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Comparative Anatomical Study of the Rabbit and Human Knee Joint

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Abstract- ***The knee joint represents one of the most complex synovial joints in vertebrates, essential for locomotion, posture, and stability. Understanding its structural variation across species provides critical insights into evolutionary adaptation and functional biomechanics. This study presents a detailed comparative anatomical analysis of the rabbit and human knee joints, with emphasis on their bony architecture, ligamentous structures and selected musculotendinous attachments. Dissections were conducted on adult rabbits and male human cadaver under appropriate laboratory conditions in the Gross Anatomy Laboratory of the Department of Human Anatomy, Lead City University, Ibadan, Nigeria. Gross morphological observations were systematically recorded, and anatomical photographs were taken and labelled for comparative illustration. The findings reveal notable differences in the morphology of the patella, the femoral patellar surface, and the proximal attachment of the extensor digitorum longus muscle (EDL), reflecting distinct biomechanical adaptations: hopping in rabbits and upright bipedalism in humans. The study concludes that while the overall structural components of the rabbit and human knee are homologous, species-specific variations exist in the configuration and functional alignment of bones and soft tissues. These differences influence locomotor mechanics, stability, and range of motion.***

Keywords: Knee joint, Comparative anatomy, Rabbit, Human, Ligaments, Biomechanics, Gross dissection, Extensor Digitorum Longus (EDL).

I. INTRODUCTION

The knee joint is a synovial hinge joint that primarily permits flexion and extension, with limited rotation in some species. It plays a central role in movement, weight bearing, and postural stability. Comparative anatomical studies of the knee joint have become increasingly important for understanding evolutionary adaptation and functional morphology among mammals. In particular, differences in bony configuration and soft tissue arrangement provide evidence of how locomotor demands shape musculoskeletal structures.4,5,6

In quadrupedal mammals such as rabbits (Oryctolagus cuniculus), the knee joint is adapted for saltatorial locomotion (a hopping mode) of movement that requires powerful extension of the hindlimb but limited upright stability. Conversely, in humans (Homo sapiens), the knee is specialized for bipedal locomotion, requiring greater joint stability, alignment, and load distribution. Understanding these comparative variations contributes to a broader comprehension of evolutionary biomechanics, translational anatomy, and even biomedical engineering.4,5,2

Although several studies have described mammalian limb joints, few have directly compared the gross anatomical configuration of the rabbit and human knee joints under identical experimental conditions. Most existing literature either focuses on functional morphology or clinical anatomy of the human knee alone. Therefore, this study aimed to comparatively evaluate the anatomical features of the rabbit and human knee joints, with particular emphasis on the morphology and structural relationships of their major osseous and soft-tissue components.

II. METHODOLOGY

This study was conducted at the Department of Human Anatomy, Lead City University, Ibadan,

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Nigeria. Laboratory facilities were equipped with dissection tools, digital imaging devices, and proper preservation media. Adult rabbits (Oryctolagus cuniculus) were acquired at the institution's (Lead City University) Animal house and a male human cadaveric knee was dissected and assessed at the institution's Gross Anatomy Laboratory, both specimens were screened to ascertain that they were free from pathological deformities. Ethical clearance was obtained from the Departmental Research Ethics Committee in compliance with institutional regulations on animal and human tissue use.

A. Dissection Procedure
Both rabbit and human knee joints were dissected using standard gross anatomical procedures. Dissection steps included:

1. Skin incision and reflection to expose superficial fascia.
2. