the shaft. The three surfaces, medial, lateral and palmar were somewhat flat and rough for ligamentous attachments. Second metacarpal was rod shaped long bone which was third in size after the third and fourth metacarpals.

Phalanges:

Sisson (1977) reported that the proximal phalanx of dog had four sided shafts, which were slightly curved dorsally. The proximal end of each had a concave surface for articulation with the metacarpal bone and deeply notched palmarly. The distal end or head had a trochlea for articulation with the middle phalanx. The middle phalanx was about two-thirds of the length of the proximal phalanx. The proximal articular surface was consisted of two cavities separated by a sagittal ridge. The distal extremity was wider and flatter than the proximal phalanx. There was no middle phalanx in first digit. Distal phalanx was in the general form of the claws of dog. The base had an articular surface adapted to the middle phalanx and was encircled by a collar of bone. The solar surface bore a flexor tubercle and on each side of

this was a foramen. The ungual process was a curved rod with a blunt-pointed free end. It was rough and porous.

Evans and Christensen (1979) studied that II to V phalanges of dog were in the form of medium length rod with enlarged extremities. Proximally at its base it bore a transversely concave articular surface with a sharp cranial border and a bituberculate palmar border. The palmar tubercles were separated by a deep groove which received the sagittal crest of the head of metacarpal. Middle phalanx was rod shaped about one-third shorter than the corresponding proximal phalanx. Each middle phalanx divided into proximal base, a middle body and a distal head. the proximal part of the distal phalanx of dog was enlarged. It had a shallow, sagitally concave articular area for contact with middle phalanx. The distal part of the distal phalanx was a laterally compressed cone which was shielded by the horny claw.

Os Coxae:

Pandit (1994) described that pelvic girdle of tiger. It was formed by 3 fused flat bones on each side of the body. In a cub, all components of the pelvis were found separate. The bones, which formed pelvic girdle, were ilium, ischium and pubis. In a cub, a small separated piece was seen between these three bones, resembling the acetabular bone of a pup. In male grown tiger, it was very narrow with small pelvic cavity. Ilium was thick, flat plate of bone in the shape of an elongated rectangle. It had the thicker caudal body with which was fused with ischium and the pubis and the relatively thinner wing. The lateral surface of the wing of ilium was mostly concave except for the thick dorsal border. The concave surface was mostly smooth except a faint rough line running parallel to the ventral border but closer to the dorsal border. The medial surface of the wing of ilium was convex dorso-ventrally with a distinct rough line running at the upper third of this surface from cranial border to the auricular surface. The remaining part of this surface was rough.

Bhamburkar *et al.* (1997) studied the comparative morphometry of the os-coxae of some domestic and wild animals for exploring the sex dimorphism in the bones.

Patil *et al.* (2000) made morphometrical observations on study of pelvis in some animals including leopard and calculated Pelvic index and Obturator index of buffalo (66.66, 69.78), ox (67.61, 70.34), horse (108.90, 61.57), panther (70.76, 63.48), sambar (72.99, 48.77) and elephant (60.82, 56.73) respectively. The lowest pelvic index was in elephant whereas highest in horses. The lowest pelvic index indicated the higher conjugated diameter of pelvis while higher pelvic index indicated greater transverse diameter of pelvis. The values of greater ischatic notch index and lesser ischatic notch index were Buffalo(45.12, 63.02), Ox(60.33,75.89), Goat(33.19,39.12), Horse(50.25,51.86), Pig(32.42,31.42), Dog (27.61,41.42), Leopard(17.58,21.06), Sambar(46.30,53.49) and Elephant(36.80,54.39) respectively. The greater and lesser ischatic notch index values were higher in ox and buffalo, which were indicative of more depth of notches while it was reduced in dog, goat, pig and leopard. The index values pelvis of different animals can be used for identification of species.

Bhayani *et al.* (2001) made biometrical observations like weight of the bone, length and width of various segments and the distance between them, ratio of length and width of various segments, conjugate and transverse diameter, obturator index.

Patella:

Sisson (1977) stated that patella of dog was long and narrow. The free surface was convex in both directions. The articular surface was convex from side to side and slightly concave proximodistally.

Pandit (1994) reported that patella of tiger was more or less oval with proximal part slightly wider than distal part. The cranial surface was convex and rough, while the caudal surface was articular and almost flat but slightly curved in dorso - ventral direction. He also stated that proximal extremity was twice large as compared to distal extremity.

Femur:

Evans and Christensen (1979) reported that femur was heaviest bone in the skeleton of dog. Proximally, it presented a smooth, nearly hemispherical head, supported by a neck on its proximolateral side and three

trochanters. The fovea capitis was small rather indistinct, circular pit on the medial aspect of head. The trochanter major was the largest tuber of the proximal extremity of the bone. Between femoral neck and greater trochanter, caudal to the ridge of bone connecting the two was deep trochanteric fossa. The lesser trochanter was a distinct, pyramid-shaped eminence which projected from the caudomedial surface of the proximal extremity near its junction with the shaft. The shaft was nearly cylindrical and was straight proximally and cranially arched distally. Its cranial, lateral and medial surfaces were not demarcated from each other, but caudal surface was flatter than the others. Distally, it was quadrangular and protrudes caudally. It contained three areas viz. medial condyle, lateral condyle and an articular groove on the cranial surface. The lateral one was convex in both the sagittal and the transverse plane. The medial condyle was smaller and less convex in both transverse and sagittal plane.

Pandit (1994) stated that femur was the longest bone in the body of tiger. The head in the proximal extremity was smooth, dome shaped, 4 cm in diameter and articulated with lunate surface of acetabulum of the pelvis. Somewhat caudal to the highest point of the head, there was a small rounded deep non-articular depression called fovea capitis. The head was separated from the rest of extremity by a constricted elongated neck, which was more prominent medially. The area below the greater trochanter was rough and showed a few blunt projections, the caudal most of which was the cervical tubercle. Below this tubercle, about 4 cm away was another rough eminence known as third trochanter. The body was cylindrical and very straight. No nutrient foramen was found on cranial aspect of the shaft of femur as in other carnivore animals. The distal extremity was larger than the proximal extremity. Both the condyles were almost in equal in size but the articular surface on the medial condyle extended caudally a few mm than the lateral condyle.

Ray *et al.* (1996) made studies on the biometry of the femur of leopard and reported that it was 23 cm long. The cranial surface was smooth and convex whereas the caudal surface was flat and smooth. The trochanter minor was situated 2 cm away from head as blunt tuberosity. The absence of

supracondyloid fossa on the shaft but presence of tuberositae supracondylaris lateralis as almost identical observation in carnivores and pigs. The circumference of proximal and distal extremity was 11.2 cm and 14 cm respectively. The circumference of the head was 7 cm and of trochantor major was 1.5 cm. The width of the trochantor major was 1.0 cm and it extended 0.6 cm above the head. The depth of trochanteric fossa was 1.7 cm whereas depth of intercondyloid fossa was 1.3 cm.

Tibia and fibula:

Tibia

Sisson (1977) reported that tibia of dog was about same length as the femur. The body formed a double curve; the proximal part was convex medially while the distal part laterally. The proximal part was prismatic, but was compressed laterally and was long craniocaudally. The remainder was almost regularly cylindrical. The distal end was quadrangular and relatively small. The articular grooves and ridge were almost sagittal. There was facet for articulation with the fibula.

Pandit (1994) observed that tibia of tiger was larger than that of the fibula. The proximal extremity was twice as large as distal extremity. It had a wide proximal face which showed two distict articular condyles. The medial and larteral condyles were seperated by non-articular rough area with many vascular foremena. The popliteal notch was present between the two condyles caudally. Tibial tuberosity was nearly 3 to 4 cm cranial to this large lateral eminence and was much less in height. Shaft of the tibia was distinctly triangular in the upper 2/3 and more or less cylindrical in the lower third. The distal extremity of the tibia was much smaller than the proximal extremity and was nearly quadrilateral. The medial surface of the extremity was longer and projected much more distally than the lateral side. This proximal bone projection was called as medial malleolus. A small articular facet was present on the rim on the lateral side for articulation with distal extremity of the fibula. The distal facet of the distal extremity of tibia presented a grooved, sagittal medial articular area for articulation with tibial tarsal below.

Fibula

Sisson (1977) reported that fibula of dog was slender and somewhat twisted and was enlarged at either end. The proximal part of the

body was separated from the tibia by a considerable interossous space, but the distal part was flattened and closely applied to the tibia. The proximal extremity was flattened and articulated with the lateral condyle of the tibia. The distal end was somewhat thicker and formed the lateral malleolus.

Pandit (1994) made study on fibula of tiger which was slightly shorter than the tibia. Cranial and caudal eminences were separated by vertical sulcus.

Tarsals:

Sisson (1977) made study on the tibial tarsal of dog and stated that it consisted of a body, neck and head, like the bone in man. The body presented a proximal trochlea for articulation with the tibia and fibula. The planter surface had three facets for articulation with the calcaneus. The head was directed a little medial and articulated with the central tarsal bone. Fibular tarsal had a long dorsal coracoid process or beak but the sustentaculum was short. The calcaneal tuber presented a sagittal groove. Central tarsal had a concave proximal surface adapted to the head of the talus. Its distal surface articulated with the first, second and third tarsal. It bore two planter tubercle. first tarsal of the dog was flattened and irregularly quadrangular. Its proximal surface articulated with the central tarsal and distal with first metatarsal. Second tarsal was smallest and wedge shaped bone. It articulated distally with the second metatarsal bone. Third tarsal was also wedge shaped, the base being dorsal, it articulated with the third metatarsal distally. Fourth tarsal was remarkably high and resembled a quadrangular prism. It proximal surface articulated with the calcaneus, it's distal with the fourth and fifth metatarsal and its medial with the central and third tarsal bones.

Evans and Christensen (1979) observed that tibial tarsal was second largest of the tarsal bone in the dog. The most prominent feature of the body was the proximal trochlea, the surface which articulated with the sagittal grooves and the intermediate ridge of the distal ridge of the distal articular surface of the tibia. Central tarsal was located between the proximal and distal rows. It articulated with all other tarsals. Second tarsal was smallest tarsal bone. It was wedge shaped bone articulated with central tarsal

proximally, third tarsal laterally, the first tarsal medially and second metatarsals distally.

Pandit (1994) studied tarsals of tiger and reported that tibial tarsal was a short bone. Body presented a broad proximal part with extensive articular trochlea on proximal and caudal surface. On the sides of the body there were facets for articulation with medial and lateral malleoli of tibia and fibula. The head of the tibial tarsal was distal extension of the bone seperated by a constricted neck showing many perfoartions. The distal head had a large transversely elongated articular area which was concave in both direction. This articulated with proximal end of central tarsal bone below. Fibular tarsal was the largest of the tarsal bones and can be easily recognized easily from the long tuber calcanei which was the proximal part of bone projecting upwards and backwards. The medial side of the tuber was longer than the lateral side. On the medial side of the fibular tarsal in the lower third a bony conical projection was present known as sustentaculum tali. On the cranial side of this projection, there was an oblong articular facet for articulation with tibial tarsal. On the distal surface of this bone, there was large quarter circle shaped facet for articulation with the central tarsal bone. first tarsal was a small narrow bone on the medial side of the distal row of tarsus. Its proximal and distal surface articulated with the central and first or second metatarsal. Laterally, it articulated with the second tarsal. Second tarsal was slightly smaller than the first one and was fixed as a wedge between the first and second tarsals. Third tarsal was better developed somewhat elongated bone fitted between the second tarsal and fourth tarsal and with the central above and the third metatarsal below. Fourth tarsal was the largest of bones of the distal row of tarsals. It was longer than the central tarsal and articulated above with the fibuilar tarsal and distally the fourth tarsal articulated with the heads of the fourth and fifth metatarsal bones. A very characteristic feature of this bone was a deep cranio-caudal groove on the proximal end of lateral surface of the bone for passage of tendon of fibularis muscle.

Metatarsals:

Sisson (1977) observed that proximal end of third metatarsal of dog was elongated dorsoplantarly and had plantar projections.

Evans and Christensen (1979) reported that first metatarsal was usually atypical bone in dog.

Pandit (1994) reported that the first metatarsal of tiger was short(4cm), thick (4cm girth) twisted stub of bone with a large saddle shaped articular facet on the proximal surface for articulation with first and second tarsal bones. Second metatarsal was thin cylindrical rod which was curved so that the convexity faces cranially. It was slightly (by about 0.5 cm) longer than the second metacarpal. Fourth metatarsal was slightly shorter (by about 0.5 cm) than the third metatarsal and had similar appearance. Two oval articular facets on the medial face of the proximal extremity help in identification of this bone. Fifth metatarsal had nearly same length as the second but was much thicker (4.2 cm girth in middle as against 3 cm of the second). The proximal extremity was compressed medio-laterally and there was a sharp curved planatar projection from the proximal extremity.

Phalanges:

Pandit (1994) reported that there were only 4 digits in hindpaw of the tiger, the first one was absent. Each developed digits i.e. second, third, fourth and fifth consisted of 3 phalanages each. These phalanges had the same features as the phanalges of digits of the forelimb. The distal or third phalanges of the digits of hindlimb were, smaller carrying smaller unguis.

Kirberger *et al.* (2003) studied radiological anatomy of the normal appendicular skeleton of the lion i.e. thoracic limb. He compared differences, similarities, or both between cheetahs, domestic cats and dogs. On the basis of evaluation, the scapula had a prominent acromion, hamate and suprahamate processes as well as prominent nutrient foramina. The humerus was similar to that of domestic cats. The humeral and ulnar nutrient foramina were placed more medially than that of domestic cats. The lateral anconeal tubercle of the olecranon (situated between the processes anconeus and tuber olecrani) was usually more prominent than the medial one and tends to be hook shaped, pointing cranially. There were no digits in the region of the elbow.

Kirberger *et al.* (2003) studied radiological anatomy of the normal appendicular skeleton of the lion i.e. pelvic limb. Based on radiographic evaluation of the thoracic limb he described that the femur of lion was similar to that of the domestic cats but the cranial and caudal middiaphyseal cortices were markedly thicken. The patella had a long narrow apex and the broad base. The head and distal extremity of the fibula were very prominent. The tarsal joint was similar to that of the domestic cats.

MATERIAL AND METHODS

MATERIAL AND METHODS

PLACE OF STUDY

The work was carried in the department of Wildlife Health and Management, College of Veterinary Science & Animal Husbandry, JNKVV, Jabalpur.

STUDY ANIMALS

Gross morphological and morphometric study were conducted on appendicular skeletons of 4 adult leopard provided by Kanha Tiger Reserve, Mandla (M.P.).

Technical Programme

The present study was performed on following bones of forelimbs and hindlimbs.

A. Forelimb (Thoracic limb):

Scapula –

- Ratio of supraspinous and infraspinous fossa
- Characteristic features of acromion process metachromion process, supraglenoid tubercle, glenoid cavity and subscapular fossa.

Humerus –

Shaft –

- General features

Proximal extremity –

- Head, lateral tuberosity, medial tuberosity and bicipital groove

Distal extremity –

- Condyles ,epicondyles , radial fossa and olecranon fossa

Radius and ulna –

Radius -

Shaft –

- General features

Proximal extremity –

- Facet for articulation with humerus and ulna and radial tuberosity

Distal extremity –

- Facet for carpals and morphology of styloid process

Ulna –

Shaft –

- General features

Proximal extremity –

- Olecranon process and semilunar notch

Distal extremity –

- Styloid pocess

Carpals –

- Number and morphological features of carpal bones.

Metacarpals –

- Number and morphological features of metacarpal bones.

Digits –

- Number and morphological features of phalanges.

B. Hindlimb (Pelvic limb): -

Os-coxae –

Ilium –

- Morphological features of the tubercoxae, tuber sacrale and greater ischiatic notch.

Ischium –

- Characteristic features of the tuber ischii, ischial arch, ischiatic spine and lesser ischiatic notch

Pubis –

- Morphological features of the surfaces and borders.

Femur –

Shaft –

- General features

Proximal extremity –

- Head, trochanter major, trochanter minor and third trochanter

Distal extremity –

- Trochlea and condyle

Patella –

- Morphological features of patella

Tibia and fibula –

Tibia –

Shaft –

- General features

Proximal extremity –

- Condyles, intercondylor eminence and poplitial notch

Distal extremity –

- Medial and lateral articular grooves

Fibula –

Shaft –

- General features

Proximal extremity –

- Head

Distal extremity –

- Medial and lateral articular grooves

Tarsals –

- Number and morphological features of tarsal bones

Metatarsals –

- Number and morphological features of metatarsal bones

Digits –

- Number and morphological features of phalanges.

C. Mensurations: -

The various parameters of long and short bones of appendicular skeleton of leopard were recorded with the help of Vernier caliper/ thread / scale in cm. For taking area of short bones pencil sketches were drawn on graph paper. The area was recorded in centimeter square (cm^2). Weight was taken with the help of electronic balance machine.

Scapula

Weight –

Length –

- Cranial border
- Caudal border
- Dorsal border
- Scapular spine
- Glenoid cavity

Width –

- Supraspinous fossa
- Infraspinous fossa
- Glenoid cavity

Height of scapular spine –

Humerus

Weight –

Length –

Shaft –

Length –

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width
- Circumference of head

Distal extremity –

- Circumference
- Width
- Depth of the olecranon fossa

Radius and ulna:

Radius –

Weight –

Length –

Shaft –

Length –

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width

Distal extremity –

- Circumference
- Width

Ulna –

Weight –

Length –

Shaft –

Length –

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width

Distal extremity –

- Circumference
- Width

Carpals –

- Weight and area of tarsal bones

Metacarpals –

- Weight, length and width of metacarpal bones

Phalanges –

- Weight, length and width of phalanges

Os-coxae:

Weight –

Ilium –

Length –

- Cranial border
- Caudal border
- Dorsal border

Ischium –

Length –

- Cranial border
- Caudal border

- Medial border
- Lateral border

Pubis –

Length –

- Cranial border
- Caudal border
- Medial border

Femur:

Weight –

Length –

Shaft –

Length

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width
- Circumference of head
- Diameter of head

Trochanteric fossa –

- Depth

Trochanteric major –

- Height/ length

Distal extremity –

- Circumference
- Width
- Depth of intercondyloid fossa

Patella:

Weight –

Length –

Width –

Maximum thickness –

Tibia and fibula –

Tibia:

Weight –

Length –

Shaft –

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width

Medial condyle:

- Length
- Width

Lateral condyle:

- Length
- Width

Distal extremity –

- Circumference
- Width

Fibula:

Weight –

Length –

Shaft –

Circumference –

- Upper part
- Middle part
- Lower part

Proximal extremity –

- Circumference
- Width

Distal extremity –

- Circumference
- Width

Tarsal –

- Weight and area of tarsal bones

Metatarsals –

- Weight, length and width of metatarsal bones

Phalanges –

- Weight, length and width of phalanges

E. Characteristic features and measurements of pelvic cavity, acetabulum and obturator foramen.

Pelvic cavity –

- Conjugate diameter
- Transverse diameter

Obturator foremen –

- Length
- Width

Acetabulum –

- Length
- Width

Pelvic symphysis –

- Length

Statistical analysis:

The data collected were analyzed for mean and standard error as per the standard procedure of Panes and Sukhatme (1967) and Snedecor and Cochran (1967).

RESULTS

RESULTS

Scapula:

Scapula was the flat bone of shoulder region had lateral and costal surfaces. The lateral surface had well developed scapular spine, which divided the surface into 2 equal areas. Supraspinous fossa had undulating surface, whereas infraspinous fossa was triangular and slightly concave at its lower third (Plate.1). At its lower part, the nutrient foramen was observed. The mean width of supraspinous fossa 4.92 ± 0.37 cm was less than infraspinous fossa (6.25 ± 0.26 cm) (Table.1). Scapular spine was thin at its middle and thicker towards the extremities. The mean length and height of scapular spine were 15.32 ± 0.95 cm and 2.4 ± 0.10 cm respectively. The distal end of the spine presented acromion process, which was blunt and overhanged the glenoid cavity. The mean distance between glenoid cavity and acromion process was 1.20 ± 0.10 cm. Small metacromion process was also present directed caudally (Plate.1). Cranial border was thin and convex with wavy course. The mean length of cranial, caudal and dorsal border was 15.57 ± 0.71 cm, 14.42 ± 0.60 cm, 7.50 ± 0.10 cm, respectively (Table.1). The caudal border was straight and thicker than the cranial border. Dorsal border was convex, thick, and rough. The rounded cranial angle was between dorsal and cranial border. The ventral angle had glenoid cavity that articulated with the head of humerus. The mean length and width of glenoid cavity were 3.45 ± 0.12 cm and 2.5 ± 0.17 cm, respectively. Cranially, it possessed the supraglenoid tubercle. Medially supraglenoid tubercle presented tubercular coracoid process.

The costal surface was wide and the cranial part of the surface was deeply concave, whereas caudal part was flattened. The cranial concave area had a line that started from the upper part of cranial border runs caudally and fades out in the middle of the cranial part. Another line present on the caudal part started from the caudal angle runs straight and terminated above the glenoid cavity (Plate.2).

Table.1 Mean and S.E. of different parameters of scapula

S. No	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	47.30	51.17	50.23	48.10	49.20	0.90
2.	Length (cm)						
	• cranial border	14.00	17.10	16.40	14.80	15.57	0.71
	• caudal border	13.00	15.90	14.70	14.10	14.42	0.60
	• dorsal border	7.30	7.80	7.50	7.40	7.50	0.10
	• scapular spine	12.50	16.70	16.10	16.00	15.32	0.95
	• glenoid cavity	3.10	3.70	3.50	3.50	3.45	0.12
3.	Width (cm)						
	• supraspinous fossa	3.80	5.40	5.30	5.20	4.92	0.37
	• infraspinous fossa	5.50	6.70	6.50	6.30	6.25	0.26
	• glenoid cavity	2.20	2.90	2.70	2.20	2.5	0.17
4.	Height of scapular spine (cm)	2.10	2.60	2.50	2.40	2.4	0.10
5.	Distance between glenoid cavity and acromion process (cm)	1.20	1.50	1.40	1.20	1.32	0.75

Plate 1: Scapula (lateral surface)

Plate 2: Scapula (medial surface)

Humerus:

The humerus was the bone of arm region directed downward and backward. It had a shaft and two extremities.

The mean length of the shaft was 14.95 ± 0.79 cm. The medial surface of the shaft was wide at its upper part and narrow distally. The mean circumference of the shaft at its upper, middle and lower part was 8.37 ± 0.34 cm, 7.05 ± 0.20 cm and 7.22 ± 0.30 cm respectively (Table.2). Teres tubercle was present in the middle of the proximal part of medial surface. Lateral surface was smooth, convex, and twisted spirally / curved. This surface was separated from the cranial surface by the deltoid ridge, which ran caudodistally. The deltoid ridge bore at its middle the deltoid tuberosity in the form of low crest. The cranial surface was triangular and clearly defined in its upper third (Plate.3). Caudal surface was smooth and slightly concave (Plate.3).

Proximal extremity comprised of head, neck, lateral tuberosity and medial tuberosity and bicipital groove (Plate.4). The mean circumference of the proximal extremity was 13.95 ± 0.41 cm and that of head was 9.65 ± 0.06 cm (Table.2). Lateral tuberosity was slightly higher than the head, and its lateral surface presented rough area for muscular attachment (Plate.4). Medial tuberosity was much smaller than the lateral and separated from the former by the bicipiital groove.

Distal extremity of the humerus consisted of medial and lateral condyles. The mean circumference of the distal extremity was 13.32 ± 0.60 cm (Table.2). The two condyles were separated by cranio-caudal groove. The condyles articulated with the facet of the radius bone and formed humero-radial articulation Lateral condyle was higher in level than medial condyle. Just above and infront of the condyles, was a shallow radial fossa. The deep olecranon fossa was observed, just above and behind the condyles (Plate.5). Depth of the olecranon fossa was 1.27 ± 0.10 cm. On the caudomedial aspect, an oval shaped, small interosseous space was noticed (Plate.5). Lateral epicondyle had a sharp edge whereas medial with blunt edge. Both the epicondyles formed the boundary of the olecranon fossa.

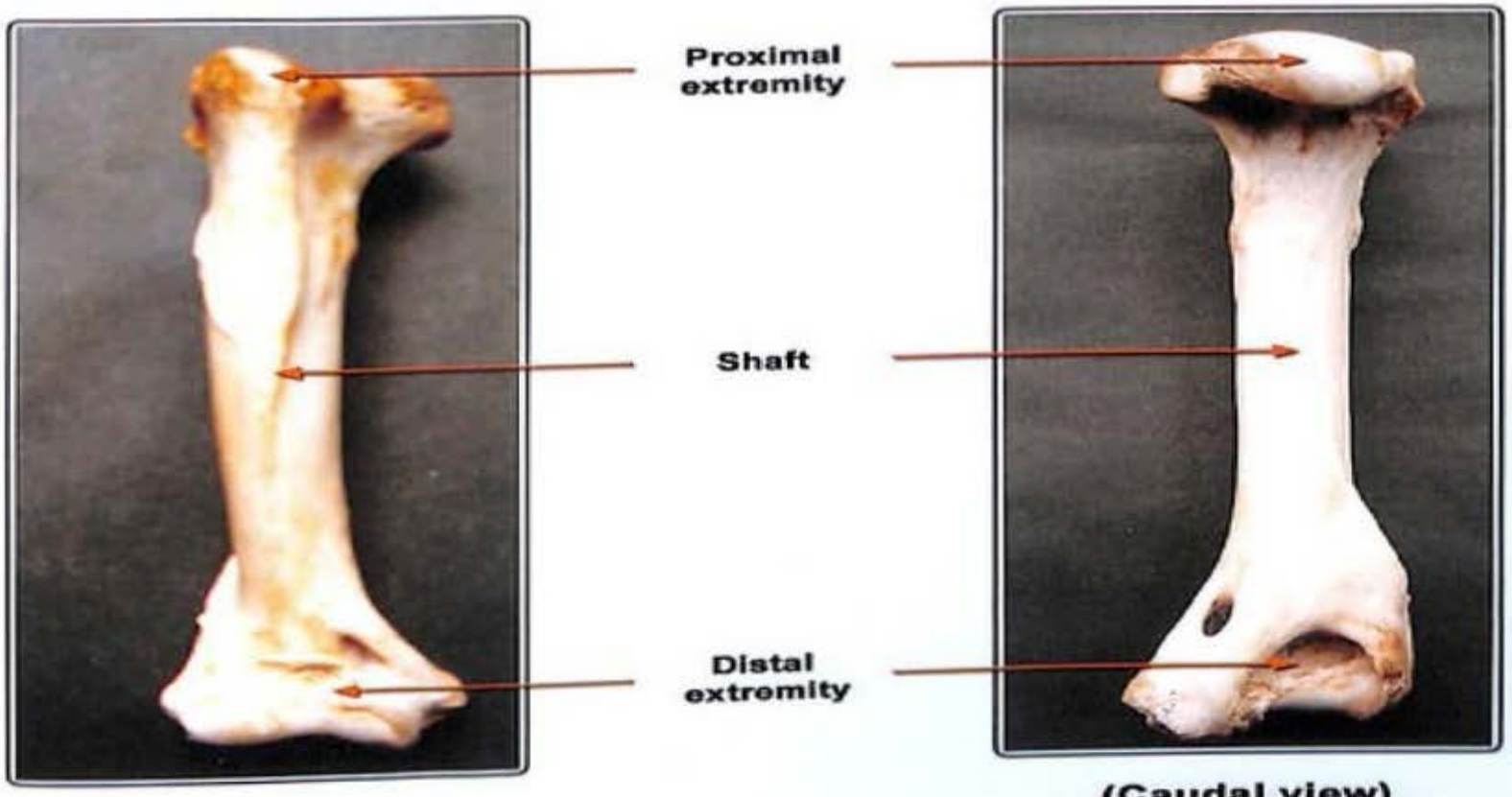

Plate 3: Humerus

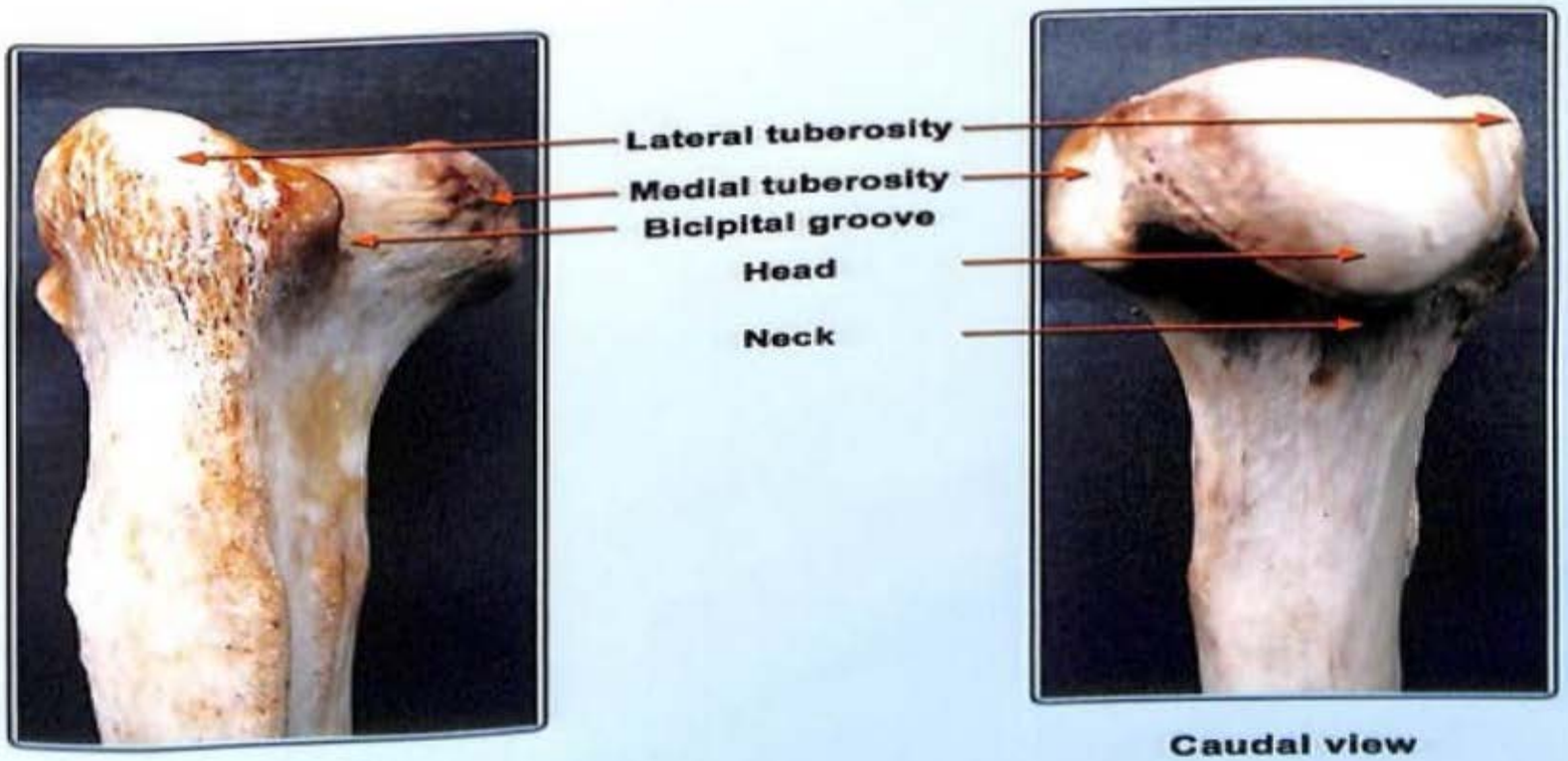

Plate 4: Humerus (Proximal extremity)

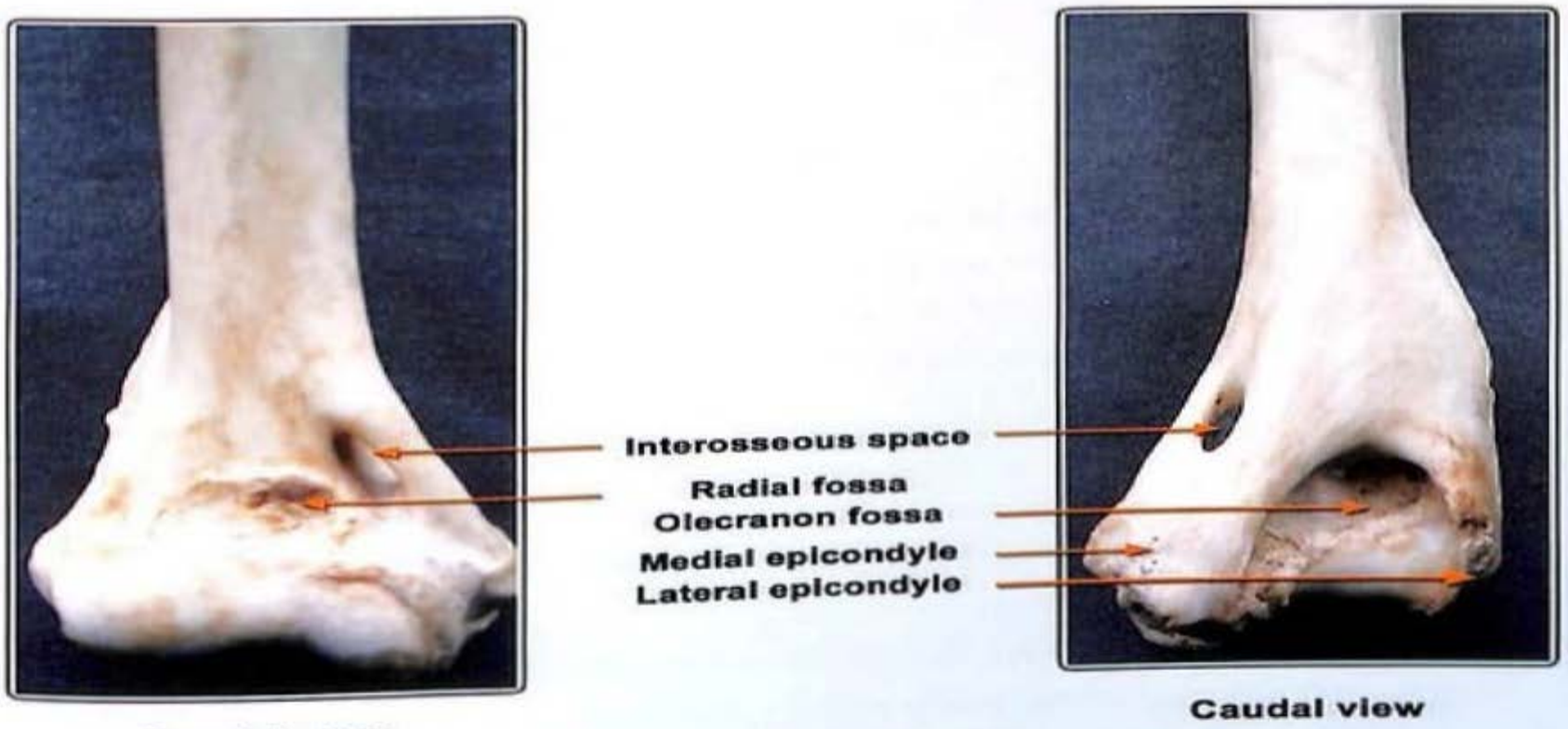

Plate 5: Humerus (Distal extremity)

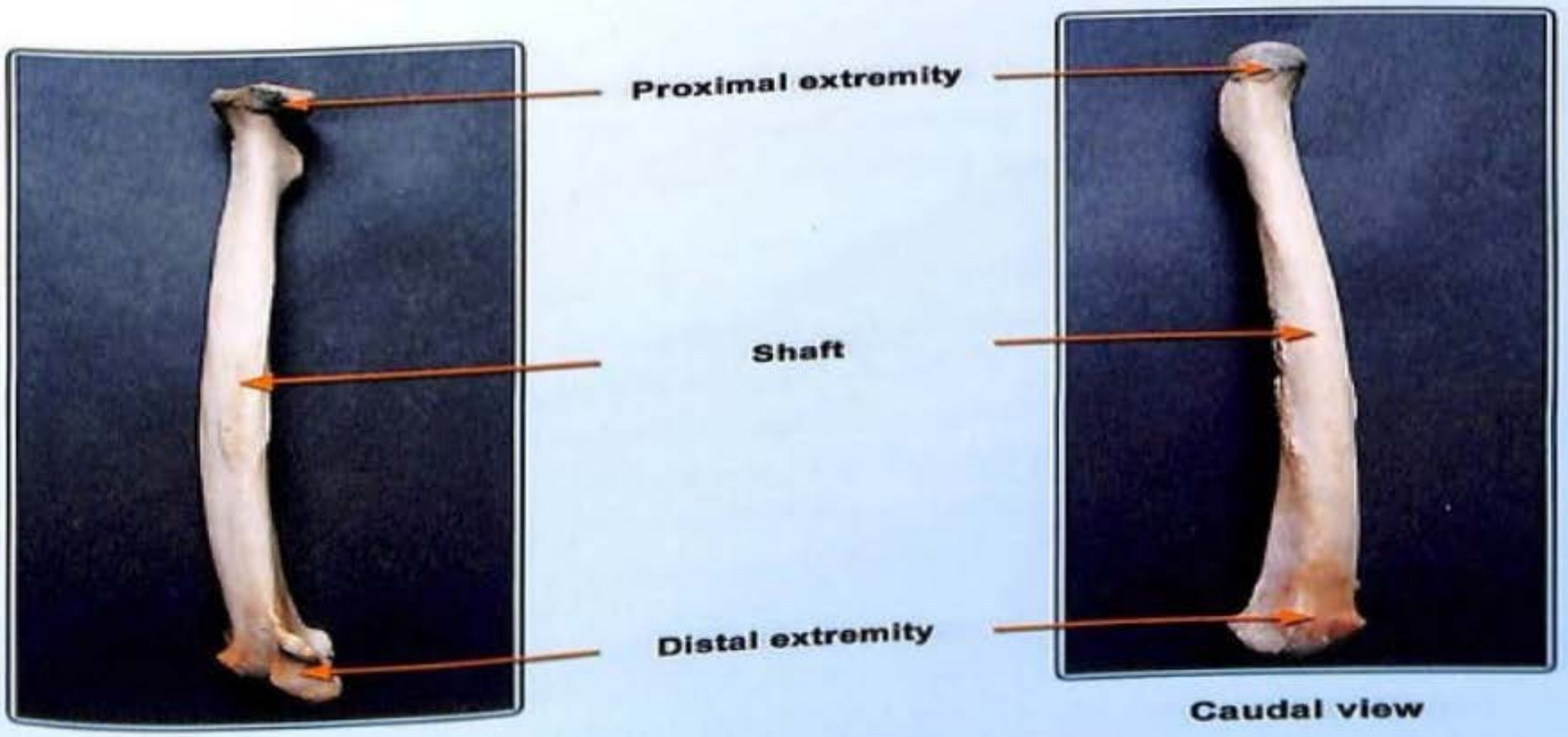

Plate 6: Radius

Radius and ulna:

Radius:

Radius and ulna in the leopard were separate bones articulated at the proximal and distal extremity leaving a narrow interosseous space present along the length of the bones. The radius was flattened cranio-caudally, situated cranio-medial to the ulna. Radius presented a shaft and two extremities.

The mean circumference of the shaft at its upper, middle and lower part was 4.72 ± 0.30 cm, 5.60 ± 0.32 cm and 6.55 ± 0.32 cm, respectively (Table.3). The cranial surface of the shaft faced cranio-medially, was slightly convex and smooth (Plate.6). It presented rough area at its middle towards the lateral border. The caudal surface was slightly concave and presented rough small eminences. This surface faced towards the ulna (Plate.6). The proximal part of the caudal surface had elongated, elliptical, smooth facet that came in contact with the medial surface of the ulna. Lateral border was straight and rough at its middle third. The medial border was more or less straight.

Proximal extremity was much smaller than the distal extremity. The mean circumference of the proximal extremity was 8.20 ± 0.15 cm (Table.3). It had oval, concave facet surrounded by the rim of the bone (Plate.7).

Distal extremity of the radius consisted of concave carpal articular surface, which was wide laterally and became narrow medially. The mean circumference of the distal extremity was 5.70 ± 0.18 cm (Table.3). Its medial border had projection distally forming the styloid process of the radius with sharp edge (Plate.8). Just above the styloid process, there was a prominent tubercle. Infront and above the distal articular surface, there were three small tubercles formed the passage of the tendons of extensor muscles.

Table.3 Mean and S.E. of different parameters of radius

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	35.07	39.38	37.58	36.24	37.06	0.92
2.	Length (cm)	15.50	18.00	17.40	16.20	16.77	0.56
3.	Shaft (cm)						
	Length	13.50	14.90	14.30	13.80	14.12	0.30
	Circumference						
	• Upper part	4.10	5.50	4.90	4.40	4.72	0.30
	• Middle part	4.90	6.40	5.80	5.30	5.60	0.32
	• Lower part	5.90	7.40	6.70	6.20	6.55	0.32
4.	Proximal extremity (cm)						
	• Circumference	7.90	8.60	8.30	8.00	8.20	0.15
	• Width	1.50	1.92	1.72	1.67	1.70	0.08
5.	Distal extremity (cm)						
	• Circumference	5.40	6.10	5,80	5.60	5.70	0.18
	• Width	1.10	1.48	1.31	1.28	1.29	0.07

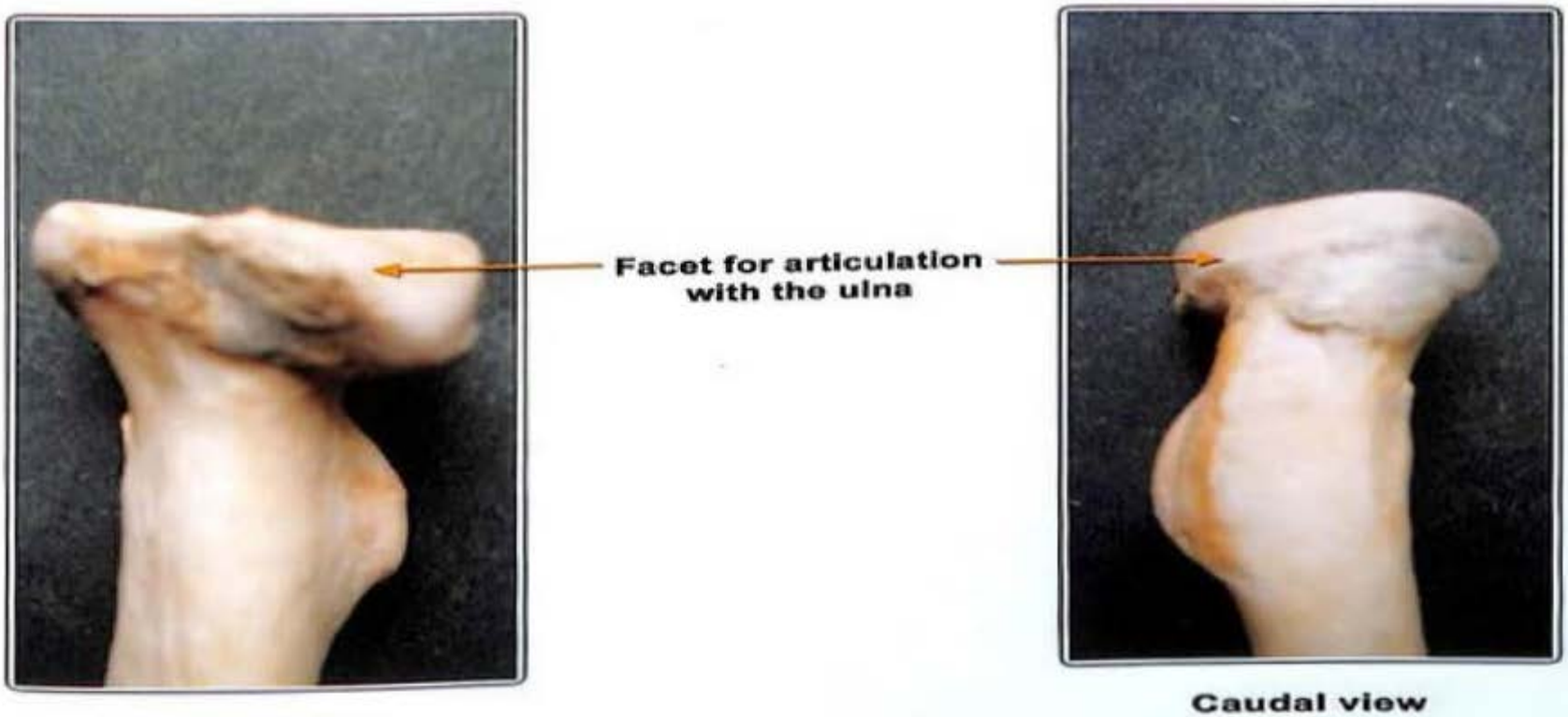

Plate 7: Radius (Proximal extremity)

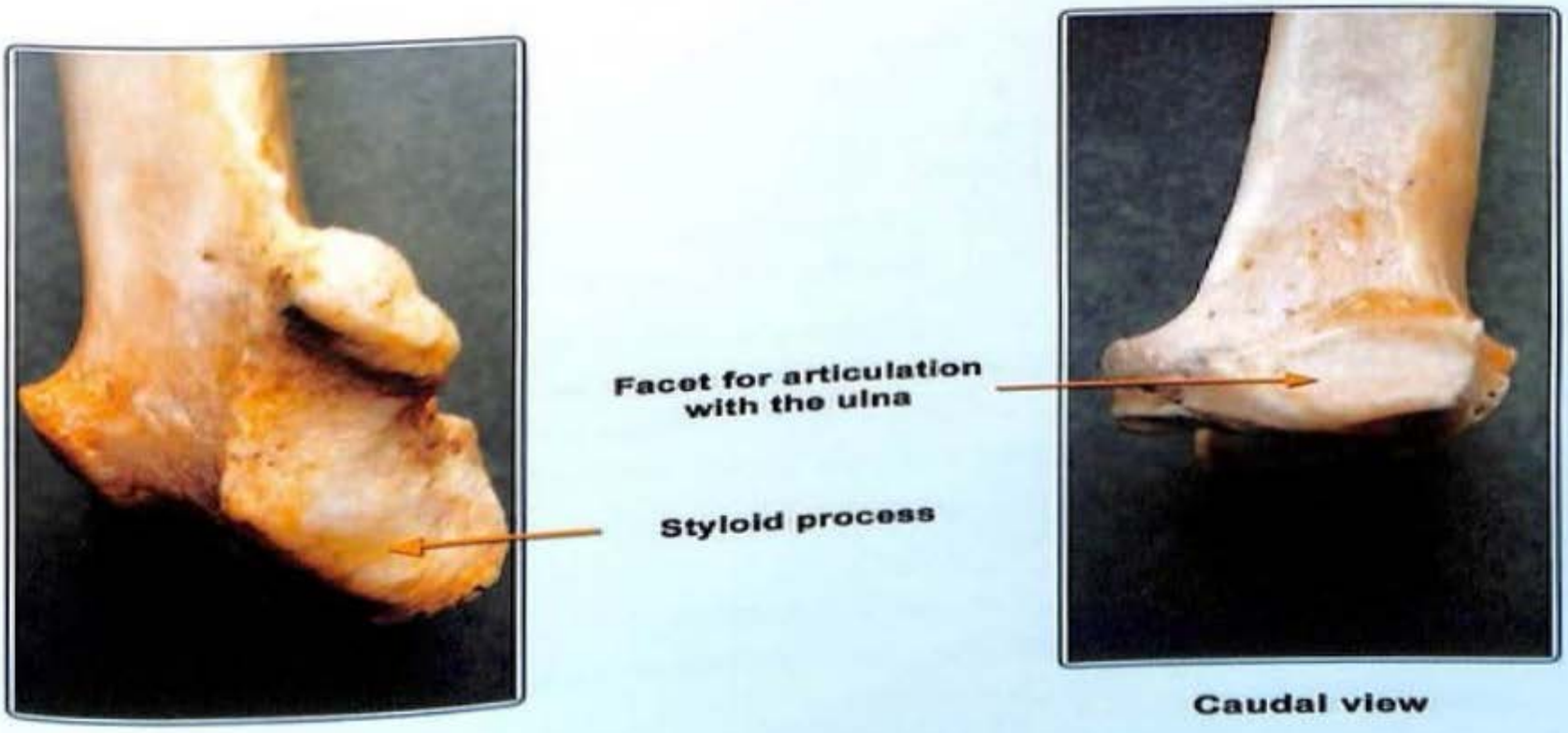

Plate 8: Radius (Distal extremity)

Ulna:

Ulna was longer than the radius and was fattened medio-laterally. It presented shaft and two extremities.

The cranial surface coursed along the caudal surface of the radius leaving a very narrow interosseous space ran throughout the length of bones. This surface was wider above and gradually narrows down (Plate.9). It was rough except at its upper one third which was smooth and slightly concave. Caudal border was thick in its upper part then gradually became thin and terminated in the form of caudal border of styloid process. Cranial border started below the facet for the medial condyle of the humerus and terminated just above facet for radius bones. The mean circumference of the shaft at its upper, middle and lower part was 7.77 ± 0.52 cm, 5.15 ± 0.30 cm and 4.07 ± 0.28 cm respectively (Table.4).

Proximal extremity bore olecranon process, anconeus process and facet for humerus. Olecranon process possessed three tubercles. The caudal one was largest (trifid). The lateral surface of the olecranon process was rough and elevated, whereas medial surface was smooth and concave. Anconeus process had wide, smooth articular surface that articulated with the medial condyle of the humerus. The distal part of the anconeus process was smooth, slightly concave and articulated with the medial condyle of the humerus. Laterally, the small horizontal elongated concave facet that articulated with the proximal extremity of the radius. The semilunar notch was smooth, half moon shaped concavity which faced cranially (Plate.10). The mean circumference of the proximal extremity was 6.75 ± 0.17 cm (Table.4).

Distal extremity was much smaller than the proximal extremity and had rounded facet towards the medial side which articulated with the distal extremity of the radius. The mean circumference of the distal extremity was 3.65 ± 0.06 cm (Table.4). Laterally, the ventrally directed blunt projection the styloid process was present (Plate.11).

Carpals:

The carpal bones of the leopard were arranged in the proximal and distal row. The bones of proximal and distal row were radial (intermedioradial), ulnar and accessory carpal. The carpals of distal row were four in number namely first, second, third and fourth carpal bones.

Table 4. Mean and S.E. of different parameters of ulna

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight	48.47	54.10	52.19	50.23	51.24	1.21
2.	Length (cm)	20.90	24.70	22.60	21.40	22.40	0.84
3.	Shaft (cm)						
	Length	14.10	16.80	16.10	15.30	15.57	0.57
	Circumference						
	• Upper part	6.50	8.90	8.30	7.40	7.77	0.52
	• Middle part	4.60	6.00	5.20	4.80	5.15	0.30
	• Lower part	3.50	4.80	4.20	3.80	4.07	0.28
4.	Proximal extremity (cm)						
	• Circumference	6.40	7.20	6.80	6.60	6.75	0.17
	• Width	1.60	1.87	1.79	1.68	1.73	0.05
5.	Distal extremity (cm)						
	• Circumference	3.50	3.80	3.70	3.60	3.65	0.06
	• Width	2.20	2.40	2.31	2.27	1.13	0.04

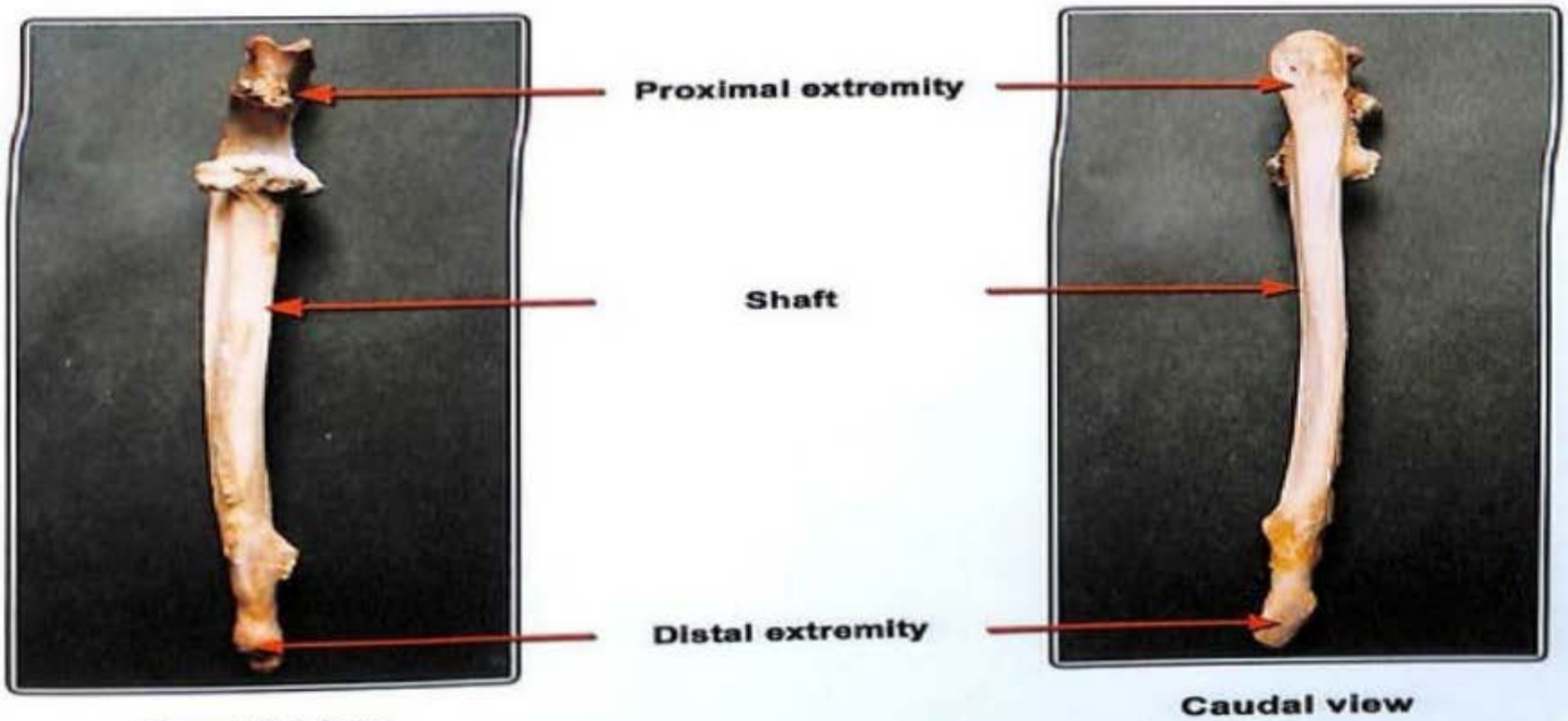

Plate 9: Ulna

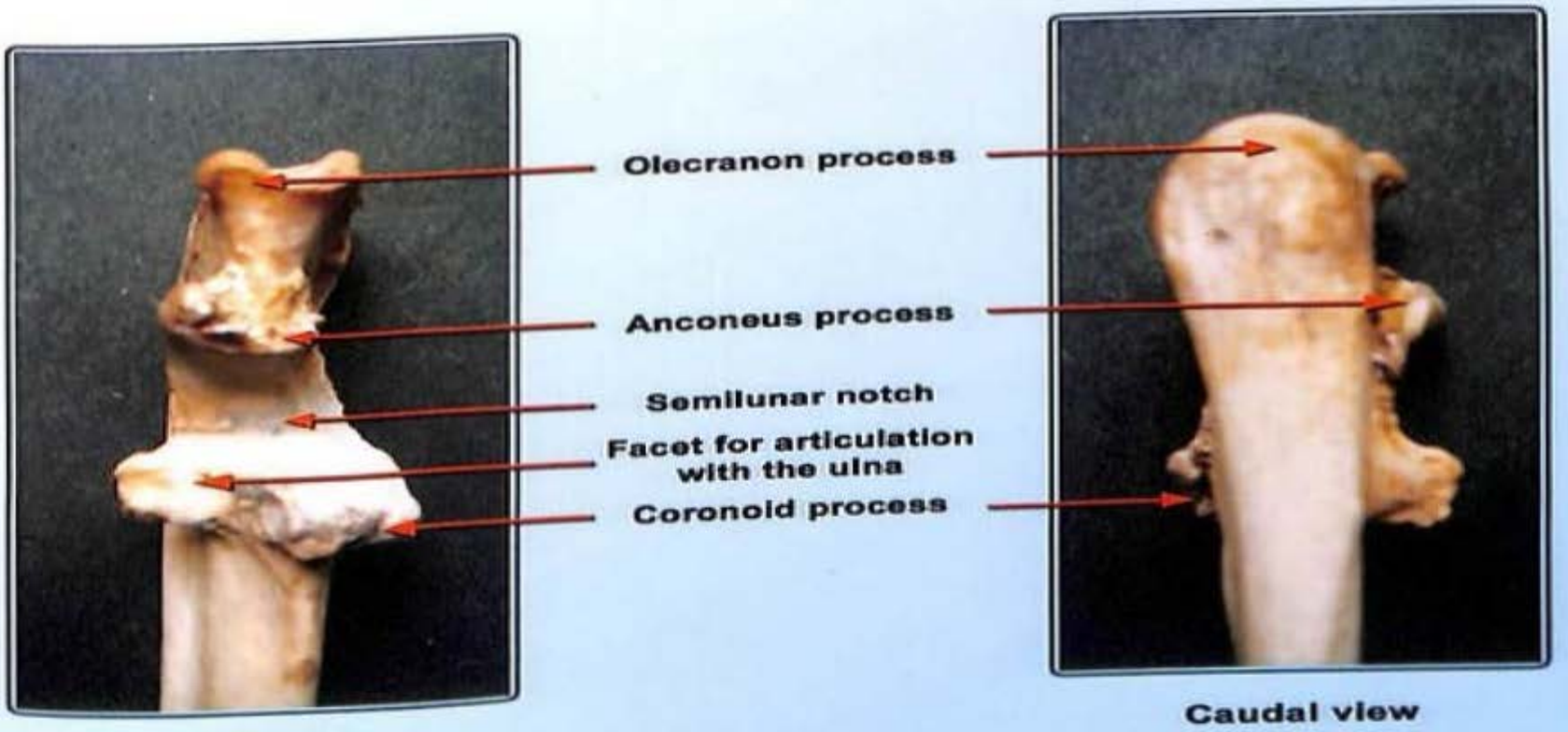

Plate 10: Ulna (Proximal extremity)

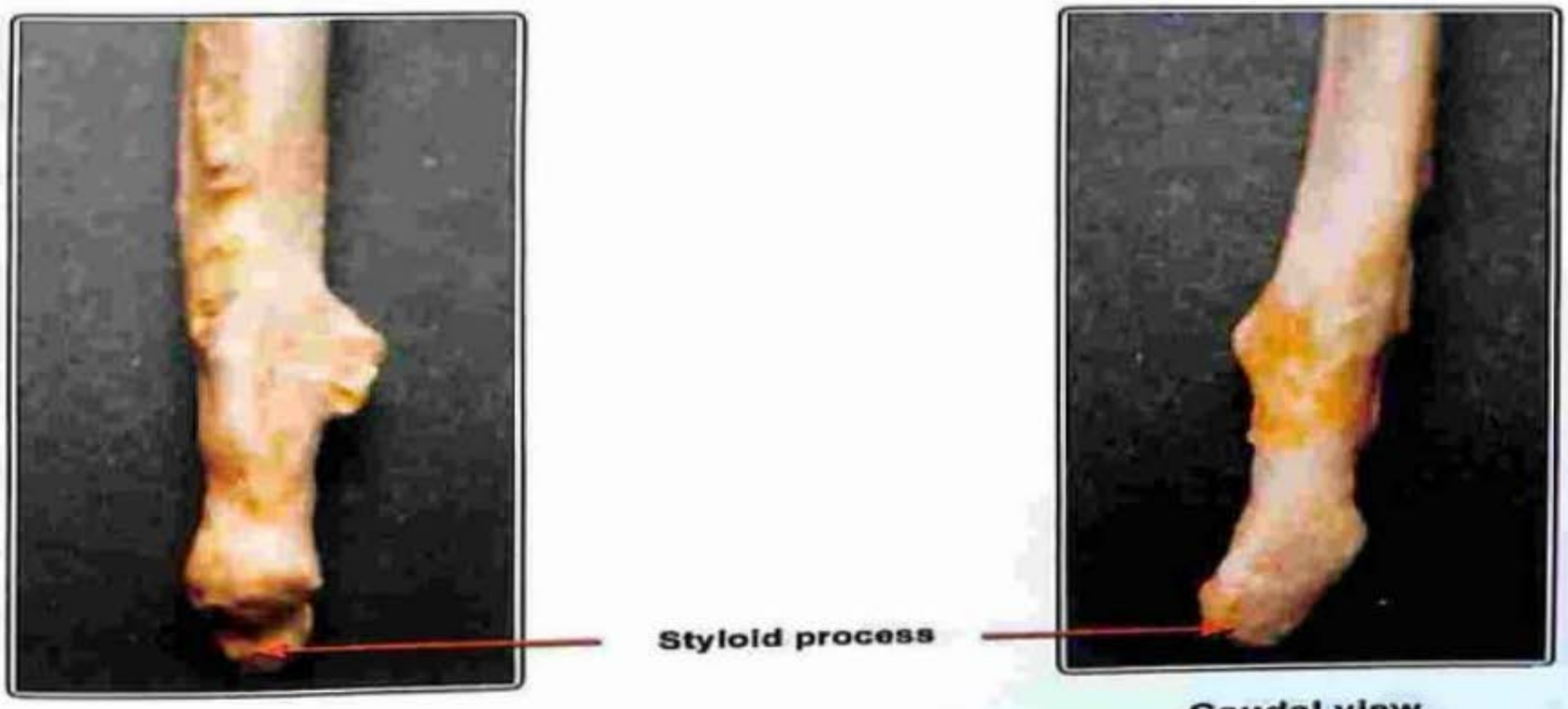

Plate 11: Ulna (Distal extremity)

Plate 12: Carpals

Radial carpal:

Radial carpal was the largest carpal among the all carpal bones (Plate.12). It was quadrilateral in shape and was flattened craniocaudally. The cranial surface was convex and caudal surface was irregularly concave. The distal surface presented facets for articulation with the carpal bones of the distal row. Laterally, it had facets for articulation with ulnar carpal.

Ulnar carpal:

The ulnar carpal was smaller than the radial carpal and quadrilateral in shape (Plate.12). It presented a facet proximally for articulation with ulna and radius, distally with IV carpal and IV metacarpal, medially with radial carpal and caudally with the accessory carpal.

Accessory carpal:

The accessory carpal bone of the leopard was constricted in the middle expanded at both the extremities (Plate.12). The basal extremity presented a saddle shaped articular facet for articulation with ulnar carpal. The basal extremity also had a small facet for articulation with the styloid process of the ulna.

First carpal:

It was flattened and smallest bone of the second row. It presented facet for articulation with the second carpal and metacarpal II. It also had articular area on its proximal part for articulation with radial carpal and on its distal part for articulation with metacarpal I.

Second carpal:

The second carpal bone was small and wedge shaped bone (Plate.12). It was compressed proximodistally and presented articular area proximally for articulation with the radial carpal. Distally, it had a facet for articulation with metacarpal II. On its lateral and medial aspects, it bore a facet for articulation with third and first carpal respectively.

Third carpal:

The third carpal was larger in comparison to the second carpal bone (Plate.12). On its caudal part, it presented a projection for articulation

with the metacarpal II. It had articular areas on its medial, lateral, proximal and distal part for articulation with the second carpal, fourth carpal, radial carpal and metacarpal III, respectively.

Fourth carpal:

The fourth carpal of the leopard was observed as largest bone of the distal row (Plate.12). On caudal aspect, it presented an enlargement. It exhibited facet on its distal medial and proximomedial aspect for articulation with the metacarpal IV and V, third carpal and radial carpal, respectively.

Metacarpals:

The metacarpal bones were five in number. The metacarpal I was shortest and thinnest among all metacarpals (Plate.13). The metacarpal II and V were in the form of irregular rods with uniform diameter. The metacarpal III and IV were longest (Plate.13). The metacarpal II and V were observed as four sided. The metacarpal III and IV were triangular in their proximal part and cylindrical distally. The metacarpal II to V were comprised of a base, body and head. The base was larger than the head and was compressed at one side. The base bore facet for articulation with carpal bones. The metacarpal II to V had facet on sides of the base for articulation with the adjacent metacarpals.

The shaft was triangular proximally and became smooth and cylindrical distally. The shaft of metacarpal V was more curved than other metacarpals. The distal extremity was articular had head, shaft and presented in the middle a prominent sagittal crest dividing the articular area in two equal parts. The sagittal ridge was prominent in caudal 3/4th.

Phalanges:

In leopards, there were five digits. Each digit was consisted of 3 phalanges (proximal, middle and distal phalanx) except first which had only two phalanges.

Table.5 Mean and S.E. of different parameters of carpals:

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Radial carpal						
	• Weight (gm)	3.46	3.78	3.67	3.52	3.60	0.07
	• Area (cm^2)	3.22	3.40	3.35	3.27	3.31	0.04
2.	Ulnar carpal						
	• Weight (gm)	1.52	1.78	1.61	1.58	1.62	0.05
	• Area (cm^2)	2.56	2.84	2.74	2.64	2.69	0.06
3.	Accessory carpal						
	• Weight (gm)	1.21	1.34	1.30	1.26	1.27	0.02
	• Area (cm^2)	2.12	2.28	2.24	2.18	2.20	0.03
4.	First carpal						
	• Weight (gm)	0.20	0.29	0.27	0.25	0.25	0.01
	• Area (cm^2)	0.74	0.86	0.81	0.78	0.79	0.02
5.	Second carpal						
	• Weight (gm)	0.59	0.71	0.65	0.61	0.64	0.02
	• Area (cm^2)	0.98	1.10	1.04	1.00	1.03	0.02
6.	Third carpal						
	• Weight (gm)	0.78	0.89	0.85	0.81	0.83	0.02
	• Area (cm^2)	2.08	2.18	2.12	2.11	2.12	0.02
7.	Fourth carpal						
	• Weight (gm)	0.81	0.97	0.93	0.88	0.89	0.03
	• Area (cm^2)	1.10	1.23	1.20	1.15	1.17	0.02

Table.6 Mean and S.E. of different parameters of metacarpals:

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	First metacarpal						
	• Weight (gm)	1.34	1.69	1.58	1.47	1.52	0.07
	• Length (cm)	1.10	1.40	1.30	1.20	1.25	0.06
	• Width (cm)	0.80	1.14	1.04	0.92	0.97	0.07
2.	Second metacarpal						
	• Weight (gm)	5.40	5.78	5.67	5.58	5.60	0.08
	• Length (cm)	5.50	5.80	5.70	5.70	5.67	0.06
	• Width (cm)	0.77	1.12	1.03	0.94	0.96	0.07
3.	Third metacarpal						
	• Weight (gm)	5.50	5.82	5.68	5.57	5.64	0.06
	• Length (cm)	6.30	6.60	6.40	6.30	6.40	0.07
	• Width (cm)	0.79	1.11	0.91	0.83	0.91	0.07
4.	Fourth metacarpal						
	• Weight (gm)	5.28	5.61	5.49	5.37	5.43	0.07
	• Length (cm)	5.80	6.00	5.90	5.80	5.87	0.04
	• Width (cm)	0.80	1.12	1.01	0.94	0.96	0.06
5.	Fifth metacarpal						
	• Weight (gm)	4.02	4.33	4.23	4.11	4.17	0.06
	• Length (cm)	4.80	5.00	4.90	4.80	4.87	0.04
	• Width (cm)	0.91	1.21	1.10	1.02	1.06	0.06

Proximal phalanx:

Proximal phalanx was longest of three (Plate.14). The proximal phalanx was consisted of proximal end and distal end. On the palmar aspects of the proximal end, on either side, there were two tubercles. The articular surface of the end was deeply concave. The cranial surface of the shaft was smooth and convex. The palmar surface of the shaft was flattened on the distal third of the shaft. On either side, there was a small tubercle. The distal end or head was in the form of trochlea. The two articular ridges of the trochlea were separated by a deep sagittal groove.

Middle phalanx:

The middle phalanx was about 2/3rd of the length of the proximal phalanx. In first digit, it was absent (Plate.14). The proximal articular surface was consisted of two concave facets separated by a faint sagittal groove. At the mid point of this extremity, cranially there was a tubercle and caudally, a deep depression. The shaft was prismatic and curved distally. The two condyles of the distal end were separated caudally by a sagittal groove.

Distal phalanx:

The distal phalanx was in the form of claw (Plate.14). The base had a concave articular surface for articulation with the middle phalanx. The solar surface presented an oval shaped tubercle and on each side of this surface was a small foramen. The ungul process was in the form of thin, triangular plate with a broad base and pointed apex.

Unguis:

The unguis were five in number in forelimb (Plate.15). It was comprised of two thin plates separated caudally by wide, gap proximally, which narrowed distally. These plates of bone which were wider proximally and tapered y distally and terminated in the form of curved apex.

Table 7. Mean and S.E. of different parameters of proximal phalanx

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	First digit						
	• Weight (gm)	1.29	1.61	1.48	1.38	1.44	0.06
	• Length (cm)	1.60	1.80	1.70	1.60	1.67	0.04
	• Width (cm)	0.81	1.11	1.02	0.90	0.96	0.06
2.	Second digit						
	• Weight (gm)	1.90	2.20	2.08	1.94	2.03	0.06
	• Length (cm)	2.40	2.60	2.50	2.40	2.47	0.04
	• Width (cm)	0.53	0.87	0.71	0.59	0.67	0.07
3.	Third digit						
	• Weight (gm)	2.50	2.82	2.70	2.56	2.64	0.07
	• Length (cm)	2.90	3.10	2.90	2.90	2.95	0.05
	• Width (cm)	0.80	1.12	0.99	0.87	0.94	0.07
4.	Fourth digit						
	• Weight (gm)	2.40	2.71	2.58	2.47	2.54	0.06
	• Length (cm)	2.90	3.00	3.00	2.90	2.95	0.02
	• Width (cm)	0.70	1.06	0.93	0.81	0.87	0.07
5.	Fifth digit						
	• Weight (gm)	1.87	2.17	2.03	1.92	1.99	0.07
	• Length (cm)	2.40	2.70	2.50	2.40	2.50	0.06
	• Width (cm)	0.50	0.83	0.71	0.58	0.65	0.07

Table 8. Mean and S.E. of different parameters of middle phalanx

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Second digit						
	• Weight (gm)	1.23	1.54	1.39	1.28	1.36	0.06
	• Length (cm)	1.90	2.10	2.00	1.90	1.97	0.04
	• Width (cm)	0.71	1.01	0.87	0.76	0.83	0.06
2.	Third digit						
	• Weight (gm)	1.59	1.88	1.75	1.64	1.71	0.06
	• Length (cm)	2.70	3.00	2.80	2.70	2.80	0.07
	• Width (cm)	0.72	1.06	0.88	0.76	0.85	0.07
3.	Fourth digit						
	• Weight (gm)	1.69	1.98	1.84	1.73	1.81	0.06
	• Length (cm)	2.50	2.70	2.80	2.50	2.62	0.07
	• Width (cm)	0.60	0.91	0.76	0.65	0.73	0.06
4.	Fifth digit						
	• Weight (gm)	1.47	1.78	1.63	1.53	1.60	0.06
	• Length (cm)	2.00	2.40	2.20	2.00	2.15	0.09
	• Width (cm)	0.69	0.90	0.81	0.72	0.78	0.04

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Table 9. Mean and S.E. of different parameters of distal phalanx

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	First digit						
	• Weight (gm)	1.04	1.32	1.18	1.09	1.15	0.06
	• Length (cm)	1.40	1.60	1.50	1.40	1.47	0.04
	• Width (cm)	2.11	2.39	2.25	2.17	2.23	0.06
2.	Second digit						
	• Weight (gm)	1.15	1.43	1.29	1.21	1.27	0.06
	• Length (cm)	1.50	1.70	1.60	1.50	1.57	0.04
	• Width (cm)	2.42	2.69	2.55	2.48	2.53	0.05
3.	Third digit						
	• Weight (gm)	1.60	1.82	1.76	1.68	1.71	0.04
	• Length (cm)	1.70	2.00	1.80	1.70	1.8	0.07
	• Width (cm)	2.50	2.78	2.63	2.57	2.62	0.05
4.	Fourth digit						
	• Weight (gm)	1.62	1.88	1.75	1.66	1.72	0.05
	• Length (cm)	1.50	1.70	1.60	1.50	1.57	0.04
	• Width (cm)	2.43	2.67	2.52	2.47	2.52	0.05
5.	Fifth digit						
	• Weight (gm)	1.21	1.50	1.36	1.25	1.33	0.06
	• Length (cm)	1.50	1.70	1.60	1.50	1.57	0.04
	• Width (cm)	2.31	2.59	2.45	2.38	2.43	0.05

Plate 13: Metacarpals
(Dorsal view)

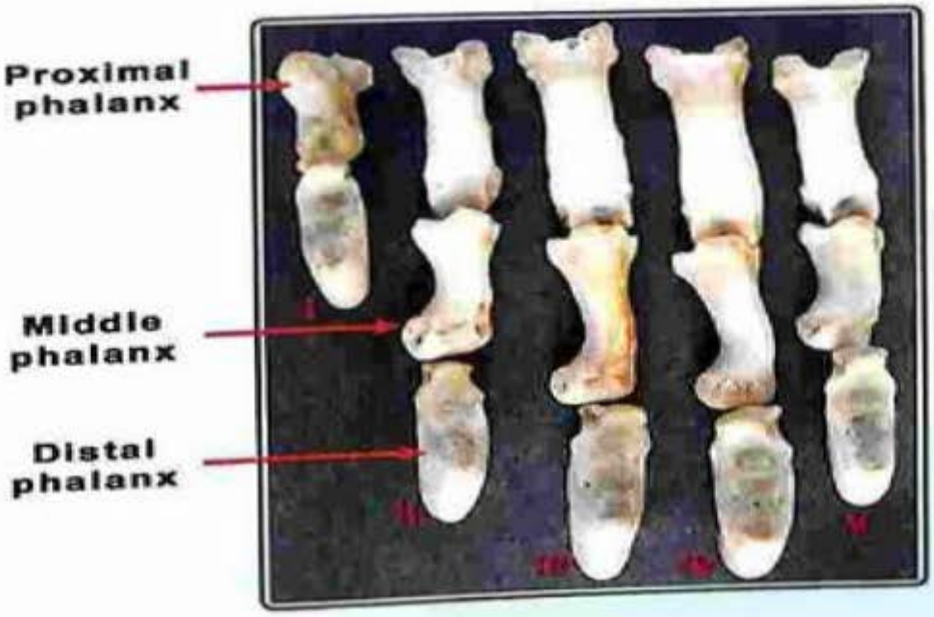


Plate 14: Phalanges
(Dorsal view)

Plate 15: Unguis

Ossa coxarum:

Ossa coxarum of leopard comprised of os coxae of both sides. Each os-coxae consisted of ilium, ischium and pubis. The mean weight of ossa coxarum was 147.02 ± 1.69 gm (Table.10).

