Kafkas Universitesi Veteriner Fakultesi Dergisi
Journal Home-Page: http://vetdergikafkas.org
E-ISSN: 1309-2251

Kafkas Univ Vet Fak Derg
31 (2): 215-221, 2025
DOI: 10.9775/kvfd.2024.33222

Research Article

Anatomy of the Knee Joint in Cattle (*Bos taurus*): Gross, Radiographic and Computed Tomographic Insights

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How to cite this article?
Choudhary OP, Saini S: Anatomy of the knee joint in cattle (Bos taurus): Gross, radiographic and computed tomographic insights. *Kafkas Univ Vet Fak Derg,* 31 (2): 215-221, 2025.
DOI: 10.9775/kvfd.2024.33222

Article ID: KVFD-2024-33222
Received: 05.11.2024
Accepted: 06.01.2025
Published Online: 10.01.2025

Abstract

Limb joint diseases significantly reduce domestic animals' productive and reproductive capabilities. The present study was conducted to examine the anatomical features of the knee joint in cattle. Four naturally dead cattle of 2-3 years were collected and used in this study to record gross anatomical, radiographical characteristics and computed tomographic (CT) scans of the knee joints. Radiographs and CT scan images provided 2D and 3D visualization of the knee joint that was made up of articulatio antebrachiocarpea, articulatio intercarpea, and articulatio carpometacarpea. The synovial sacs of the intercarpal and carpometacarpal articulations were interconnected. The interosseous ligament connected the depression on the posterior margin of the distal radius with the intermediate and ulnar carpal bones. In the intercarpal articulation, one interosseous ligament was observed between the non-articular area on the distal surface of the intermediate carpal and the non-articular area of the fourth carpal. In the carpometacarpal joint, an interosseous ligament was observed connecting the non-articular area on the lateral surface of the fused second and third carpals to the non-articular area at the proximal end of the large metacarpal. The fibers of this ligament were blended with the interosseous ligament that connects the two carpal bones in the distal row. This study can help as an analytic tool for definitive diagnosis, prognosis, and research of the cattle knee joint.

Keywords: Carpal bones, Cattle, Computed tomography, Knee joint, Ligament, Radiography

Introduction

The conditions affecting the joints of animal limbs significantly impair their productive and reproductive capabilities [1]. The carpal joint is referred to as a common cause of forelimb lameness in cattle [2,3]. The carpal region is a complex thoracic limb part comprising various structures, including the knee joint, ligaments, tendons, and muscles [2-5].

The carpal joint consists of three main joints: the antebrachiocarpal joint, intercarpal joints, and carpometacarpal joints, among all the carpal bones [6-12]. The knee joint may experience pathological changes affecting the joint structures, ligaments, and tendons in the carpal region [13-16]. Furthermore, bovine carpal joints provide a cost-effective, safe, and easily reproducible model for educating on basic ligament studies and their repair techniques before patient interaction [17].

Diagnostic imaging techniques, such as radiography and CT scans, can enhance the chances of a definitive diagnosis, potentially improving the prognosis and treatment outcomes in affected cattle [18]. CT scans have shown significant utility in diagnosing various musculoskeletal conditions in veterinary medicine [19]. Their primary advantages over radiography and ultrasonography include three-dimensional imaging and the ability to simultaneously visualize bone and soft tissue structures without overlapping. CT scan offers advantages such as improved bone contrast and reduced examination time. Additionally, there is increasing interest in utilizing CT scans and MRI for bovine orthopedic applications [20]. Comprehensive information exists regarding the anatomy of joints in horses, dogs, pigs, and ox, as outlined in standard textbooks on veterinary anatomy [5,21-23]. The data generated from this study can enhance diagnostic accuracy by establishing a baseline for normal radiographic and CT findings. This baseline aids in distinguishing between normal variations and pathological changes in cattle limbs. Furthermore, the information can facilitate the early detection of conditions such as osteochondrosis, arthritis, or fractures. Comprehensive anatomical and imaging insights allow for better planning of minimally invasive surgical procedures, including arthrotomy or joint stabilization techniques, guiding arthroscopy. This approach can reduce recovery times and improve overall outcomes.

This study aims to thoroughly characterize the anatomy of cattle knee joints through gross observation, radiography, and computed tomography. The nomenclature from the Nomina Anatomica Veterinaria was used in this article to describe the anatomical terminologies with respect to cattle knee joints [24].

Materials and Methods

Ethical Statement

Institutional animal ethics approval is not necessary for this study because the samples were collected from cattle that died naturally.

Animals

The present study was conducted on the eight knee joints (right and left forelimbs from each animal) of the cattle. The duration of the study was January 2024 to September 2024. Four naturally dead cattle were obtained from a Gaushala near the College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Rampura Phul, Punjab, as well as from the Teaching Veterinary Clinical Complex (TVCC) of the college. After postmortem examination, the samples were processed using standard anatomical techniques for this study.

Processing of Samples for Gross Anatomy

After deskinning the collected cattle, the internal viscera/organs were removed carefully, preserved in a 10% buffered formalin solution, and used for undergraduate student teaching. For this study, the knee joints were cut by the electric saw and macerated with a hot water maceration technique to remove the skin and fascia over the knee joint. The gross photographs of the cattle knee joints were captured by the Apple iPhone 14 Pro in the department and labeled accordingly with the help of Adobe Photoshop version 24.0.

Radiography and CT Scan of the Knee Joints

The radiographs were taken from the X-ray machine (Toshiba ROTANODE™-Toshiba X-Ray Tube E7869X) from the Department of Veterinary Surgery and Radiology, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Rampura Phul, Punjab. CT scans of the knee joint were taken from the dorsal, ventral and lateral aspects using a CT scan machine (General Electronic company, Japan: GE Prospeed F2) with the following custom: X-ray tube potential: 120 kV, tube current: 80 mA, slice thickness: 3 mm. Image analysis was conducted on a desktop computer using specialized software (RadiAnt DICOM Viewer 2024.2) for multiplanar 3D reconstructions. The images were assessed to visualize and identify bone, cartilage, and soft-tissue structures of the cattle knee joint.

Results

The gross anatomical, radiographical and CT scan anatomy of the knee joint of cattle was demonstrated in *Fig. 1*, *Fig. 2*, *Fig. 3*, *Fig. 4*, *Fig. 5*, and *Fig. 6*. Two- and three-dimensional (2D and 3D) images produced by radiography and CT scans were used to analyze the cattle knee joint *(Fig. 3*, *Fig. 4*, *Fig. 5*, and *Fig. 6)*. The carpal or knee joint in cattle was a composite diarthrodial joint, often referred to as the knee joint in animals. It comprises three main articulations: the articulatio antebrachiocarpea (radio-carpal joint), formed by the distal extremity of the radius and ulna (styloid process), the proximal carpal row (radial, intermediate, ulnar, and accessory carpal); articulatio intercarpea (the intercarpal joint), situated between the proximal and

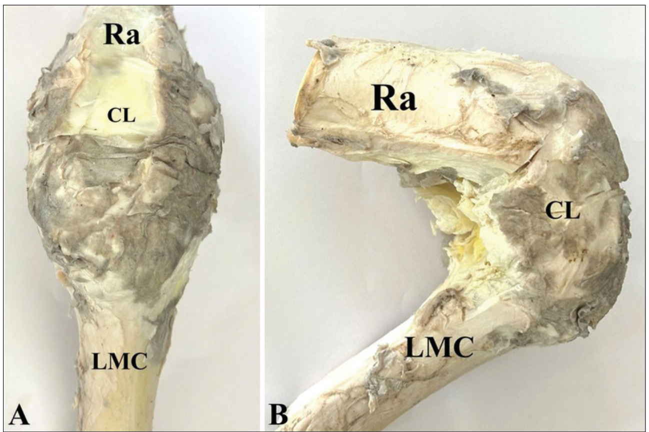

Fig 1. Dissected knee joint (A, B) of cattle (left limb) showing radius (Ra), capsular ligament (CL) and large metacarpal bone (LMC)

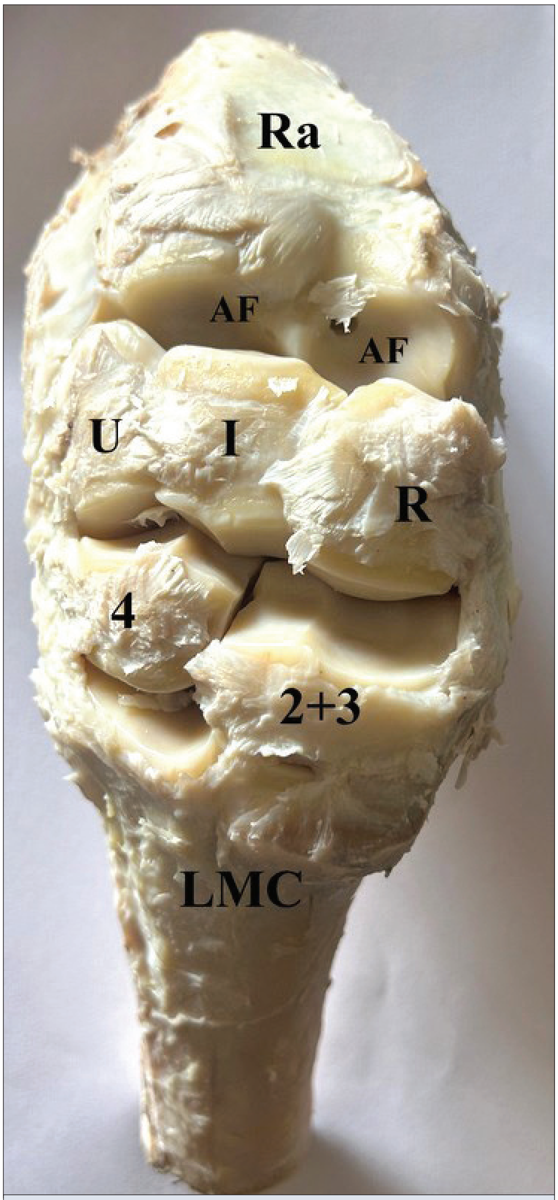

Fig 2. Dissected knee joint of cattle (right limb) showing radius (Ra) articular facets of radius (AF), carpal bones of proximal and distal row (R, I, U, 2+3, 4), and large metacarpal bone (III)

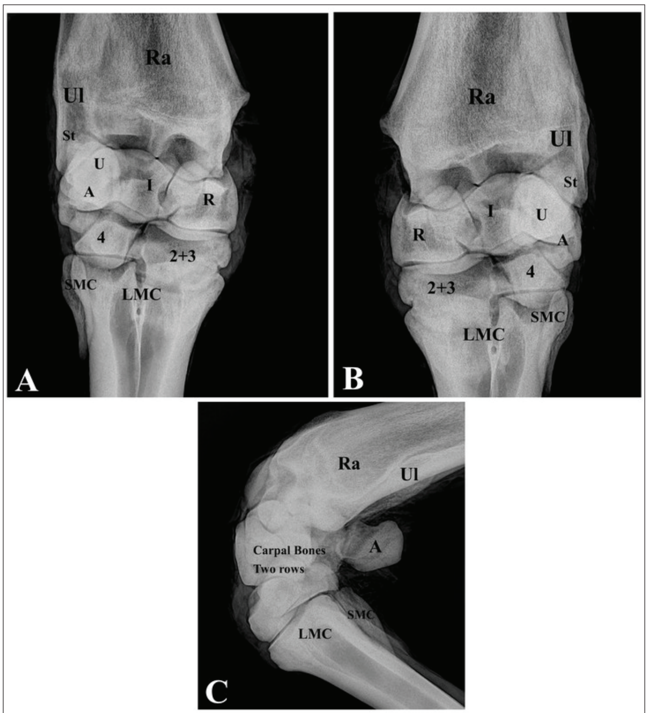

Fig 3. Radiographs (A, B, C) of the knee joint (left limb) of cattle showing radius (Ra), ulna (Ul), radial, intermediate, ulnar and accessory carpal bones (R, I, U, A) in the proximal row; 2+3, 4th in the distal row, fused third and fourth large metacarpal (LMC-III+IV) and fifth small metacarpal (SMC-V)

distal rows (second-third fused and fourth carpal) of carpal bones; and the articulatio carpometacarpea (carpometacarpal joint), which connects the distal carpal row to the proximal end of the large metacarpal bone (III+IV) and the structures adjacent to these osseous components.

The radiographs and CT images clearly show the two rows of carpal bones, which were distinctly separated by the radiocarpal, intercarpal, and carpometacarpal joints (*Fig. 3*, *Fig. 5*). To better understand the cattle knee joint in three dimensions, 3D reconstruction was created and demonstrated (*Fig. 6*).

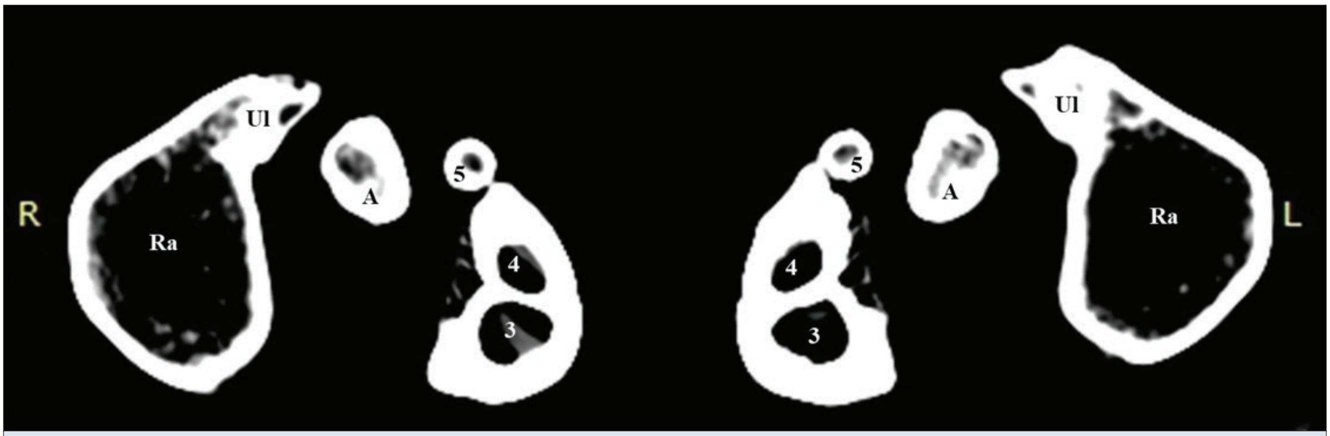

Fig 4. Cross-sectional computed tomographic (CT) image of the knee joint of right (R) and left (L) side of cattle showing radius (Ra), ulna (Ul), and accessory carpal bones (A), two medullary cavities of large metacarpal (III+IV) and small metacarpal (V)

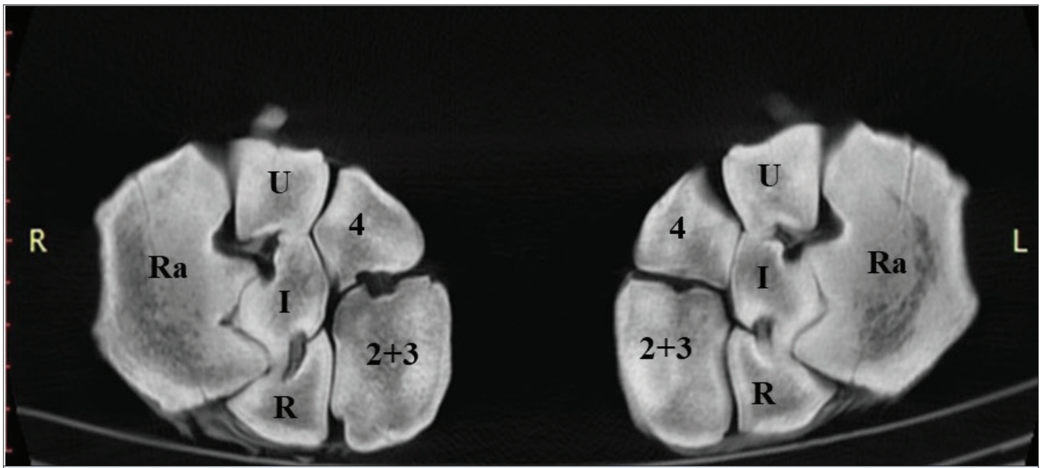

Fig 5. Transverse CT scans of the cattle knee joint of the right (R) and left (L) side showing radius (Ra), radial, intermediate and ulnar (R, I, U, A) in the proximal row, 2+3, 4th in the distal row

