



## Gross anatomy and computed tomography-based three-dimensional modeling of the humerus and femur in goat (*Capra hircus*) for enhanced veterinary anatomy education

JYOTI SAINI<sup>1,2</sup> and OM PRAKASH CHOUDHARY<sup>1</sup>✉

College of Veterinary Science, Rampura Phul, Bathinda, Punjab 151 103  
Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab, India

Received: 22 May 2025; Accepted: 29 August 2025

### ABSTRACT

The present study aims to characterize the morphometrical, computed tomography (CT), and 3D reconstructions of the humerus and femur of goat to enhance teaching and create accurate, detailed models of the humerus and femur bones of adult goats for veterinary anatomy education. While valuable, traditional methods of teaching anatomy often encounter limitations like specimen variability and preservation issues. The hot water maceration technique was used to process the goat's limbs to obtain the bones, followed by cleaning, varnishing, and painting the characteristic features with synthetic enamel paint. A total of 13 biometric measurements of the humerus and 12 of the femur were manually measured with the help of a digital vernier calliper, and five more parameters were measured by computed tomography from the humerus and femur of goats to establish a comprehensive baseline dataset for future studies on small and large ruminants. The data presented in this study will serve as a valuable reference for both anatomical education and comparative anatomical research. High-resolution CT scans were employed to capture precise structural details, which can be subsequently used to develop 3D digital models. These images can be used in educational settings to provide an interactive and detailed learning experience, enhancing student engagement. The findings demonstrate the potential of integrating modern imaging technology that maintains anatomical accuracy, is helpful in both academic and practical contexts, and supports surgical planning and educational modelling in veterinary curricula.

**Keywords:** 3D modelling, Anatomical education, Coloured bones, Computed tomography, Goat

The study of anatomical structures plays a crucial role in veterinary education and animal healthcare. Accurate representation and understanding of bone morphology are essential for students and practitioners to develop a comprehensive knowledge of musculoskeletal anatomy (Salvagno and Albarella 2017). Biometrical studies on anatomy using computed tomography make a vital contribution to breed identification in the era of technological advancements in veterinary anatomy (Choudhary *et al.* 2023a). In this context, the humerus and femur of the goat (*Capra hircus*), commonly used in veterinary practice and research settings, provide significant insights for anatomical study due to their functional and structural similarities to those of other mammalian species. The coloured long bones and mounted skeletons of different domestic animals and birds in the laboratory enhance the effectiveness of teaching and learning osteology and arthrology (Modesta

*et al.* 2019, Bansal and Saini 2024). Artificial intelligence and technological advancements in veterinary anatomy are fundamentally transforming the field, leading to highly precise and accurate diagnoses (Choudhary *et al.* 2023b, 2025, Choudhary and Singh 2025, Vickram *et al.* 2025).

The femur is a key bone for assessing bone health and diagnosing conditions like osteoporosis, fractures, or growth abnormalities. It reflects overall skeletal strength and nutritional adequacy in goats, which is vital for breeding and production. The goat femur and humerus are widely used as an experimental model for studying human bone diseases, such as osteoporosis and fracture healing. Its size and structure are comparable to those of human bones, making it ideal for testing biomedical innovations (Gudea and Stefan 2013, Zedda *et al.* 2017). The morphology of the femur and humerus offers insights into how different species adapt their hindlimbs for running, climbing, or jumping. Comparative studies with other animals, such as sheep, cattle, or humans, enhance our understanding of weight-bearing adaptations and musculoskeletal evolution (Wille and Frewin 1986, Zedda *et al.* 2017, Manjunath and Santhosh 2023).

Traditional methods of teaching anatomy often rely on

Present address: <sup>1</sup>College of Veterinary Science, Rampura Phul. Guru Angad Dev Veterinary and Animal Sciences University, Ludhiana, Punjab. <sup>2</sup>Rani Lakshmi Bai Central Agricultural University, Jhansi. ✉Corresponding author email: dr.om.choudhary@gmail.com

cadaveric dissection, which, while effective, has limitations such as resource availability, preservation issues, and ethical concerns. To supplement these traditional approaches, modern imaging technologies, such as computed tomography (CT) and 3-dimensional (3D) modelling, present innovative opportunities (Choudhary 2021, 2025). In recent years, developments in medical imaging systems have led to the replacement of two-dimensional (2D) anatomical structures with three-dimensional (3D) models (Rubio *et al.* 2020). In the medical sector, models can be obtained using cross-sectional imaging methods (computed tomography, magnetic resonance imaging, positron emission tomography, etc.) and have an important role in the detailed examination of structures, diagnosis, treatment, and prognosis of diseases (Parthasarathy 2014, Morone *et al.* 2019). CT scanning enables the non-destructive visualization of internal bone structures, providing high-resolution images that can be processed into detailed 3D models. These models offer an interactive, reusable teaching tool to enhance spatial understanding and engagement (Dayan *et al.* 2019, Sareen 2023).

The present study was designed to elaborate a detailed morphological and biometric analysis of the humerus and femur of adult goats using CT scan images in both 2D and 3D formats. The goal was to develop accurate, scalable models that serve as practical teaching aids in veterinary anatomy education and learning, thereby bridging the gap between classical teaching methods and modern technological advancements in the era of artificial intelligence (Choudhary *et al.* 2025ab). The results of this study could establish a precedent for utilizing digital and 3D tools to teach and learn complex anatomy in various

educational settings. The nomenclature from the Nomina Anatomica Veterinaria was used in this article to describe the anatomical terminology with respect to the humerus and femur of the goat (Nomina Anatomica Veterinaria 2017).

## MATERIALS AND METHODS

In the present study, the forelimb and hindlimb of four adult goats of 6–8 months of age were collected from the nearby slaughterhouse of Rampura Phul. This study was carried out in the Department of Veterinary Anatomy, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Science University, Rampura Phul, from January 2025 to March 2025. Ethical permission was not required for this study, as the samples were collected from slaughterhouses located at Rampura Phul, Punjab.

After collecting the samples, the forelimbs and hindlimbs of goats were kept separately in a container for the hot water maceration process (Choudhary *et al.* 2020). After hot water maceration, the bones were kept in a hydrogen peroxide solution for one day to remove the remaining soft tissue, followed by thorough cleaning with water, a week of sun-drying, and varnishing to prevent microbial growth (Choudhary *et al.* 2020).

After the processing mentioned above, out of the eight bones of the humerus and femur, four were painted with synthetic enamel paint (Asian Paints) in different colours to highlight their characteristic anatomical features (Choudhary *et al.* 2020). The remaining were used for morphometry and computed tomography to measure the various parameters listed in Tables 1–4. The biometry was carried out with the help of a vernier calliper (Mitutoyo digimatic caliper, Model CD-8<sup>o</sup>ASX, 0–200 mm in range and 0.01mm resolution, made in Japan).

The gross images were captured from the OnePlus 6T

Table 1. Biometrical parameters of the humerus in an adult Goat.

Parameter	Humerus	
	Right (cm)	Left (cm)
Maximum length of humerus (MLH)	21.95±0.18	21.6±0.22
Proximal width of humerus (PWH)	4.72±0.24	4.39±0.18
Distal width of humerus (DWH)	3.85±0.09	3.97±0.08
Cortex thickness of humerus (CTH)	2.15±0.06	2.24±0.11
Circumference of humerus (proximal epiphysis) (CHPE)	16.3±0.14	16.35±0.18
Circumference of humerus (mid of shaft) (CHS)	8.10±0.07	8.02±0.02
Circumference of humerus (distal epiphysis) (CHDE)	12.47±0.08	12.5±0.11
Height of the proximal epiphysis of the humerus (HPEH)	2.56±0.06	2.66±0.07
Length of the caput of the humerus (LC)	3.40±0.11	3.32±0.08
Greatest depth of the caput of humerus (GDCH)	3.57±0.07	3.69±0.05
Breadth of capitulum (BC)	1.24±0.12	1.36±0.06
Breadth of trochlea (BT)	2.61±0.04	2.58±0.12
Depth of distal epiphysis of humerus (DDEH)	0.27±0.02	0.25±0.03

Table 2. Biometrical parameters of the femur in an adult Goat

Parameter	Femur	
	Right (cm)	Left (cm)
Maximum length of femur (MLF)	23.6±0.09	23.9±0.05
Proximal width of femur (PWF)	5.08±0.17	4.98±0.20
Distal width of femur (DWF)	4.69±0.11	4.78±0.08
Cortex thickness of femur (CTF)	2.12±0.07	2.15±0.08
Circumference of femur (proximal epiphysis) (CFPE)	13.40±0.06	13.2±0.17
Circumference of femur (mid of shaft) (CFS)	7.30±0.04	7.40±0.06
Circumference of femur (distal epiphysis) (CFDE)	15.92±0.04	16.22±0.08
Height of the proximal epiphysis of the femur (HPEF)	2.04±0.03	2.06±0.05
Length of the caput of the femur (LCF)	2.62±0.09	2.75±0.09
Greatest depth of the caput of the femur (GDCHF)	2.60±0.04	2.58±0.07
Distance between ridges of trochlea (DRT)	1.75±0.03	1.84±0.11
Depth of trochlea (DT)	0.27±0.05	0.26±0.04

Table 3. Measurements of the humerus by CT scan in an adult goat

Parameter	Right (cm)	Left (cm)
Maximum length of humerus (MLH)	21.15±0.12	21.13±0.10
Proximal width of humerus (PWH)	4.89±0.06	4.80±0.07
Distal width of humerus (DWH)	3.78±0.04	3.65±0.06
Diaphysis diameter of humerus (cranio-caudal) (DDHC)	1.97±0.08	1.94±0.09
Diaphysis diameter of humerus (medio-lateral) (DDHL)	1.47±0.02	1.39±0.03

model of the phone in HD resolution and labeled accordingly with the help of Adobe Photoshop version 24.0. The CT scan images were acquired from anterior, posterior, dorsal, and ventral views using a device from General Electric Company, Japan, with the following settings: X-ray tube potential, 120 kV; tube current, 80 mA; and slice thickness, 2 mm. The CT scan files were transferred from the CT scan machine to the desktop computer in DICOM format. The computed tomography image analysis was performed on a desktop computer utilizing specialized software, DICOM viewer (RadiAnt DICOM Viewer 2024.2). Humerus and femur bone reconstructions were performed using 3D Slicer (5.0.2) software. Statistical analysis of the data was done as per the standard procedure (Snedecor and Cochran 1994).

## RESULTS AND DISCUSSION

The goat's humerus and femur were obtained from the

Table 4. Measurements of the femur by CT scan in an adult goat

Parameter	Right (cm)	Left (cm)
Maximum length of femur (MLF)	23.74±0.03	23.81±0.05
Proximal width of femur (PWF)	4.51±0.03	4.49±0.04
Distal width of femur (DWF)	4.42±0.05	4.39±0.05
Diaphysis diameter of femur (cranio-caudal) (DDFC)	1.73±0.10	1.71±0.09
Diaphysis diameter of femur (lateral-lateral) (DDFL)	1.5±0.03	1.48±0.06

limbs using the standard hot water maceration method, followed by applying varnish, as shown in Figs. 1A and 2A. Then, each characteristic feature of the humerus and femur was painted in a distinct colour to clearly distinguish their anatomical features for better understanding of anatomical structures in veterinary anatomy education, as outlined in Figs. 1B and 2B. The coloured bones were more self-explanatory than those used regularly in undergraduate veterinary anatomy classes, as evaluated by college students. The students also responded that these prepared coloured bones, along with the routine bones, can serve as a new tool for veterinary anatomy education and learning in veterinary institutions. In the present study, various biometric parameters were measured using a digital vernier caliper and are listed in Tables 1 and 2.

Despite the rapid advancements in anatomy, such as 3D laser scanning, 3D printing, and artificial intelligence, which have significantly transformed veterinary anatomy education, studying detailed bone morphology still requires

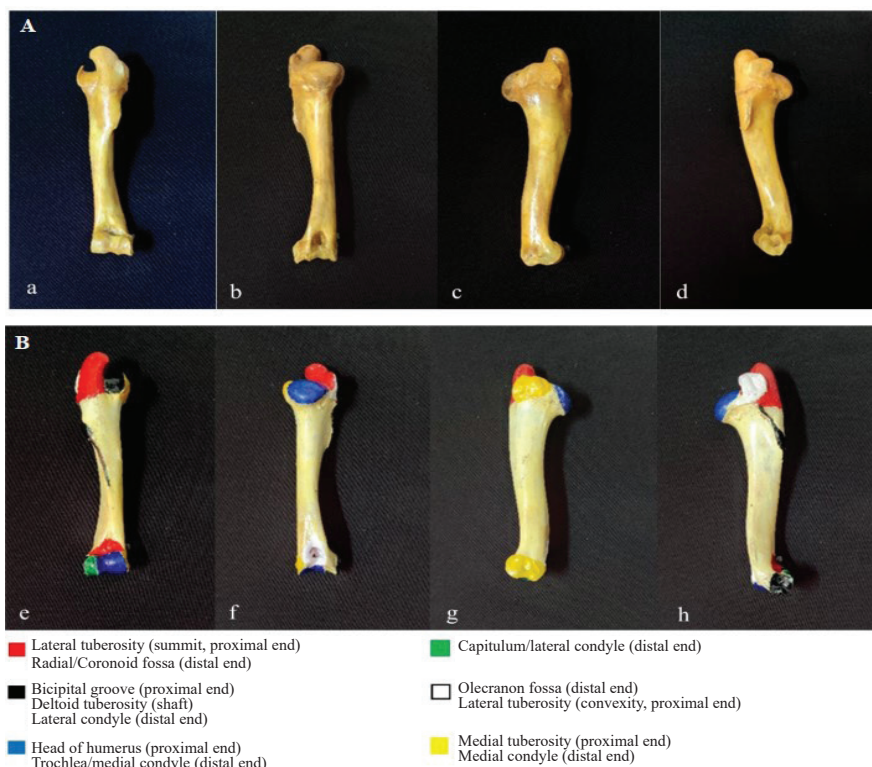


Fig. 1. A: Left humerus of goat, a: anterior view, b: posterior view, c: medial view, d: lateral view, B: Coloured right humerus of goat, e: anterior view, f: posterior view, g: medial view, h: lateral view



Fig. 2. A: Left femur of goat a: anterior view, b: posterior view, c: medial view, d: lateral view, B: Right femur of goat, e: anterior view, f: posterior view, g: medial view, h: lateral view

physical specimens for enhanced veterinary anatomy education (Choudhary *et al.* 2025ab, Fidanci and Orhan 2025). Therefore, this study aims to provide new insights into analyzing the humerus and femur by emphasizing their key anatomical features through gross examination and color coding of important structures. The painted humerus and femur displayed in the laboratory setting proved to be a valuable educational tool in veterinary anatomy education, capturing the interest of both students and visitors to the department's museum, as corroborated earlier by Paramasivan *et al.* (2021) and Bansal and Saini (2024). Using distinct colors to highlight specific features, such as the lateral and minor tuberosities of the humerus, greatly enhanced the clarity and accessibility of the bone structures (Figs. 2 and 4). This new and innovative anatomical approach made the bones more self-explanatory, contributing to a deeper understanding of the functional anatomy of the skeletal system. These results align with similar studies that have emphasized the importance of visual aids in anatomical education (Smith *et al.* 2019, Choudhary *et al.* 2025a).