Ilium-

It was placed in a vertical direction parallel to each other. The lateral or gluteal surface was deeply concave while medial surface was rough and had at its lower part, elongated curved, bean shaped facet for articulation with the wings of the sacrum. The dorsal border was thick and rounded. Lateral or cranial border was thin in its upper fourth. Caudal border was also thick and presented at its middle a projection. Greater ischiatic notch was shallow and rounded (Plate.16). Ischiatic spine was not well developed. Cranial angle was thin and sharp while the caudal angle was thick and rounded. Acetabular angle met with the ischium and pubis at the acetabulum.

Ischium-

It was much smaller than the ilium and had twisted appearance. The acetabular part was vertical while symphysial part was horizontal. It formed the caudal part of the floor of the pelvic cavity. Lateral border was thick, rounded and lesser ischiatic notch was not prominent. Medial border was thin, rough, met with the same border of the opposite bone, and formed the caudal part of the pelvic symphysis. Cranial border was thin, concave, and formed the caudal boundary of the obturator foramen. Caudal border was thick, rough, met with the same border of the opposite bone, and formed the v-shaped ischial arch. The caudolateral angle (tuber ischii) was very thick and rough (Plate.16). The pelvic surface was smooth and concave. The ventral surface was rough.

Pubis-

The caudal border was thick and formed the cranial boundary of the obturator foramen. The cranial border was thin and sharp. The medial border met with the opposite bone and formed the symphysis pubis (Plate.17). The medial angle presented a tubercle. The pelvic surface was concave whereas ventral surface was slightly convex.

Table 10. Mean and S.E. of different parameters of os-coxae

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	143.30	151.10	148.23	145.46	147.02	1.69
2.	Length (cm)						
	• cranial border	8.80	9.50	9.20	8.90	9.10	0.15
	• caudal border	7.10	7.70	7.40	7.20	7.35	0.13
	• dorsal border	4.90	5.40	5.20	5.10	5.15	0.10

Table11. Mean and S.E. of different parameters of pelvic cavity, acetabulum and obturator foramen

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Conjugate diameter (cm)	6.90	7.40	7.10	7.00	7.10	0.10
2.	Transverse diameter (cm)	5.20	5.40	5.30	5.20	5.27	0.04
3.	Pelvic symphysis (cm)						
	• Length	5.30	5.90	5.60	5.40	5.55	0.13
4.	Obturator foremen (cm)						
	• Length	4.76	5.10	4.90	4.80	4.89	0.07
	• Width	2.50	2.80	2.60	2.50	2.60	0.07
5.	Acetabulum (cm)						
	• Length	2.90	3.30	3.20	3.00	3.10	0.09
	• Width	2.60	3.00	2.80	2.60	2.75	0.09
6.	Acetabulum cavity (cm)						
	• Depth	1.80	2.10	1.90	1.90	0.95	0.06

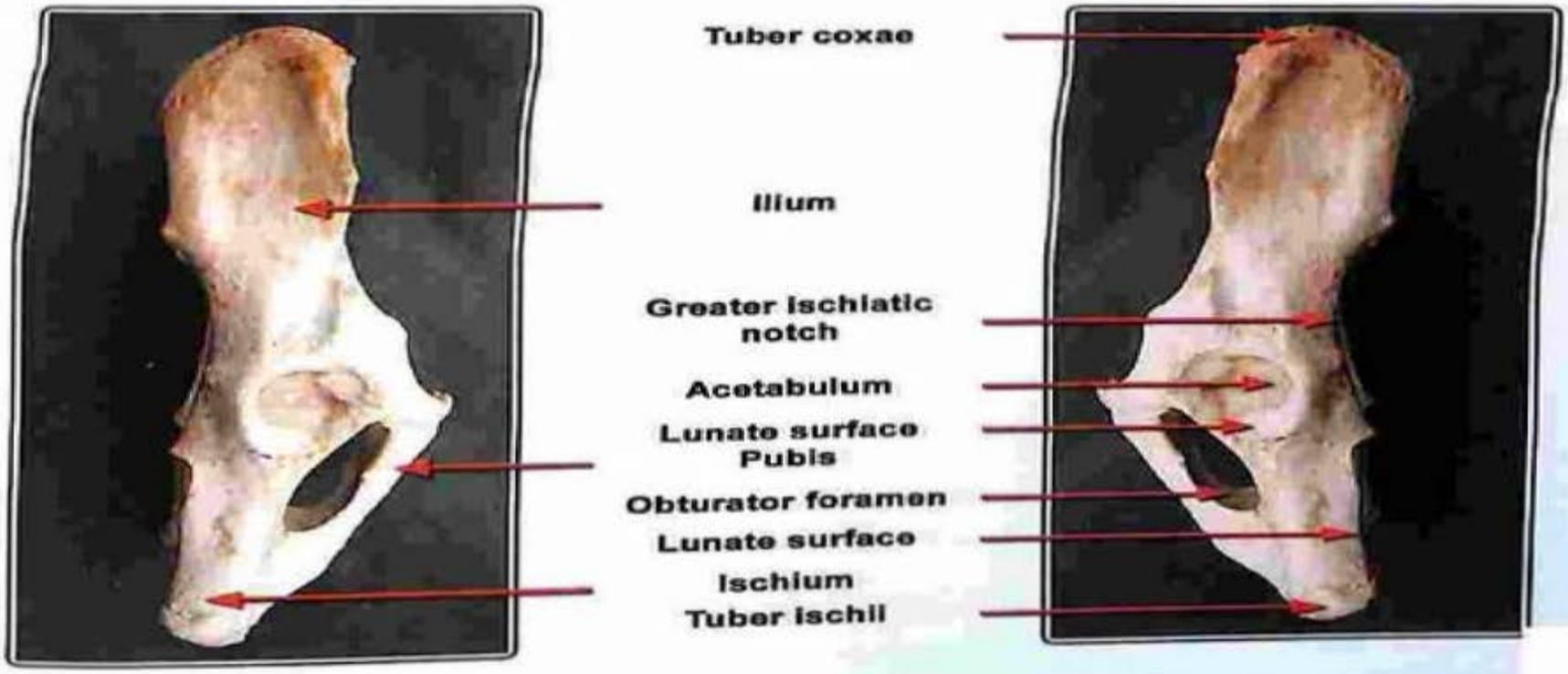


Plate 16: Os coxae (Lateral view)

Plate 17: Ossa coxarum

Pelvic cavity:

The mean length of pelvic symphysis was 0.55 ± 0.13 cm (Table.11). At the pelvic inlet, mean conjugate diameters was 7.10 ± 0.10 cm. The mean transverse diameter was 5.27 ± 0.04 cm.

Acetabulum:

This was formed by the union for corresponding angles of ilium, ischium and pubis (Plate.16). It had an outer smooth articular part which was notched at the postero medial aspects. The mean length and width of acetabulum was 3.10 ± 0.09 cm and 2.70 ± 0.09 cm, respectively (Table.11). The mean depth of acetabulum was 0.95 ± 0.06 cm.

Obturator foramen:

It was the largest foramen of the body situated between the pubis and ischium (Plate.17). It was an oval shaped aperture whose axis was directed outward and forward. The mean length and width of obturator foramen was 4.89 ± 0.07 cm and 2.60 ± 0.07 cm, respectively (Table.11).

Femur:

Femur was the longest bone of the appendicular skeleton of leopard. It was strong, heavy and cylindrical, directed downward and forward in an oblique manner. It articulated with acetabulum to form hip joint and with, tibia, fibula and patella below to form stifle joint. It presented a shaft and two extremities.

The shaft was uniformly cylindrical (Plate.18). The mean circumference of the shaft was 7.17 ± 0.15 cm, 6.55 ± 0.08 cm and 7.97 ± 0.22 cm at its upper, middle and lower parts, respectively (Table.12). Lateral, medial and cranial surfaces were smooth except proximal part of the cranial surface was rough. The upper third of the caudal surface was rough while lower one third was smooth and expanded (Plate.18). The lesser trochanter was in the form of a small tuberosity, situated at the upper part of medial border (Plate.19). Distal part of the medial border presented rough prominence known as medial supracondyloid crest in the form of rough prominence. At the same level, towards the lateral side, lateral supracondyloid crest was present.

Proximal extremity of the femur comprised of head, greater trochanter, and deep trochanteric fossa. Trochanter major was lower in position than the head (Plate.19). The mean circumference and width of the proximal extremity was measured 12.30 ± 0.21 cm and 4.97 ± 0.05 cm, respectively (Table.12). The head of femur was smooth, spherical and placed medially. It was 7.85 ± 0.10 cm in circumference and 3.67 ± 0.18 cm in diameter and articulated with the cotyloid cavity of os coxae to form hip joint. The fovea capitis was in the form of small depression located slightly medial to the center. Neck was prominent medially. On the lateral side of proximal extremity, there was compressed mass of bone known as greater trochanter rough muscular lines for muscular attachment. Trochanteric ridge connected greater and lesser trochanter and was oblique. Between neck and greater trochanter, there was a deep depression, the trochanteric fossa (Plate.19). The mean depth of trochanteric fossa was 1.60 ± 0.03 cm.

Distal extremity of femur was larger than proximal extremity. It consisted of trochlea, cranially and condyles, caudally. The mean circumference and width of distal extremity were measured as 14.92 ± 0.63 cm and 4.61 ± 0.06 cm respectively (Table.12). The trochlea was 2.25 ± 0.10 cm wide. The medial ridge of the trochlea was lower and shorter than lateral ridge. The lateral aspects of both the condyles were rough and presented shallow depression. The medial condyle was regular and more convex than the lateral condyle (Plate.20). The lateral condyle was slightly lower in position than the medial condyle. The intercondyloid fossa was wide and rough. The mean depth of intercondyloid fossa was 1.47 ± 0.04 cm.

Patella:

The patella was the largest sesamoid bone of the body, articulated with the trochlea of femur and formed femoro-patellar articulation. It was oval in shape with proximal part slightly wider than the distal part. The cranial surface was convex and rough in its upper part. Caudal surface was almost flat slightly raised in its middle parts and articulated with trochlea. Base of patella was wider and much thicker than the apex (Plate.21). Both medial and lateral borders were sharp and converge at the apex. The total mean length of the patella was 2.92 ± 0.17 cm. The mean width of the patella in its middle part was 2.35 ± 0.15 cm. Maximum thickness of the patella was 1.25 ± 0.12 cm (Table.12).

Table 12. Mean and S.E. of different parameters of femur

S. No.	Paramsters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	113.97	130.37	123.65	118.51	121.63	1.76
2.	Length (cm)	23.00	27.20	25.00	24.10	24.82	0.44
3.	Shaft (cm).						
	Length	17.50	22.50	20.50	19.50	20	0.62
	Circumference						
	• Upper part	6.60	7.90	7.80	6.70	7.17	0.15
	• Middle part	6.20	6.90	6.80	6.30	6.55	0.08
	• Lower part	7.00	8.90	8.60	7.40	7.97	0.22
4.	Height/ length of trochanter major (cm)	3.90	5.90	5.70	5.10	5.15	0.22
5.	Head (cm)						
	• Circumference	7.50	8.00	8.40	7.90	7.85	0.10
	• Diameter	2.70	4.30	4.20	3.50	3.67	0.18
6.	Depth (cm)						
	• Trochanter fossa	1.50	1.60	1.60	1.50	1.60	0.03
	• Intercondyloid fossa	1.30	1.70	1.50	1.40	1.47	0.04
7.	Proximal extremity (cm)						
	• Circumference	11.20	13.10	12.90	12.10	12.30	0.21
	• Width	4.70	5.20	5.08	4.92	4.97	0.05
8.	Distal extremity (cm)						
	• Circumference	13.80	16.40	15.50	14.20	14.92	0.53
	• Width	4.50	4.80	4.64	4.53	4.61	0.06
9.	Width of trochlea (cm)	2.00	2.50	2.30	2.20	2.25	0.10

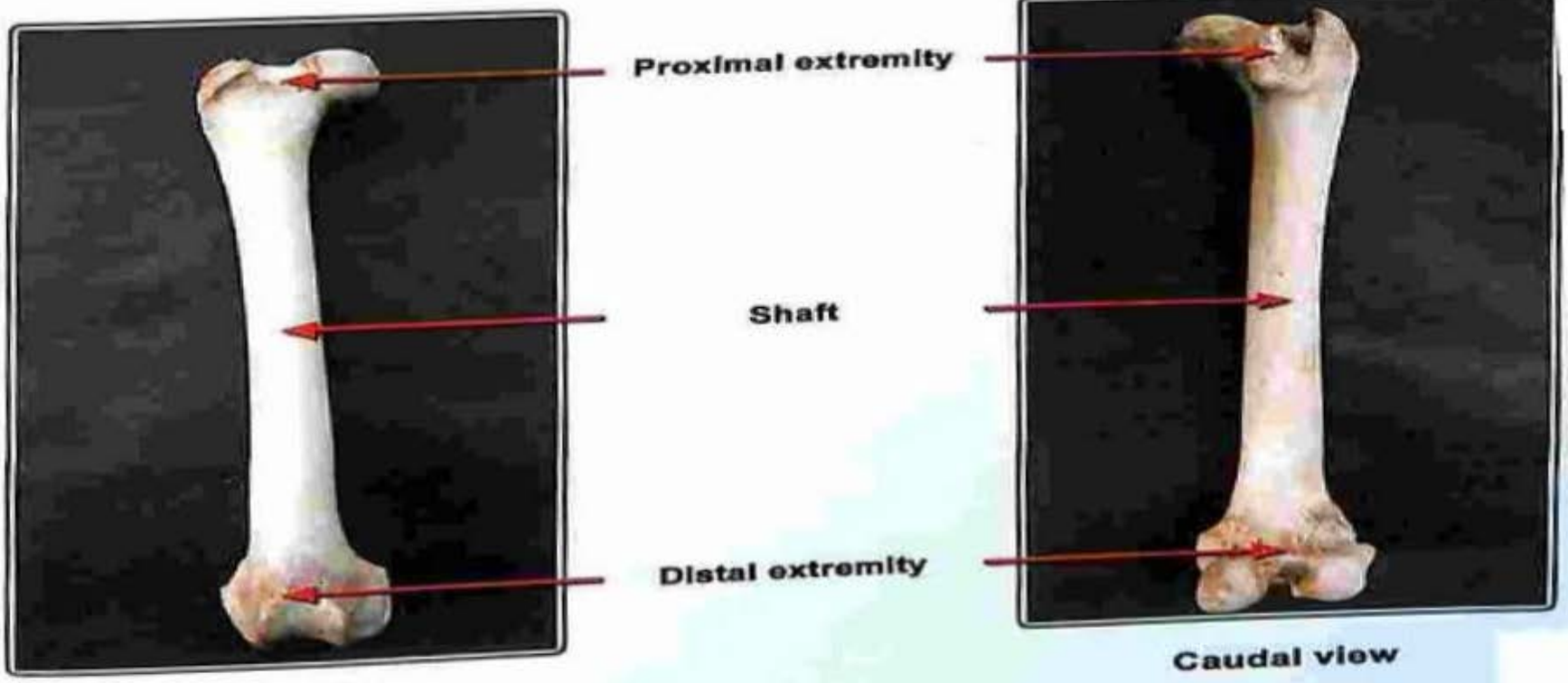


Plate 18: Femur

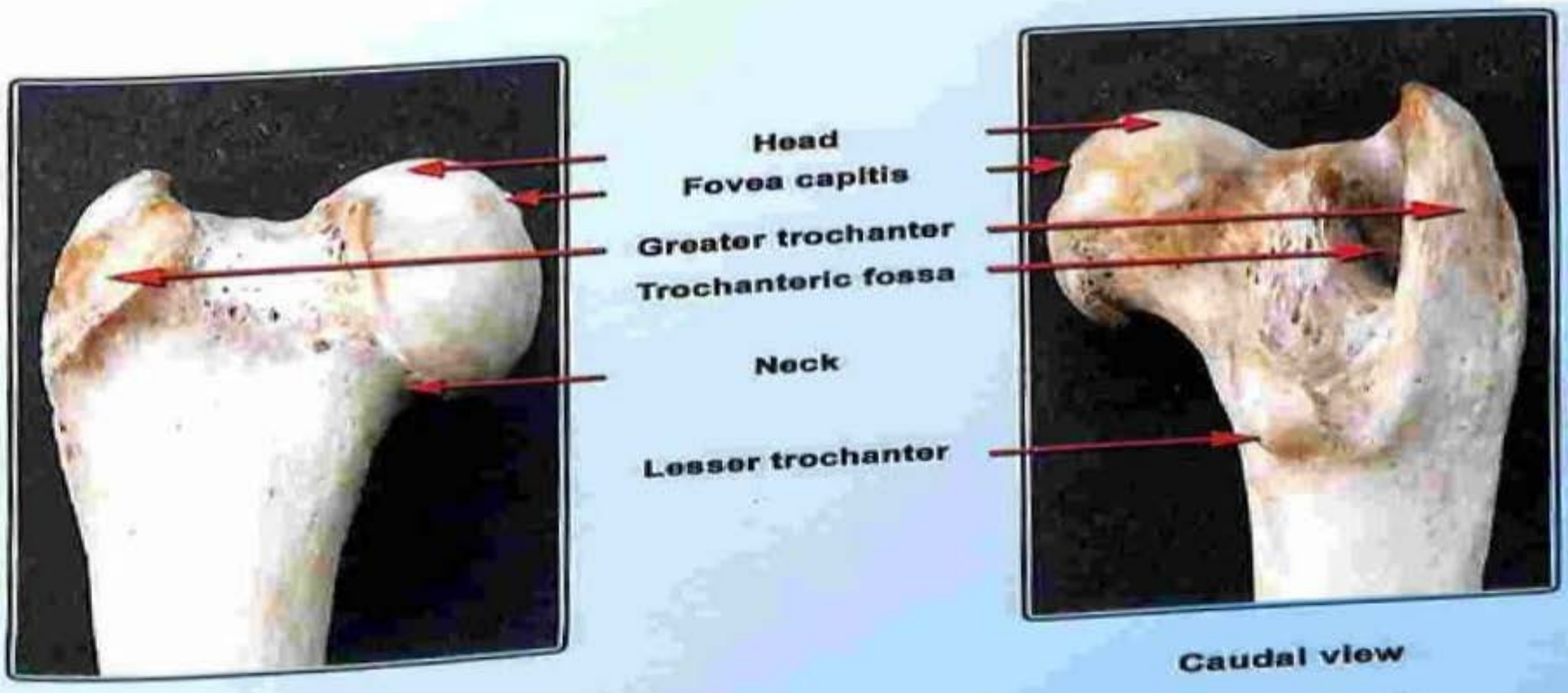


Plate 19: Femur (Proximal extremity)