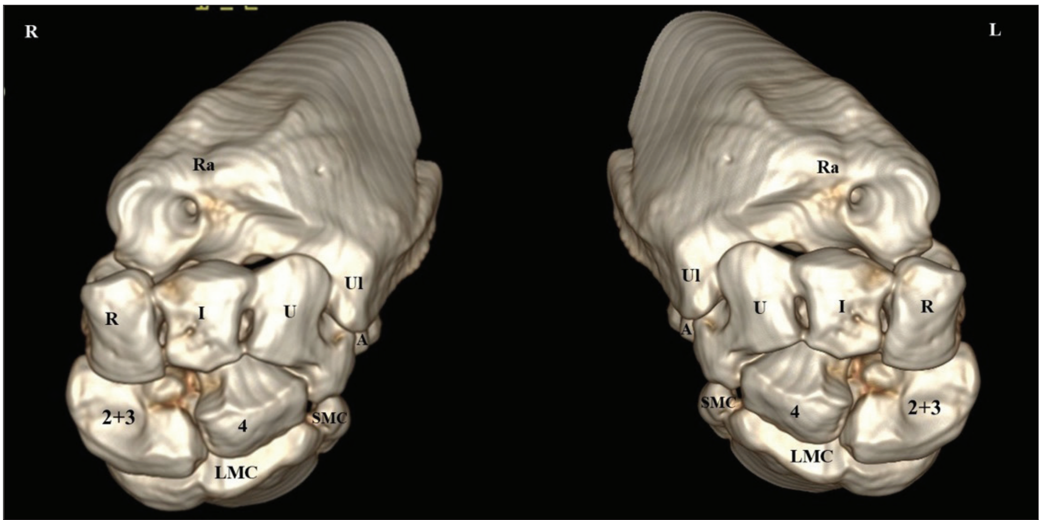

Fig 6. 3D computed tomographic (CT) images of the cattle knee joint of the right (R) and left (L) side showing radius (Ra), ulna (Ul), radial, intermediate, ulnar and accessory carpal bones (R, I, U, A) in the proximal row, 2+3, 4th in the distal row, large metacarpal (LMC) and small metacarpal (SMC)

The results showed that the anatomical features of the cattle knee joint resembled small and large ruminants, and few differences were noticed among other domestic animals, as discussed in this study.

Discussion

The gross, radiographic and CT scan morphology of cattle knee joint was composed of a diarthrodial joint formed by the articulatio antebrachiocarpea, articulatio intercarpea and the articulatio carpometacarpea, as reported earlier in buffalo calves, bovines, cattle and ox [1,2,21,25]. In contrast to this finding, the distal end of the ulna was not involved in the formation of the carpal joint in donkeys [12]. This is because the ulna does not extend to the distal end of the radius and is limited to the distal third of the radius. The radiographs and CT images visualize the two rows of carpal bones, which were distinctly separated by the radiocarpal, intercarpal, and carpometacarpal joints. Also, the metacarpus in cattle comprised a large metacarpal bone and a smaller external metacarpal bone. The large metacarpal bone (III+IV) is formed by the fusion of the third and fourth metacarpal bones during fetal development, with remnants of this dual origin still observable in adulthood. The smaller metacarpal bone (V) is positioned along the upper outer edge of the large metacarpal bone and does not contribute to the articulation with the carpus as mentioned in bovines and ox [2,5]. The knee joint capsule of cattle was comprised of a common outer fibrous capsular ligament and three inner synovial pouches, one for each joint (radiocarpal, intercarpal, and carpometacarpal joint) as described previously in buffalo calves [1].

In the present study, the dorsal ligament of the knee joint was membranous, with its superior border attached to the radius and its inferior border attached to the proximal extremity of the large metacarpal, as reported earlier in buffalo calves [1]. The right and left borders were united with the medial and lateral collateral ligaments of the knee joint, as reported in buffalo calves [1]. It was strengthened dorsally by the retinaculum extensorium, which surrounded the extensor tendons of the extensor muscles of the forearm region.

The volar carpal ligament was thick and strong, extending from the distal articular surface of the radius to the proximal end of the large metacarpal. The retinaculum flexorium arising from the accessory carpal to bridge the sulcus carpi was attached to the bones of the carpus and the metacarpus region in the present study, as confirms the findings of [1] in buffalo calves.