In the present study, the humerus grossly presented the major lateral tuberosity, which extended proximally above the head of the humerus. The cranial part of the lateral tuberosity was elongated. The laterally located caudal part of the lateral tuberosity presented a convex proximal margin (Fig. 1B, red colour). The medially located minor

medial tuberosity was elongated in a craniocaudal direction and proximally presented an almost flat proximal margin, which was slightly above the head of the humerus (Fig. 1B, blue colour). The demarcation between the cranial and caudal parts of the minor tuberosity was indistinct. A single intertubercular groove separated the major and minor tuberosities (Fig. 1B, black colour). In the mediolateral (ML) CT scan image of the humerus, the major and minor tubercles extended proximally above the head of the humerus. The deltoid tuberosity was extended in a proximodistal direction and formed the distal part of the triceps muscle line (Fig. 1B, black colour). The crest of the minor tubercle was absent. The lateral supracondylar crest was less prominent. Distally, the cranial surface of the condyle of the humerus presented a concave radial fossa elongated mediolaterally, sloped from proximomedial to distolateral (Fig. 1B, red colour). The articular surface of the condyle of the humerus presented a medially located and grooved trochlea humeri and a laterally located capitulum humeri. The trochlea humeri were larger than the capitulum humeri and extended more proximally than the capitulum humeri (Fig. 1B, blue and green colour). The supratrochlear foramen was absent. The lateral and medial surfaces of the lateral and medial condyles of the humerus, respectively, presented a depression for the origin of the extensors and flexors, respectively, of the carpus and digits. The lateral and medial epicondyles of

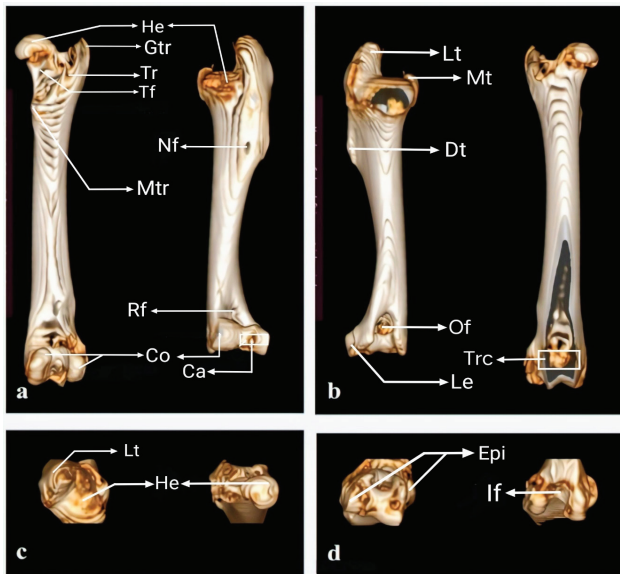


Fig. 3. 3D imaging of the humerus and femur of a goat. a: anterior view, b: posterior view, c: dorsal view, d: ventral view. He: head, Gtr: greater trochanter, Tr: trochanteric ridge, Tf: trochanteric fossa, Mtr: minor trochanter, Nf: nutrient foramen, Rf: radial fossa, Co: condyles, Ca: caput, Lt: lateral tuberosity, Mt: medial tuberosity, Dt: deltoid tuberosity, Of: olecranon fossa, Trc: trochlea, Le: lateral epicondyle, Epi: epicondyles, If: intercondyloid fossa

the humerus were almost of the same size. The medial epicondyle was square, whereas the lateral epicondyle formed an obtuse angle. The ovoid olecranon fossa was deep and almost vertically oriented (Fig. 1B, white colour and Fig. 3). Morphologically, the study identified several distinct features of the humerus that were consistent with those described in previous studies. For example, the major lateral tuberosity, which extends proximally above the head of the humerus, served as a key attachment site for the supraspinatus and infraspinatus muscles. These findings corroborated previous anatomical descriptions in large and small ruminants (Sisson 1975, König *et al.* 2007, Choudhary and Singh 2016, Dyce *et al.* 2018, Brown and Taylor 2020, Alvites *et al.* 2021) and highlighted the importance of the tuberosities in muscle attachment and limb movement. Additionally, the identification of the inter-tubercular groove and its relationship with the minor tuberosity was significant, as this groove facilitated the passage of the tendon of the long head of the biceps brachii muscle, an important feature for shoulder stability and function (Harper *et al.* 2018, Manjunath and Santhosh 2023).