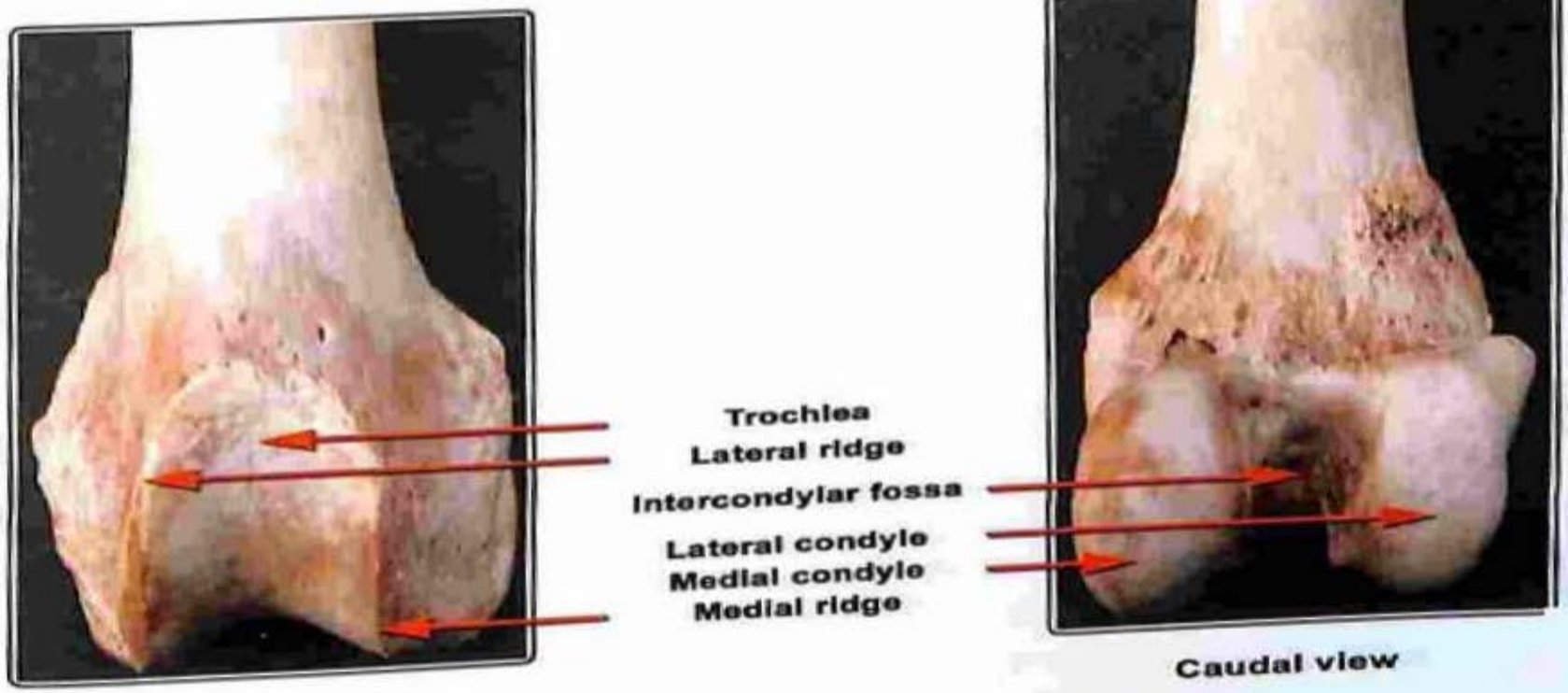


Plate 20: Femur (Distal extremity)

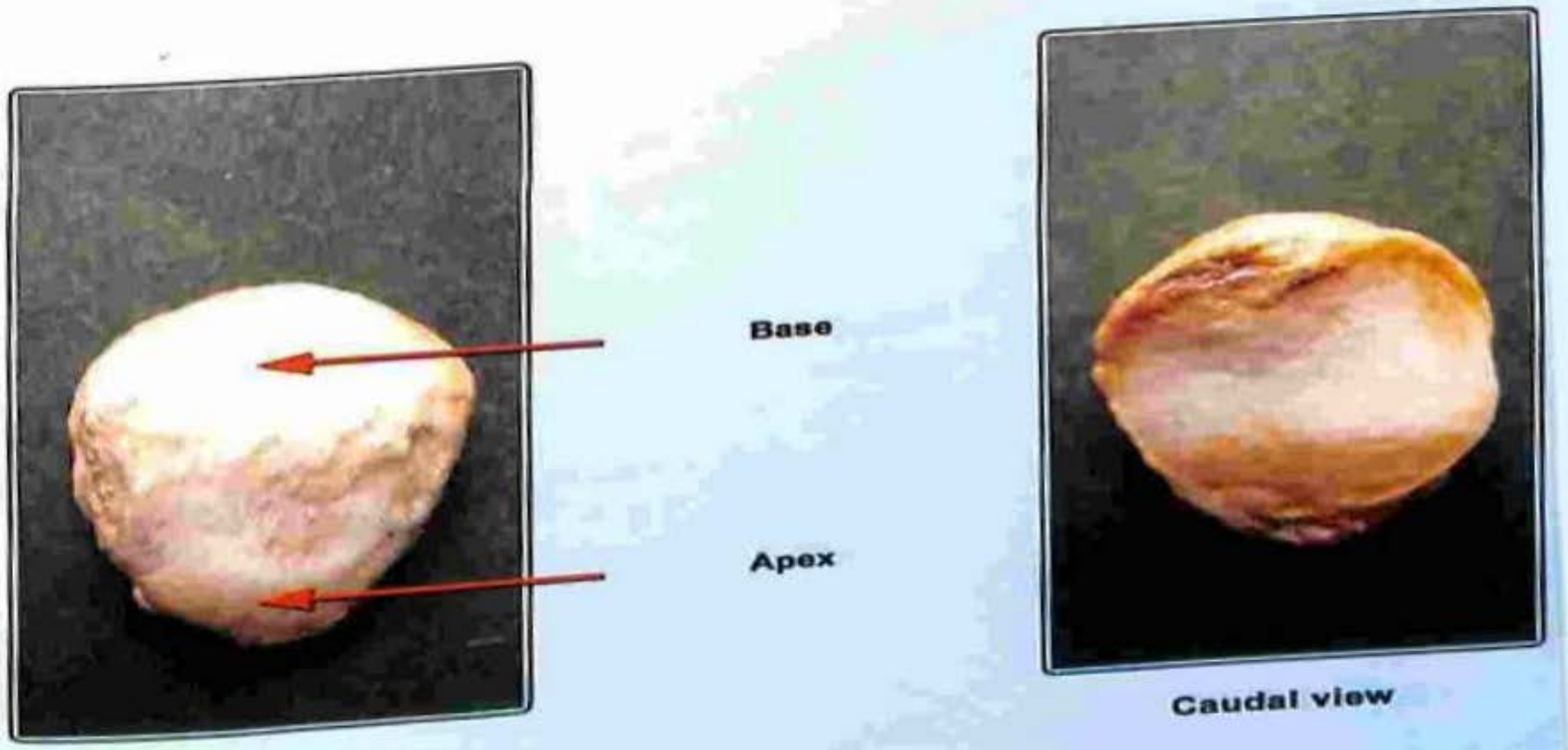


Plate 21: Patella

Tibia and Fibula:

Tibia:

It was the larger of the two bones in the leg region. The total mean length of tibia was 22.72 ± 0.70 cm. It had a shaft and two extremities.

The shaft was prismatic at its upper two third and cylindrical at its lower third (Plate.22). The mean circumference of the shaft was 9.62 ± 0.47 cm, 6.67 ± 0.15 cm and 6.62 ± 0.92 cm at its upper, middle and lower part respectively (Table.14). Medial surface of the shaft was rough and slightly concave close to the proximal extremity and smooth and straight distally. Lateral surface was smooth and deeply concave at its upper fourth straight in its distal 3/4th. Caudal surface was straight and had two distinct oblique popliteal lines in its upper half (Plate.22). Nutrient foramen was present on the upper fourth of the caudal surface very close to the lateral border.

The proximal extremity was much larger than the distal extremity. It had medial and lateral condyles. The mean circumference and width of the proximal extremity was 14.00 ± 0.41 cm and 4.65 ± 0.14 cm respectively (Table.14). The mean length of the medial condyle (3.32 ± 0.12 cm) was more than the lateral condyle (2.97 ± 0.08 cm) whereas mean width of medial condyle (1.70 ± 0.10 cm) was less than the lateral condyle (1.92 ± 0.12 cm) (Table.14). The intercondyloid eminences (medial and lateral) were of more or less of same height. The free edge of medial eminence was sharp while that of lateral one was blunt. In front of the lateral condyle, there was a large elliptical smooth area (Plate.23). Such area was absent in front of the medial condyle. Cranial part of proximal extremity presented tibial tuberosity, which was rough at its upper part and smooth at its lower part (Plate.23). Sulcus muscularis on the cranial aspects of the lateral condyle was shallow. Popliteal notch was distinct on the caudal aspect of the proximal extremity between two condyles. On caudo-lateral aspect on the lateral condyle, there were two small facets for articulation with proximal extremity of the fibula bone.

Distal extremity of the tibia presented two cranio-caudally directed oblique articular grooves. The mean circumference and width of the

distal extremity was 9.27 ± 0.15 cm and 3.15 ± 0.06 cm respectively (Table.14). The medial articular groove was much deeper than lateral one. Laterally, the distal extremity presented an articular facet, which articulated with distal extremity of fibula. Medial mallelous presented rough area for the attachment of collateral ligament (Plate.24).

Fibula:

It was very thin and flattened mediolaterally and curved distally. It presented a shaft and two extremities.

The mean circumference of the shaft was 2.32 ± 0.03 cm, 2.75 ± 0.04 cm and 2.45 ± 0.03 cm at its upper, middle and lower part respectively (Table.15). The shaft was thin and cylindrical in proximal third and flat in the lower 2/3rd (Plate.25). The medial surface was flat and did not come in contact with tibia. Lateral surface was convex and faced laterally in upper 2/3rd. The cranial border was sharp in the upper 2/3rd. The caudal border was blunt in upper 2/3rd and became sharp in lower 1/3rd.

The mean circumference and width of the proximal extremity was 4.75 ± 0.06 cm and 1.81 ± 0.03 cm respectively (Table.15).The proximal extremity was convex compressed transversely. Laterally, there were two eminences viz. cranial and caudal separated by a vertical sulcus (Plate.26).

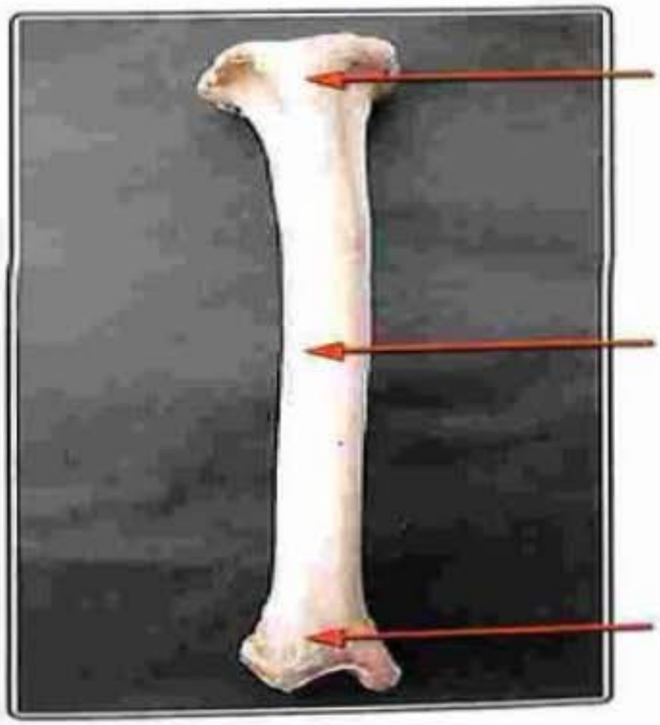
The mean circumference and width of distal extremity were measured 4.82 ± 0.05 cm and 2.02 ± 0.04 respectively (Table.15). The distal extremity was also compressed medio-laterally and much thicker than proximal extremity. The medial surface on its cranial aspects had a wider articular facet articulated with the tibia and also with the fibular tarsal. There was another articular facet caudally which articulated only with fibular tarsal bone. On the lateral aspect of the extremity there was deep, vertical groove known as the sulcus malleolaries lateralis. Lateral malleolus was the distal extremity of fibula (Plate.27).

Table 14. Mean and S.E. of different parameters of tibia

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	94.81	98.23	96.67	95.18	96.22	0.78
2.	Length (cm)	21.00	24.10	23.60	22.20	22.72	0.70
3.	Shaft (cm)						
	Length	17.00	19.90	19.50	18.00	18.6	0.67
	Circumference						
	• Upper part	8.90	11.00	9.50	9.10	9.62	0.47
	• Middle part	6.40	7.10	6.70	6.50	6.67	0.15
	• Lower part	5.50	9.40	5.90	5.70	6.62	0.92
4.	Medial condyle(cm)						
	• Length	3.00	3.60	3.40	3.30	3.32	0.12
	• Width	1.50	2.00	1.70	1.60	1.70	0.10
5.	Lateral condyle(cm)						
	• Length	2.80	3.20	3.00	2.90	2.97	0.08
	• Width	1.60	2.20	2.00	1.90	1.92	0.12
6.	Proximal extremity (cm)						
	• Circumference	13.00	15.00	14.10	13.90	14.00	0.41
	• Width	4.30	5.00	4.70	4.60	4.65	0.14
7.	Distal extremity(cm)						
	• Circumference	9.00	9.70	9.30	9.10	9.27	0.15
	• Width	3.00	3.30	3.20	3.10	3.15	0.06

Table 15. Mean and S.E. of different parameters of fibula

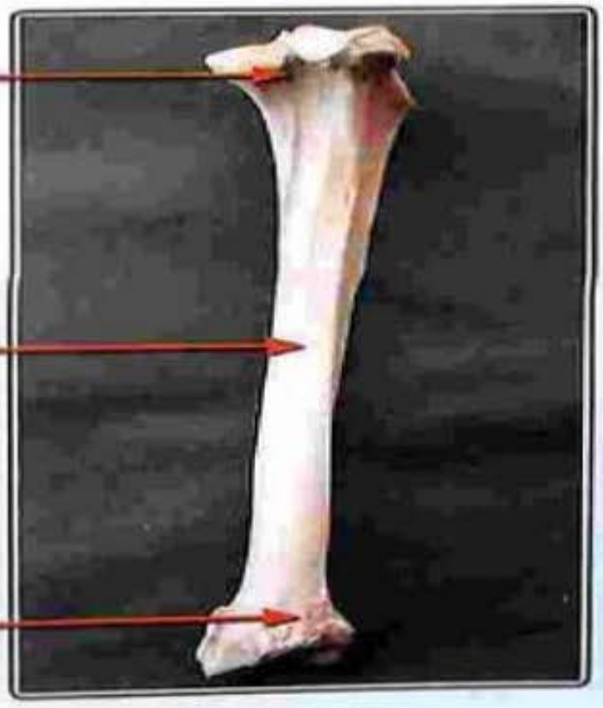
S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Weight (gm)	10.37	14.29	12.38	11.31	12.08	0.42
2.	Length (cm)	19.70	22.80	21.30	20.70	21.12	0.32
3.	Shaft(cm)						
	Length	16.60	19.50	18.10	17.50	17.92	0.60
	Circumference						
	• Upper part	2.20	2.50	2.30	2.30	2.32	0.03
	• Middle part	2.60	3.00	2.70	2.70	2.75	0.04
	• Lower part	2.30	2.60	2.20	2.40	2.45	0.03
4.	Proximal extremity (cm)						
	• Circumference	4.40	5.00	4.90	4.70	4.75	0.06
	• Width	1.62	1.91	1.81	1.92	1.81	0.03
5.	Distal extremity (cm)						
	• Circumference	4.60	5.80	5.40	4.90	4.82	0.05
	• Width	1.86	2.27	2.03	1.92	2.02	0.04