The lateral collateral ligament of the knee joint is a flat band attached proximally to the distal end of the radius and the styloid process of the ulna, as reported in ox [21]. Distally, it connected to the proximal ends of the large and small metacarpals, as observed earlier in buffalo calves [1]. Small and deeply placed, the proximal, middle, and distal limbs of the lateral collateral ligament connected the ulna to the ulnar carpal, the ulnar carpal to the fourth carpal, and the fourth carpal to the large metacarpal as reported in buffalo calves [1,26]. The previous study described the two deep branches as extending from the styloid process of the ulna, with one limb going to the ulnar carpal and the other to the fourth carpal [22].

The medial collateral ligament was thick, wide, and strong and extended between the styloid process of the radius and proximal extremity of the large metacarpal, as also reported in buffalo calves [1]. The small, short, deeply placed proximal, middle, and distal limbs connected the distal end of the radius and the radial carpal, radial carpal, and the fused second and third carpal and fused second and third carpal and large metacarpal, respectively. The medial collateral ligament was stronger in the cattle knee joint due to the axis of the limb having a medial deviation at the carpus, as earlier reported in buffalo calves [1].

The radio-ulnar-carpal articulation (articulatio antebrachiocarpea) is a ginglymus joint formed by the radius, ulna, and the proximal articular surfaces of the first row of carpal bones, as noted in buffalo calves and bovines [1,2]. The articular surface of the radius was elongated and featured three oblique facets for the radial, intermediate, and ulnar carpals. In contrast, the ulna (specifically the styloid process) had a single articular facet for the ulnar carpal. Additionally, the accessory carpal was articulated with the ulnar carpal at the posterior aspect through a single articular facet.

The articulatio antebrachiocarpea consisted of radio-carpal (articulatio radiocarpea) and ulnar-carpal (articulatio ulnocarpea). This joint is supported by one oblique ligament, four posterior ligaments, and one interosseous ligament. The oblique ligament, known as the ligamentum radiocarpium dorsale, extended from the dorsal aspect of the distal end of the radius to the ulnar carpal. On the volar aspect, four ligaments were extended from the radius to the radial carpal, from the radius to the intermediate carpal in two bands, from the radius to the ulnar carpal, and from the ulna to the ulnar carpal. The interosseous ligament connects the depression located in the middle of the posterior margin of the distal end of the radius to the non-articular areas on the lateral surface of the intermediate carpal and the medial surface of the ulnar carpal. This has also been reported in buffalo calves [1], where the authors described the ligament as 'λ' shaped. Additionally, two oblique and three posterior ligaments were identified in ox [21] and yaks [27].

The composite hinge joint between the proximal and distal row of carpal bones was articulatio mediocarpea, as reported in buffalo calves [1]. Two oblique anterior ligaments, four posterior ligaments, and one interosseous ligament were observed. One of the two oblique ligaments extended between the radial and fourth carpal, while the other connected the ulnar carpal to the fourth. On the volar aspect, the ligaments connected the radial carpal to the fused second and third carpals, the intermediate carpal to the fourth carpal, the ulnar carpal to the fourth carpal, and the accessory carpal to the fourth carpal. Additionally, one interosseous ligament was found between the non-articular area on the distal aspect of the intermediate carpal and the non-articular area of the fourth carpal. Four posterior ligaments were noted in the ox [21,23].

The articulatio intercarpea (intercarpal articulations) was formed between the carpal bones of the same row of the proximal and distal rows. These articulations were characterized by well-defined articular surfaces, ensuring stability and functionality within the cattle knee joint, as reported previously in buffalo calves [1]. The articulatio intercarpea proximale were plane (arthrodial) type and consisted of three ligaments intercarpea dorsalia (dorsal internal carpal ligament) and two ligaments intercarpea volaria (volar intercarpal ligament). On the dorsal aspect, the dorsal intercarpal ligaments connect the radial carpal to the intermediate carpal, the intermediate carpal to the ulnar carpal, and the ulnar carpal to the accessory carpal, as reported previously in buffalo calves [1]. On the volar aspect, the volar intercarpal ligaments connect the intermediate carpal to the ulnar carpal and the ulnar carpal to the accessory carpal. Three interosseous ligaments connected the non-articular areas of the adjacent carpal bones. The articulatio intercarpea distale was plane (arthrodial) type and had one dorsal, one volar, and an interosseous ligament between the fused second-third carpal and fourth carpal. The interosseous ligament connected the non-articular areas of the lateral surface of the fused second and third carpals to the medial surface of the fourth carpal, as reported previously in buffalo calves [1].