In craniocaudal and mediolateral views of the gross and CT scan image of the femur, there was a slight curvature at the lateral aspect. The caput was round and distinguishable from the trochanteric fossa. The greater trochanter attaches to most gluteal muscles, providing these hip extensors with a long lever arm (Fig. 2B, in red, and Fig. 3). The major roundness of the caput in goats is confirmed by the measurements reported in Table 2, where the length and



Fig. 4a and 4b. CT scan images of humerus (a) and femur (b) of goat showing 1: maximum length of the bone, 2: proximal width, 3: distal width, 4: mediolateral 5: craniocaudal diameter of medullary cavity

greatest depth values are indicated. A distinct oval-shaped small pit (fovea capitis femoris) was present in the medial part of the caput. The orientation of the neck (collum femoris) is another characteristic. When observed from a cranial or caudal view, the neck was nearly sloped and inclined cranially. Consequently, the top of the caput was in line with the trochanter major in the goat (Fig. 2B, red). The shaft (corpus ossis femoris) was nearly cylindrical, while the facies aspera in the caudal surface was broad. In the distal epiphysis, the relative depth of the trochlea ossis femoris, which articulates with the patella, was marked (Fig. 2B, yellow colour and Fig. 3). CT scan image of the femur articulation with the tibia was formed by two condyles oriented caudodistally and separated by a deep intercondyloid fossa (Fig. 2B, red and blue colour and Fig. 3). Similarly, femur morphology revealed several notable features. The round caput of the femur, along with its distinct fovea capitis femoris, plays a critical role in attaching the ligamentum teres femoris, which is essential for hip joint stability (Choudhary and Singh, 2016, Marco *et al.* 2017, Williams *et al.* 2016). The cranially inclined orientation of the femoral neck and its relationship with the trochanter major were consistent with the anatomical adaptations seen in species with specialized locomotion, particularly quadrupeds (Davis and Martin 2019, Manjunath and Santhosh 2023). The study also highlighted the curvature of the femur, which has functional implications for load distribution during movement, further corroborating findings from biomechanical studies (Johnson and Green, 2017, Paramasivan *et al.* 2021).

No significant difference was found between the biometric parameters of the right and left limb bones of the

humerus and femur in the goat. Tables 3 and 4 present the measurement values of the humerus and femur, as measured with the DICOM viewer as shown in Fig. 4a and 4b. No significant differences were observed in morphological and morphometrical parameters measured by the routine method and those visualized in the CT-scanned images using the DICOM viewer.

The biometric parameters showed no significant difference between the right and left bones of the humerus and femur, suggesting bilateral symmetry in bone structure. This result was consistent with studies on other mammals, where symmetry between the limbs is typically maintained for efficient locomotion and balance (Choudhary *et al.* 2013, Smith *et al.* 2019, Brown and Taylor 2020). Additionally, the measurements obtained from the DICOM viewer for CT images supported these findings, indicating no significant differences in other parameters. This reinforces the reliability of the measurement techniques used in this study and the consistency of bone development.

The present study's methodology, which includes hot water maceration followed by varnishing and the application of distinct color codes, offers a novel approach to anatomical visualization. By creating easily distinguishable bone features, this technique enhances the educational value of skeletal specimens. It improves the learning experience for students and researchers alike, as previously highlighted in the study on the coloured goat skeleton (Choudhary *et al.* 2025b). Future studies could explore the use of color-coded models in other species to assess further the effectiveness of this approach in different anatomical contexts.

In conclusion, the morphological, biometrical, and CT scan analyses showed no significant differences. The innovative use of color-coding for the humerus and femur of goats provides valuable insights into bone structure and function, serving as a helpful tool for veterinary anatomy education and learning. The study's findings align with previous anatomical research, suggesting that visual enhancements significantly improve the understanding of complex skeletal features. These results contribute to the growing body of knowledge in comparative anatomy and biomechanics, offering potential applications in both educational and clinical settings.