Proximal extremity

Shaft

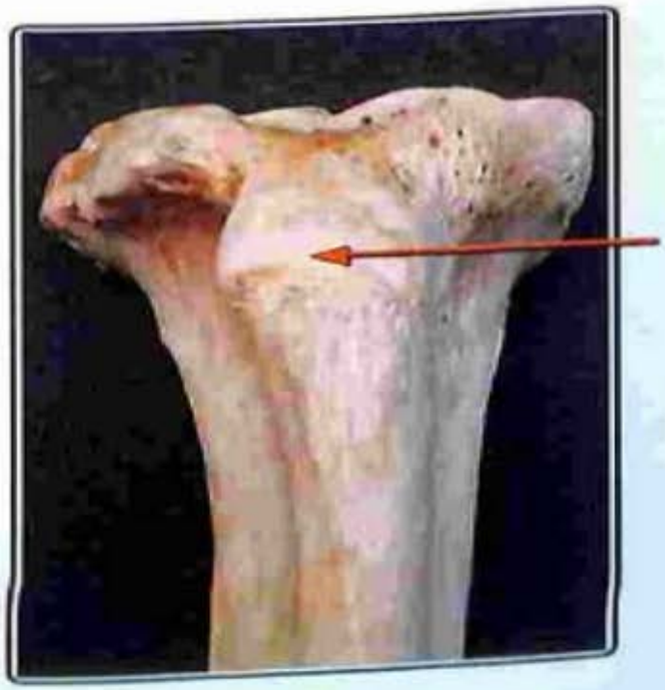
Distal extremity



Cranial view

Caudal view

Plate 22: Tibia



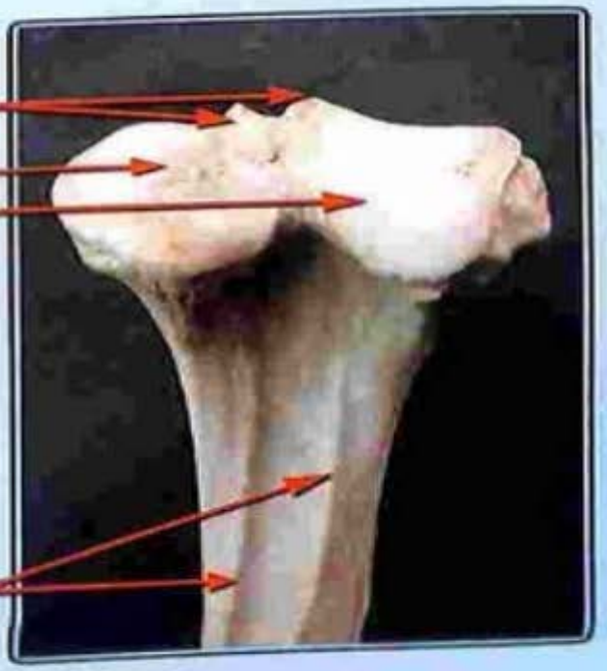
Intercondyloid eminences

Medial condyle

Lateral condyle

Tibial tuberosity

Popliteal lines



Cranial view

Caudal view

Plate 23: Tibia (Proximal extremity)

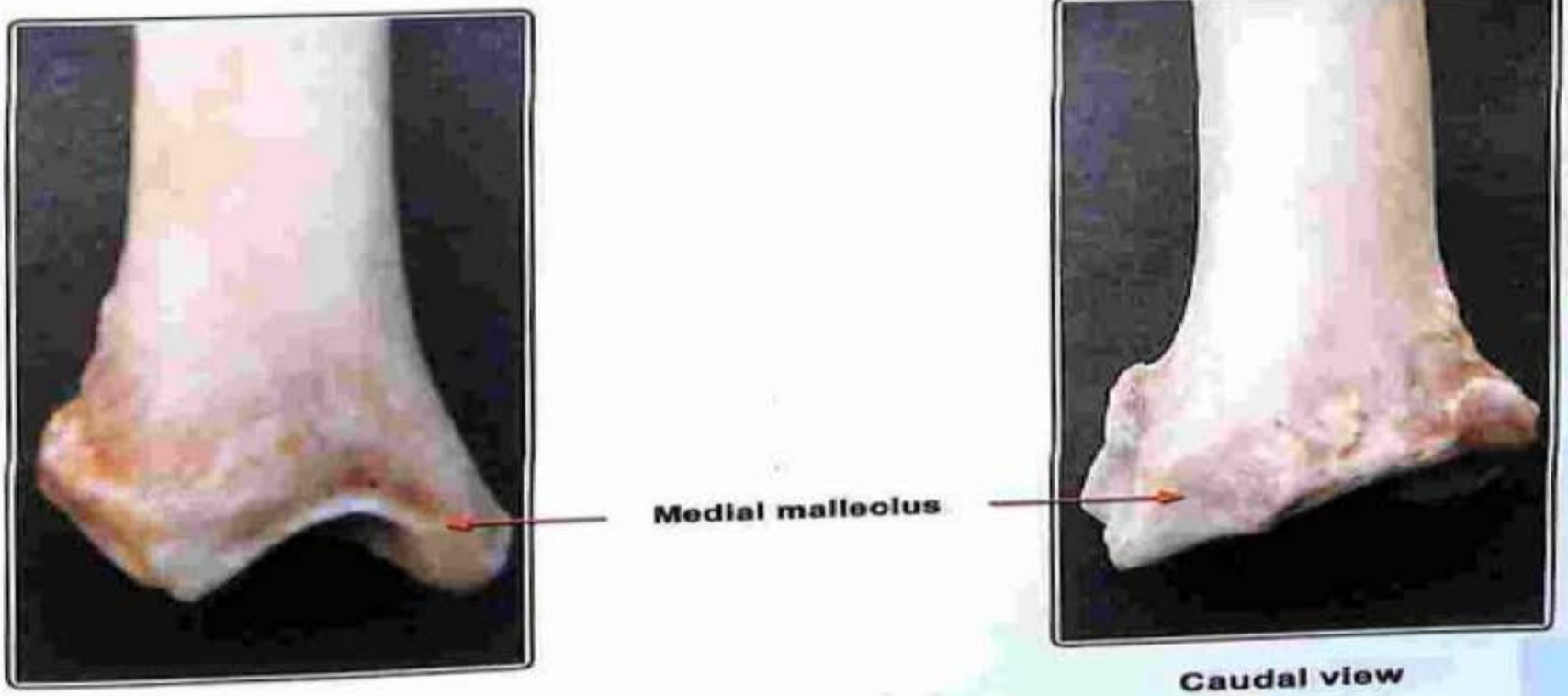


Plate 24: Tibia (Distal extremity)

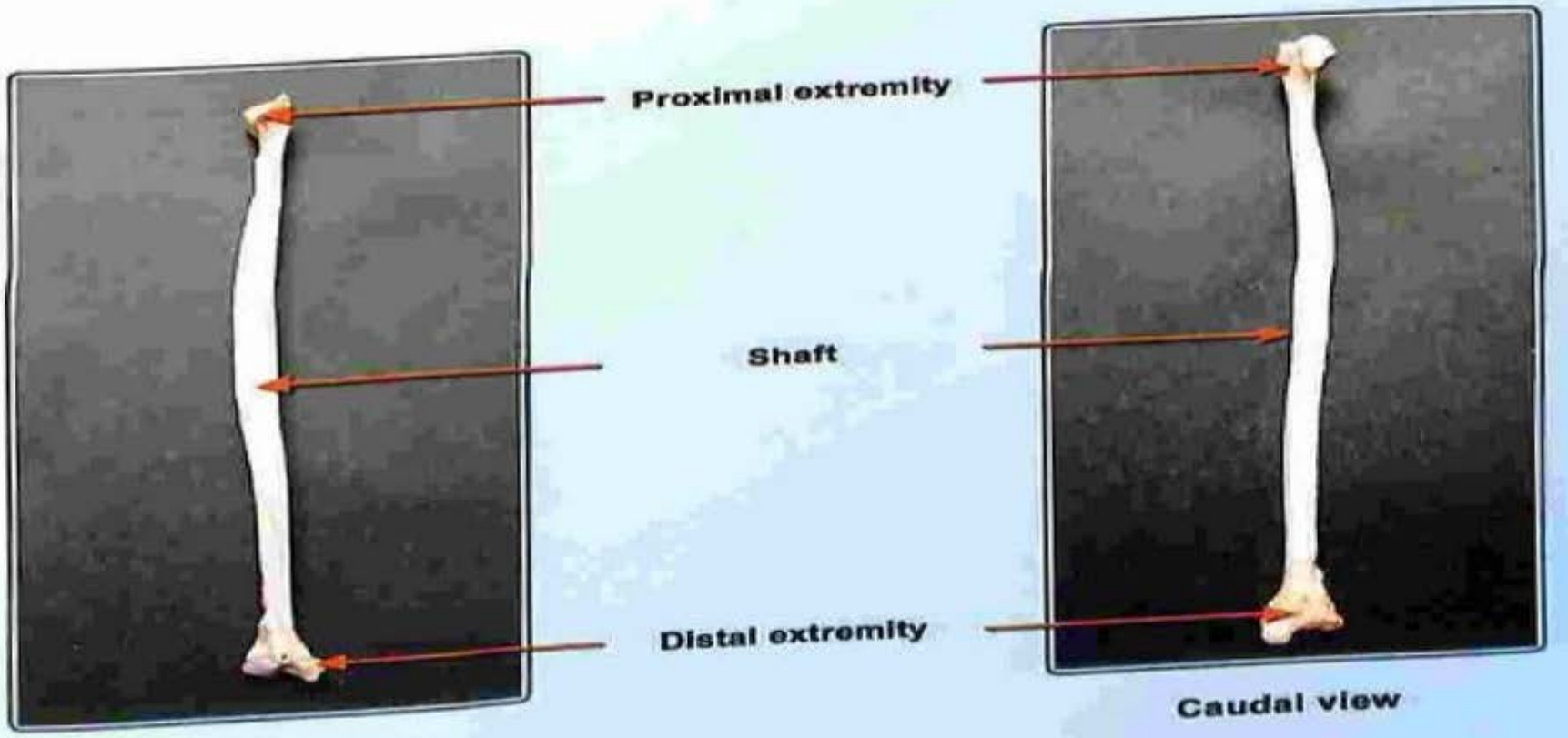


Plate 25: Fibula

Tarsal:

The number of tarsal bones was 7 viz. tibial tarsal, fibular tarsal, central tarsal, first, second, third and fourth tarsal arranged in two transverse rows. Tibial and fibular tarsal were presented in proximal. First, second and third in the distal row. Central and fourth were interposed between the two.

Tibial tarsal:

It was second largest bone and was medial bone of first row (Plate.28). The trochlear ridges directed craniodorsally. It had head, body and neck.

The body had cranio-proximally located trochlea. The ridges of the trochlea were not of equal size. The trochlear ridges were slightly oblique. The lateral one was longer, wider than the medial one. Medial one was smaller with sharp edge. The ridges were separated by cranio-dorsal grooves. Laterally, the body had slightly concave smooth facet articulated with the styloid process of the ulna. Caudally, the body had two facet separated by deep wide groove. The lateral articular area was concave and about double the size of medial. The medial articular area was straight and oval in shape.

Head was directed medio-distally in the form of a rounded smooth, convex projection and articulated with the proximal surface of the central tarsal bone. The neck was junction between head and body.

Fibular tarsal:

The fibular tarsal was the largest and longest bone of the tarsus (Plate.28). The distal half of the bone had a wide transverse groove and presented three processes. The tuber calcanei formed the proximal half of the bone. Its free proximal end was bulbous and compressed. The medial and lateral processes separated by a wide groove. The sustentaculum tali was medial in position. On the plantar side, of this surface, there was shallow groove for the passage of the tendons. The dorsomedial side had a concave, oval facet for articulation with the medial articular surface of the tibial tarsal. The dorsal articular surface was convex for articulation with the tibial tarsal. Distally, the bone presented an articular large facet.

Central tarsal:

The central tarsal was present on the medial side of the tarsus and was placed between proximal and distal row. It articulated with all other tarsal bone. Proximally, it had a large, concave, oval facet for articulation with head of tibial tarsal and a small facet for articulation with the fibular tarsal (Plate.28). Distally, the central tarsal presented facet for articulation with the first, second and third tarsal and laterally for the proximal half of fourth tarsal.

First tarsal:

It was compressed transversely (Plate.28). It presented facet for articulation with central tarsal, second tarsal and I metatarsal

Second tarsal:

It was the smallest of the tarsal bones (Plate.28). It was a wedge shaped. It articulated with central tarsal proximally, the third tarsal laterally, first tarsal medially and second metatarsal distally.

Third tarsal:

The third tarsal was irregularly elongated in shape, wide infront and narrow behind (Plate.28). The plantar side was in the form of round tuberosity. Its proximal surface articulated with central tarsal. Distally, it articulated III metatarsal. Laterally it presented a curved facet for articulation with the corresponding facet of the fourth tarsal. Medially, it had a facet for articulation with second tarsal and metatarsal bones.

Fourth tarsal:

The fourth tarsal was thick, massive bone which accommodated central and third tarsal on its medial side (Plate.28). Proximal surface presented a large facet for articulation mainly with fibular tarsal and partly with the tibial tarsal. Medially, it presented articular facet for articulation with the central and third tarsal. Its distal surface had a large articular facet for articulation with the IV and V metatarsal bone. The distal half of the lateral surface had a wide groove for the passage of the tendons.

Table.16 Mean and S.E. of different parameters of tarsals:

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Tibial tarsal						
	• Weight (gm)	9.29	9.87	9.72	9.54	9.60	0.12
	• Area (cm^2)	6.17	6.75	6.58	6.40	6.47	0.12
2.	Fibular tarsal						
	• Weight (gm)	17.61	18.11	18.03	17.87	17.90	0.11
	• Area (cm^2)	8.39	8.96	8.78	8.60	8.68	0.12
3.	Central tarsal						
	• Weight (gm)	3.09	3.64	3.46	3.32	3.37	0.11
	• Area (cm^2)	2.65	3.21	3.05	2.92	2.95	0.11
4.	First tarsal						
	• Weight (gm)	0.50	0.81	0.66	0.54	0.62	0.06
	• Area (cm^2)	0.42	0.78	0.57	0.47	0.56	0.07
5.	Second tarsal						
	• Weight (gm)	0.73	0.98	0.87	0.79	0.84	0.05
	• Area (cm^2)	0.68	0.90	0.81	0.72	0.77	0.04
6.	Third tarsal						
	• Weight (gm)	2.39	2.62	2.50	2.44	2.48	0.04
	• Area (cm^2)	1.81	2.07	1.99	1.87	1.93	0.05
7.	Fourth tarsal						
	• Weight (gm)	2.90	3.21	3.02	2.97	3.02	0.06
	• Area (cm^2)	1.69	1.99	1.80	1.75	1.80	0.06

Metatarsals:

The metatarsal bones were five in number and numbered I to V from medial to lateral side (Plate.29). They were comparatively longer than the metacarpal bones. The I metatarsal bone was observed in the form of small, atypical bone. The metatarsal II was shorter in comparison to metatarsal III, IV and V (Plate.29). The metatarsal II to V were consisted of a base, shaft and head. The base or proximal end was elongated craniocaudally and had a caudal projection. The III and IV bore facet for articulation with the two small rounded sesamoid bones. The base articulated with the tarsal bones. The shaft was observed triangular in proximal part, quadrangular in the middle. The shaft of metatarsal II was prismatic proximally and flattened distally. The shaft of III and IV metatarsal was massive than II. The shaft was flattened craniocaudally and semi cylindrical in shape. The shaft of metatarsal IV was slightly more curved than metatarsal III. The shaft of metatarsal V was more curved than metatarsal II to IV and was compressed craniocaudally (Plate.29). The distal extremity of metatarsal II to V was comprised of a ball shaped head. The articular head was divided into two areas by a prominent sagittal ridge. I metatarsal was rudimentary atypical and was much shortest. The metatarsal III and metatarsal IV were longest (Plate.29). The metatarsal V was slightly shorter than the metatarsal II.

PHALANGES:

The first digit was absent in the hindlimb (Plate.30). These phalanges bore same features as the phalanges in the forelimb. The third phalanx was small as compare to that of the third phalanx in forelimb.

UNGUIS:

The unguis was four in number in hindlimb (Plate.31). The characteristic features were same as those of unguis in forepaw.