The articulatio carpometacarpea (carpometacarpal articulation) was an amphiarthrodial joint formed by flattened articular surfaces of carpal bones of the distal row and those of the large metacarpal as reported in buffalo calves [1]. Two dorsal and two volar ligaments connected fused second & third carpal and fourth carpal separately to the large metacarpal. An interosseous ligament was present, connecting the non-articular area of the lateral surface of the fused second and third carpals to the non-articular area at the proximal end of the large metacarpal. The fibers of this ligament blended with the interosseous ligament that connects the two carpal bones of the distal row, as noted in buffalo calves [1], but this blending was not observed in the white cattle by the same authors. The presence of two anterior ligaments, two posterior ligaments, and two interosseous ligaments was described earlier in ox [19]. The radiocarpal (articulatio antebrachiocarpalis) and midcarpal joints (articulatio mediocarpalis) allowed for flexion, extension, adduction, and abduction. The intercarpal joints (articulatio intercarpalis) exhibited slight gliding movements, whereas the carpometacarpal joints (articulatio carpometacarpalis) showed no movement. The individual carpal bones featured well-developed articular facets. Additionally, the interosseous and collateral ligaments were robust structures that limited joint movement, as noted in buffalo calves [1]. The present study provided a detailed gross and radiographic anatomy of the cattle's knee joint. The structures of cattle's knee joints were similar to those of small and large ruminants; however, they differed from those of other domestic animals.

Several technological advancements in veterinary anatomy have been revolutionizing this discipline. However, the need for gross specimens in veterinary anatomy education cannot be replaced by artificial intelligence applications, as dissections provide valuable insight into anatomical structures [28-31]. This study conducted a detailed examination of the knee joint anatomy of cattle and suggested that dissected specimens are more valuable than online veterinary anatomy content and AI applications.

Detecting fractures in the complex carpal joints of domestic animals can be challenging with radiography due to overlapping bone structures. In such cases, CT scans help identify fractures and determine their location and configuration [12,32,33]. The use of cross-sectional imaging techniques in CT has significantly enhanced the ability of radiologists to make proper diagnoses. The application of CT in bovine orthopedics is constrained by factors such as cost, limited availability, and the requirement for general anesthesia [34]. However, despite these costs, CT scans should be considered valuable diagnostic tools, particularly for economically significant cattle. Early diagnosis using these imaging techniques can help prevent financial losses associated with delayed identification of conditions and their prognosis [18].

In summary, the anatomical and imaging of the knee joint of cattle resembled that of other ruminants. The present study provided an in-depth analysis of cattle knee joints that can be used in pathological conditions related to the joint. Cross-sectional imaging provides a solution for assessing complex structures when radiographic interpretation proves challenging, as it spatially separates overlapping structures seen in standard radiographs. This enables precise evaluation of the number and anatomical details of the bones. This study also offers valuable anatomical insights into the cattle knee joint and can add new data to the available literature, benefiting clinical practice and research.

Declarations

Availability of Data and Materials: The data that support the findings of this study are available from the corresponding author (O.P. Choudhary) upon reasonable request.

Acknowledgement: The author expresses gratitude to the Dean, College of Veterinary Science, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Rampura Phul, Punjab, for providing the necessary facilities to complete this work. Thanks are extended to Mr. Moti Masih, Laboratory Assistant, and Mr. Namdev Singh, DPL of the Department of Veterinary Anatomy, for their assistance in processing the knee joint sample for this study. The support from the Department of Veterinary Surgery, College of Veterinary Science, Guru Angad Dev Veterinary and Animal Sciences University, Rampura Phul, Punjab, and Gaurav Diagnostic Laboratory, Rampura Phul, Punjab is also sincerely acknowledged.

Funding Support: This study did not receive a specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Ethical Statement: Institutional animal ethics approval is not necessary for this study.

Conflict of Interest: The authors declared that there is no conflict of interest.

Declaration of Generating Artificial Intelligence: The article and/or tables and figures were not written/created by Artificial Intelligence (AI) and AI-assisted technologies.

Author's Contributions: Writing the original draft and design, OPC; methodology, OPC and JS; planned and investigation, OPC and JS; software, OPC and JS; formal analysis, OPC and JS; writing-review, editing and visualization, OPC and JS; supervision, OPC. All authors have read and agreed to the published version of the manuscript.

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