#### REFERENCES

- Alvites R D, Branquinho M V, Sousa A C, Lopes B, Sousa P, Mendonça C, Atayde L M, Mauricio A C. 2021. Small ruminants and its use in regenerative medicine: recent works and future perspectives. *Biology* **10**(3): 249.
- Bansal N, and Saini J. 2024. Transforming animal bones from waste into teaching aid. *Vet Alumnus* **46**(1): 85–87.
- Brown T J and Taylor K M. 2020. Anatomy of the shoulder joint: Gross morphology and functional implications. *Journal of Veterinary Anatomy* **45**(3): 215–27.
- Choudhary O P. 2021. Three-dimensional computed tomography reconstructions: A tool for veterinary anatomy education. *Annals of Medicine and Surgery* **11**:102497.
- Choudhary O P. 2025. Animal models for surgeries and implants: A vital tool in medical research and development. *Annals of Medicine & Surgery* **87**(7): 4090–95.
- Choudhary O P, Mathur R, Joshi S and Yadav S. 2013. Gross and biometrical studies on humerus and radius ulna of chital (*Axis Axis*). *Indian Journal of Veterinary Anatomy* **25**(1): 23–24.
- Choudhary O P and Singh I. 2016. Morphometrical studies on the femur and patella of Indian blackbuck (*Antilope cervicapra*). *Indian Veterinary Journal* **93**(11): 64–66.
- Choudhary O P and Singh D. 2025. Gross anatomy of the mandible in Murrah buffalo (*Bubalus bubalis*). *Buffalo Bulletin* **44**(1): 1–7.
- Choudhary O P, Priyanka, Kalita P C, Arya R S, Kalita A. Doley P J and Keneisenuo. 2020. A morphometrical study on the skull of goat (*Capra hircus*) in Mizoram. *International Journal of Morphology* **38**(5):1473–78.
- Choudhary O P, Saini J and Challana A. 2023a. Coloured goat skeleton preparation to support veterinary anatomy education. *Indian Journal of Small Ruminants* **31**(1): 109–11.
- Choudhary O P, Challana A and Saini J. 2023b. ChatGPT for veterinary anatomy education: An overview of the prospects and drawbacks. *International Journal of Morphology* **41**(4): 1198–202.
- Choudhary O P, Infant S S, As V, Chopra H and Manuta N. 2025a. Exploring the potential and limitations of artificial intelligence in animal anatomy. *Annals of Anatomy* **258**: 152366. <https://doi.org/10.1016/j.aanat.2024.152366>.
- Choudhary O P, Jyoti S and Challana A. 2025b. Coloured goat skeleton preparation to support veterinary anatomy education. *Indian Journal of Small Ruminants* **31**: 109–11. 10.5958/0973–9718.2025.00011.6.
- Davis M E and Martin M P 2019. Biomechanics of the femur in quadrupeds: A comparative analysis. *Journal of Comparative Anatomy* **31**(2): 134–42.
- Dayan M, Beşoluk K, Eken E, Aydogdu S and Turgut N. 2019. Three-dimensional modelling of the femur and humerus in adult male guinea pigs (guinea pig) with computed tomography and some biometric measurement values. *Folia morphologica* 10.5603/FM.a2019.0002.
- Dyce K M, Sack W O and Wensing C J G. 2018. *Dyce, Sack, and Wensing's Textbook of Veterinary Anatomy*. 5<sup>th</sup> Edition, pp. 732–36. Elsevier Philadelphia USA.
- Fidanci S G and Orhan I. 2025. The role of 3D laser scanning and printing in Veterinary Anatomy education: A study on feline scapula and humerus. *Indian Journal of Animal Research* 10.18805/IJAR.BF–1986.
- Gudea A I and Ştefan A C. 2013. Histomorphometric, fractal and lacunarity comparative analysis of sheep (*Ovis aries*), goat (*Capra hircus*) and roe deer (*Capreolus capreolus*) compact bone samples. *Folia Morphologica* **72**(3): 239–48.
- Harper G S, Thompson J M and Gray M A. 2018. The role of the tuberosities in shoulder stability and function. *Anatomical Journal of Animal Sciences* **12**(4): 97–104.
- Johnson A R and Green E A. 2017. Visual learning in anatomy: The impact of color-coding skeletal features. *Journal of Medical Education* **29**(1): 45–56.
- König H E, Liebich H G and Bragulla H. 2007. *Veterinary Anatomy of Domestic Mammals: Textbook and Colour Atlas*. 3<sup>rd</sup> Edition. Schattauer Verlag, New York.
- Manjunath T H and Santhosh C S. 2023. Morphometric study of adult dry femur and its forensic importance. *International Journal of Academic Medicine and Pharmacy* **5**(5): 1241–44.
- Marco Z, Maria R P, Desire B, Marcella C, Vijay S, Antonio C and Vittorio F. 2017. Differences in femoral morphology between