Table 17. Mean and S.E. of different parameters of metatarsals

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	First metatarsal						
	• Weight(gm)	0.54	0.81	0.68	0.60	0.65	0.05
	• Length (cm)	2.00	2.20	2.10	2.00	2.07	0.04
	• Width (cm)	0.81	1.01	0.97	0.91	0.92	0.04
2.	Second metatarsal						
	• Weight(gm)	6.38	6.76	6.56	6.47	6.54	0.08
	• Length (cm)	7.00	7.20	7.10	7.00	7.07	0.04
	• Width (cm)	0.90	1.19	1.02	0.96	1.01	0.06
3.	Third metatarsal						
	• Weight(gm)	8.92	9.10	9.01	8.99	9.00	0.03
	• Length (cm)	7.80	8.00	7.90	7.80	7.87	0.04
	• Width (cm)	1.02	1.20	1.14	1.08	1.11	0.03
4.	Fourth metatarsal						
	• Weight(gm)	8.77	8.98	8.92	8.87	8.88	0.04
	• Length (cm)	7.90	8.10	8.00	7.90	7.97	0.04
	• Width (cm)	1.01	1.22	1.15	1.07	1.11	0.04
5.	Fifth metatarsal						
	• Weight(gm)	4.86	5.05	4.99	4.91	4.95	0.04
	• Length (cm)	6.70	6.90	6.80	6.70	6.77	0.04
	• Width (cm)	1.63	0.82	0.76	0.70	0.97	0.21

Table 18. Mean and S.E. of different parameters of proximal phalanx

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Second digit						
	• Weight (gm)	2.35	2.81	2.48	2.42	2.51	0.10
	• Length (cm)	2.60	2.70	2.70	2.60	2.65	0.02
	• Width (cm)	0.80	1.12	0.93	0.84	0.92	0.07
2.	Third digit						
	• Weight (gm)	2.85	3.15	3.02	2.94	2.99	0.06
	• Length (cm)	2.90	3.20	3.00	2.90	3.00	0.07
	• Width (cm)	0.90	1.20	1.07	1.00	1.04	0.06
3.	Fourth digit						
	• Weight (gm)	3.02	3.27	3.14	3.05	3.12	0.05
	• Length (cm)	2.90	3.20	3.00	2.90	3.00	0.07
	• Width (cm)	0.91	1.18	1.14	1.01	1.06	0.06
4.	Fifth digit						
	• Weight (gm)	2.43	2.68	2.55	2.48	2.53	0.05
	• Length (cm)	2.50	2.70	2.60	2.50	2.57	0.04
	• Width (cm)	0.80	1.12	0.96	0.88	0.94	0.06

Table 20. Mean and S.E. of different parameters of distal phalanx

S. No.	Parameters	Skeleton I	Skeleton II	Skeleton III	Skeleton IV	Mean	S.E.
1.	Second digit						
	• Weight (gm)	0.79	1.06	0.91	0.85	0.90	0.05
	• Length (cm)	1.40	1.60	1.50	1.40	1.47	0.04
	• Width (cm)	1.90	2.16	2.01	1.96	2.00	0.05
2.	Third digit						
	• Weight (gm)	1.21	1.48	1.33	1.26	1.31	0.05
	• Length (cm)	1.50	1.80	1.60	1.50	1.60	0.07
	• Width (cm)	2.10	2.35	2.23	2.17	2.21	0.05
3.	Fourth digit						
	• Weight (gm)	1.21	1.49	1.38	1.28	1.34	0.06
	• Length (cm)	1.60	1.80	1.70	1.60	1.67	0.04
	• Width (cm)	2.10	2.37	2.27	2.20	2.23	0.05
4.	Fifth digit						
	• Weight (gm)	1.14	1.40	1.26	1.20	1.25	0.05
	• Length (cm)	1.50	1.70	1.60	1.50	1.57	0.04
	• Width (cm)	2.00	2.29	2.13	2.09	2.12	0.06

Plate 30: Phalanges (Dorsal view)

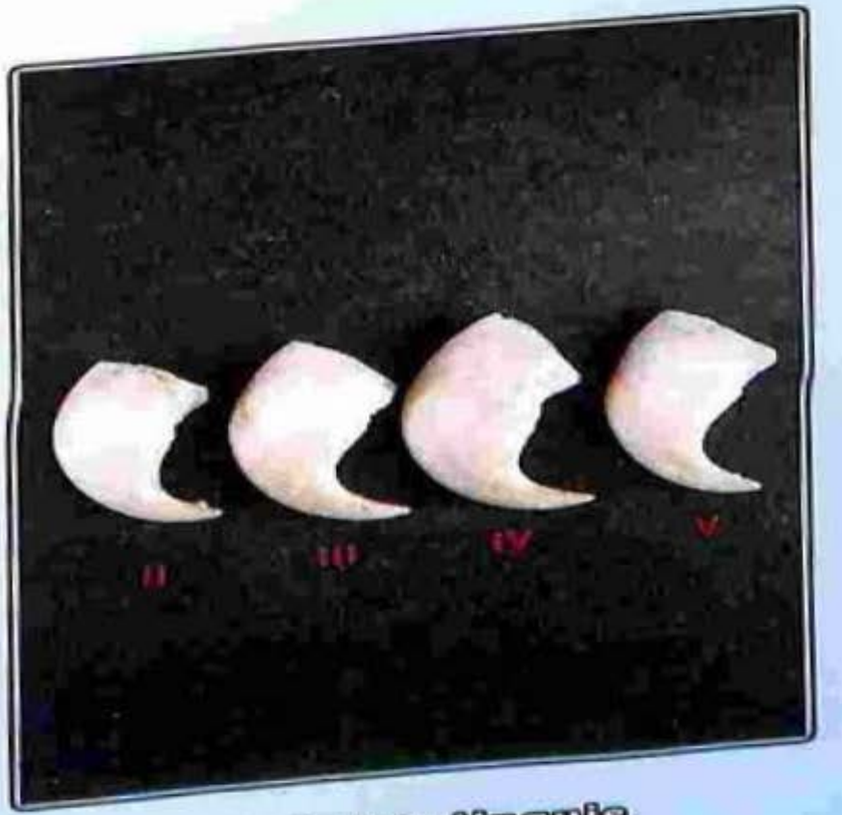


Plate 31: Unguis

DISCUSSION

DISCUSSION

Scapula:

The lateral surface of the scapula of leopard had well developed scapular spine, which divided the surface into 2 equal areas. The present observation is accordance with the report of Panday *et. al,* (2004) in lion, Bordoloi *et. al,* (1998) and Pandit (1994) in tiger. The acromion process, which was blunt and overhanged the glenoid cavity. Small metacromion process was also present. The characteristic features of the scapula of leopard resembled to that of tiger, (Pandit, 1994). Maximum width of supraspinous fossa and infraspinous fossa were 4.92 ± 0.37 cm and 6.25 ± 0.26 cm which were little lower than in lion (5.38 ± 0.06 cm and 6.45 ± 0.18 cm), respectively reported Panday *et. al,* (2004). Borders of scapula resembles with that of dog except caudal which was straight and thin in leopard whereas straight and thick in dog (Sisson, 1977).

The scapula of leopard differs from that of dog by its undulating supraspinous fossa.. The metacromion process was present about 2.8 cm behind the acromion process whereas in case of dog metacromion process was just above the acromion process (Raghvan, 1964). The subscapular fossa of the scapula of the leopard was undulating whereas in case of lion, it was very deep near glenoid cavity (Panday *et. al,* 2004).

Humerus:

The medial surface of the shaft was wide at its upper part and narrower distally. Lateral surface was smooth, convex and twisted and separated from the cranial surface by deltoid surface. The presence of comparatively wider biciipital groove in the proximal extremity may probability due to for giving passage to a thick a tendon of biceps brachii muscle. Comparatively the wider medial, lateral, cranial and caudal surface of the shaft provides lodgment of comparatively thick muscle than the dog. Since the leopard is more fast running animals than the dog.

At distal extremity, there was no supratrochler formena as reported by Sisson (1977) and Evans and Christensen (1979) in dog. Just above the medial condyle an oval shaped small interossous space recorded

in the present observation confirm the report of in tiger (Pandit, 1994) and Ray *et al.*, (1997) in leopard.

Radius and ulna:

Radius:

The radius bone of leopard was flattened cranio-caudally and placed cranio-medial to the ulna. The cranial surface was slightly convex with rough small eminences. The lateral border was straight and rough at its middle third. The medial border was blunt, smooth and slightly convex similar morphology of lateral and medial border has been described by Pandit (1994) in tiger.

Proximal extremity was much smaller than the distal extremity and had oval, concave facet surrounded by a rim. Distal extremity of radius consisted of concave carpal articular surface which was wide laterally and narrows medially. Its medial border had projection distally forming styloid process as reported in dog, Sisson (1977) and in tiger, Pandit (1994). The semilunar notch was smooth, half moon shaped concavity which faced cranially as in dog (Evans and Christensen, 1979).

Ulna:

Ulna was longer than the radius in case of leopard. It was flattened, mediolaterally. Cranial border was thick in upper part then gradually became thin and terminated in the form of styloid process. The olecranon posses 3 tubercles. The caudal tubercle was largest. Similar report has been stated by Sisson (1977) in dog. The lateral surface of olecranon process was rough and elevated whereas medial surface was smooth and concave.

Carpals:

The carpal bones of the leopard were seven in number arranged in the proximal and distal row. The bones of the proximal row were intermedioradial, ulnar and accessory carpals. The carpals of the distal row were first, second, third and fourth. The present observation tallies with the report of (Sisson, 1977) in the dog whereas Pandit (1994) described the radial carpal as a separate bone in the tiger. The accessory carpal of the leopard was constricted in the middle expanded at both the extremities whereas

Sisson (1977) stated that accessory carpal of dog was cylindrical in shape. Evans and Christensen (1979) stated that accessory carpal was truncated rod shaped bone in the dog. Pandit (1994) stated that accessory carpal bone was a small, rod shaped bone in the tiger. The first carpal was observed as a flattened and smallest bone of second row in the leopard. Sisson (1977), Evans and Christensen (1979) in the dog and Pandit (1994) in tiger also reported first carpal as smallest carpal bone in the distal row. The gross morphology of the wedge shaped second carpal bone in the leopard observed in the present study was in accordance with that of Sisson (1977), Evans and Christensen (1979) in the dog and Pandit (1994) in tiger. The present observation made on the third and fourth carpal of the leopard tallied with that of Sisson (1977), Evans and Christensen (1979) in the dog and Pandit (1994) in tiger

Metacarpals:

In the leopard, metacarpals bones were five in number. The metacarpal I bone was shortest and thinnest amongst all metacarpals.

The present observation was in accordance with that of Sisson (1977) and Evans and Christensen (1979) in dog and Pandit (1994) in tiger.

Phalanges:

The articular surface of the proximal phalanx was deeply concave. The present study tallied with the report of Sisson (1977) in dog. The middle phalanx was absent in the first digit of leopard as also has been stated by Sisson (1977) and Evans and Christensen (1979) in dog. The proximal articular surface consisted of two concave facets separated by a faint sagittal groove as described by Sisson (1977) in dog. The ungul process of distal phalanx was in the form of thin, triangular plate with a broad base and pointed apex. The present study resembled with the finding of Evans and Christensen (1979) in dog who reported that distal part of distal phalanx was in the form of compressed cone.

Ossa Coxarum:

Ossa Coxarum of leopard was comprised of os coxae of both sides. Each os coxae consisted of ilium, ischium and pubis.

Ilium-

Ilium was placed in a vertical direction parallel to each other. The lateral surface/ gluteal surface of the ilium was deeply concave. The medial surface was rough and had at its lower part, elongated curved, bean shaped facet. The present observation tallied with the description of ilium of tiger (Pandit, 1994)

Ischium-

The ischium was much smaller than the ilium and presented in a twisted appearance. The pelvic surface was smooth and concave to accommodate the organs of the pelvic cavity. The ventral surface was rough for muscular attachment. The gross morphological features of the ishium observed in the present study resembled to that of tiger, (Pandit, 1994) and dog, (Sisson, 1977).

Pubis-

The pelvic surface was concave which had increased the volume of pelvic cavity whereas ventral surface was slightly convex for attachment of muscles. The gross morphology of the pubis of leopard resembled to that of tiger, (Pandit, 1994) and dog (Evans and Christensen, 1979). The articular facet for articulatiuon with the wings sacrum was bean shaped in leopard whereas the articular area has been reported as comma shaped in tiger, (Pandit, 1994). In the leopard, the conjugate diameter of pelvic measured was 6.9cm. Transverse diameter was 5.2 cm and vertical/oblique diameter was 4.9 cm.

Femur:

Femur was the longest bone in the appendicular skeleton of leopard. The shaft was regularly cylindrical except at the extremities. The present study tallied with the report of Pandit (1994) in tiger. It was strong, heavy and cylindrical bone. The cranial, medial and lateral surfaces were

smooth except proximal end of the cranial surface, which was rough. The caudal surface was rough in its upper third and smooth and expanded at its lower third whereas Ray (1996) reported that caudal surface was flat and smooth in leopard. The lesser trochanter was in the form of small tuberosity.

The proximal extremity of femur was comprised of head, greater trochanter and deep trochanteric fossa. The mean circumference of the proximal and distal extremities was measured as 12.30 cm and 14.92 cm, respectively whereas Ray (1996) recorded 11.2 cm and 14.00cm in the same species. Trochanter major was lower in position than the head. The head of femur was smooth, spherical and placed medially similar to that of tiger, (Pandit, 1994). The femur of leopard was comprised of three trochanters, trochanter major trochanter minor and third trochanter. The present observation coincided with that of Pandit (1994) in tiger. Sisson (1977) and Evans and Christensen (1979) has reported two trochanter in dog.

Distal extremity of femur was larger than proximal extremity. The medial ridge was slightly lower in position than the lateral ridge. The articular surface of the trochlea was wider. The lateral condyle was slightly higher than the medial in case of leopard. The lateral condyle was slightly lower in position than the medial condyle. The medial condyle was regular and more convex than the lateral condyle whereas Evans and Christensen (1979) reported that the medial condyle was smaller and less convex than that lateral condyle in dog.

Patella:

Patella was the largest sesamoid bone of the apppendicular skeleton of leopard. The cranial surface was rough and convex at its upper part whereas caudal surface was almost flat and slightly raised in the dorso-ventral direction. Base of patella was wider and much thicker than the apex. Both medial and lateral borders were sharp and converged at the apex. Similar observation was recorded by Sisson (1977) in dog, Pandit (1994) in tiger and Kirberger *et al.* (2003) in lion.

Tibia:

Tibia was larger than the fibula. The shaft was prismatic at its upper 2/3rd and more or less cylindrical at its lower 3rd resembled with that of tiger (Pandit, 1994).

The proximal extremity was much larger than the distal extremity. It was comprised of medial and lateral condyles. Popliteal notch was distinct on the caudal aspect of the proximal extremity between two condyles and resembled with that of tiger, Pandit (1994). The length of the medial condyle was more (3.32 ± 0.12 cm) was more than the lateral condyle (2.97 ± 0.08 cm), whereas width of medial condyle (1.70 ± 0.10 cm) was less than the lateral condyle (1.92 ± 0.12 cm). The medial and lateral spines were more or less same height and it tallies with the report of tiger Pandit (1994) in tiger. The condyles of proximal extremity of tibia of leopard were larger than that of dog.

The distal extremity was compressed medio-laterally and had two articular facets. The present observation on the tibia of leopard coincides with the description on tibia of dog (Sisson, 1977) except that tibia of leopard as whole was more massive. The popliteal lines were more prominent. Proximal and distal extremity was larger. The tibial crest was thicker in comparison to that of dog (Sisson, 1977).

Fibula:

Fibula of the leopard was thin. The shaft was irregular, flattened medio laterally and curved distally. It presented three surfaces medial, lateral and caudal. The cranial border was sharp in the upper 2/3rd.

The proximal extremity was convex and compressed transversely. Laterally, there were two eminences viz. cranial and caudal separated by a vertical sulcus and resembles to that of tiger (Pandit, 1994).

The distal extremity was also compressed medio-laterally and much thicker than proximal extremity and tallied with that of dog (Sisson, 1977).

Tarsals:

Body of tibial tarsal had cranio-proximally located trochlea. Similar findings had been reported in dog by Sisson (1977). Head was directed medio-distally and was in line with that of Pandit (1994) in tiger who reported that the head of tibial tarsal was distal extension of the bone separated by a constricted neck. The dorso medial side of the sustenculum tali of fourth tarsal had a concave, oval facet for articulation with the tibial tarsal and the present study tallied with the finding of Pandit (1994) in tiger. The fourth tarsal was thick, massive bone the present observation supported the statement of Sisson (1977) in dog and Pandit (1994) in tiger.

Metatarsals:

Shaft of II metatarsal was prismatic proximally and flattened distally. The present study contraindicated the study of Pandit (1994) in tiger. Who reported that second metatarsal of tiger was thin cylindrical rod shaped curved bone.

Phalanges:

The first digit was absent in the hindlimb and the present finding was in line with that of Pandit (1994) in tiger. Who also reported that, there was only four digits of the tiger. The first one was being absent.

SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTHER WORK

the sharp styloid process of the radius. Ulna was longer than the radius and was flattened medio-laterally. Olecranon process had three tubercles. The caudal tubercle was largest. There were seven carpal bones arranged in the proximal and distal row. The metacarpal bones were five in number. The metacarpal I was shortest and thinnest among all metacarpals. Each digit was consisted of three phalanges in which proximal phalanx was longest. The middle phalanx of the first digit was absent. The unguis were five in number in forepaw.

Hindlimb

Each os-coxae consisted of ilium, ischium and pubis. The gluteal surface of the ilium was deeply concave while medial surface was rough and had at its lower part, elongated curved, bean shaped facet for articulation with the wings of the sacrum. Ischium was much smaller than the ilium and had twisted appearance. The acetabular part was vertical while symphysical part was horizontal. Trochanter major of proximal extremity of femur was lower in position than the head. Trochanteric ridge connected greater and lesser trochanter and was less oblique. The shaft of femur was uniformly cylindrical. The circumference of the shaft was 7.17 ± 0.15cm, 6.55 ± 0.08 cm and 7.97 ± 0.22 cm at its upper, middle and lower part, respectively. The mean length, width and maximum thickness of the patella were 2.92 ± 0.17 cm, 2.35 ± 0.15 cm and 1.25 ± 0.12 cm, respectively. The proximal extremity of tibia was much larger than the distal extremity and had medial and lateral condyles. The sulcus muscularis on the cranial aspects of the lateral condyle was shallow. Fibula was thin and slightly shorter than the tibia. The number of tarsal bones was seven viz. tibial tarsal, fibular tarsal, central tarsal, first, second, third and fourth tarsal arranged in two transverse rows. Metatarsals were comparatively longer than the metacarpal bones. The first digit was absent in the hindpaw and unguis were four in number.

Conclusion:

The following conclusions were drawn out of the present study.

- The gross morphological and morphometrical parameters were established.
- The major bones of leopard differentiated on gross morphological and morphometrical parameters with the bones of other species.
- The information obtained by the study will be of academic importance.
- The data base of the present study will be helpful as an aid in wildlife forensic for conviction of the poacher in the court of law.

Suggestions:

1. Gross morphological features and measurements of schedule-I animal should be studied for preparation of a complete database for species identification.
2. Comparative ostetological studies of major bones of schedule-I animals of Wildlife Protection Act 1972 should be carried out.
3. Radiological study of major bones of leopard may be useful for identification and determination of age.
4. Microscopic anatomical characteristic of cross section and longitudinal section of major bones may be useful for identification of species.
5. Similar studies on characteristic features of axial skeleton of leopard should be carried out.
6. The forest department must develop linkage with the Department of Wildlife Health and Management, College of Veterinary science and Animal Husbandry, Jabalpur for advance studies on different parameters of bones of important native wild species to develop data base as an aid in Wildlife Forensic.

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VITA

The author, Devendra N. Podhade was born on 22nd October 1979 at Karanja (Lad). He passed his High School Certificate Examination in the year 1995 and Senior School Certificate Examination in the year 1998. He obtained his B.V.Sc. & A.H. Degree in the year 2005 from Nagpur Veterinary College, Nagpur.

The same year, he joined M.V.Sc. & A.H. programme in the Department of Wildlife Health and Management, College of Veterinary Science & Animal Husbandry, Jabalpur. He represented the colleges in various sports events during his graduation.