- sheep (*Ovis aries*) and goat (*Capra hircus*): Macroscopic and microscopic observations. *Zoomorphology* **136**: 145–58.
- Modesta M. 2019. Gross osteology and radiology of the pelvic limb of the adult small East African goat. *Anatomia Histologia Embryologia* **48**(3): 234–43.
- Morone P J, Shah K J, Hendricks B K and Cohen–Gadol A A. 2019. Virtual, 3-dimensional temporal bone model and its educational value for neurosurgical trainees. *World Neurosurgery* **122**: e1412–15.
- NAV: Nomina Anatomica Veterinaria 2017. The International Committee on Veterinary Gross Anatomical Nomenclature. Published by the Editorial Committee Hannover (Germany), Columbia, MO (USA), Ghent (Belgium), Sapporo (Japan), 6th ed., (Revised version).
- Paramasivan S, Sathyamoorthy O R, Sivagnanam S, Rajathi S and Sivakumar S A. 2021. Tools and techniques in preparation of coloured bones and skeletons for effective teaching, learning and museums. *Indian Journal of Animal Research* 10.18805/IJAR.B-4717.
- Parthasarathy J. 2014. 3D modeling, custom implants and its future perspectives in craniofacial surgery. *Annals of Maxillofacial Surgery* **4**(1): 9–18.
- Rubio R R, Bonaventura R D, Kournoutas I, Barakat D, Vigo V, El–Sayed I and Abla A A. 2020. Stereoscopy in surgical neuroanatomy: Past, present, and future. *Operative Neurosurgery* **18**(2): 105–17.
- Salvagno L and Albarella U. 2017. A morphometric system to distinguish sheep and goat postcranial bones. *Plos One* **12**(6): e0178543.
- Sareen K. 2023. Development of a navigable 3D virtual model of temporal bone anatomy. *Journal of visual communication in medicine* **46**(1): 14–18. 10.1080/17453054.2023.2169110.
- Sisson S. 1975. *Ruminant Syndesmology: The Anatomy of the domestic animals*. 5<sup>th</sup> Edition, pp. 787–90. W.B. Saunders Company, Philadelphia, USA.
- Smith H D, Jackson P A and Lewis S T. 2019. The use of color in anatomical education: Enhancing understanding and retention. *Medical Education Review* **52**(2): 155–62.
- Snedecor G W and Cochran W G. 1994. *Statistical Methods*. (8<sup>th</sup> Edn.), Iowa State Univ. Press, Ames, Iowa, USA.
- Vickram A, Infant S S and Chopra H. 2025. AI-powered techniques in anatomical imaging: Impacts on veterinary diagnostics and surgery. *Annals of Anatomy* **258**: 152355.
- Wille K H and Frewin J. 1986. The Locomotor System of Domestic Mammals. In *The Anatomy of the Domestic Animals*, pp. 181–213. Verlag Paularey Berlin.
- Williams D J, Walker P T and Hunt S A. 2016. Anatomy of the femur and its role in hip joint function. *Journal of Orthopedic Research* **34**(5): 567–74.
- Zedda M, Palombo M R, Brits D, Carcupino M, Sathe V, Cacchioli A and Farina V. 2017. Differences in femoral morphology between sheep (*Ovis aries*) and goat (*Capra hircus*): macroscopic and microscopic observations. *Zoomorphology* **136**(1): 145–58.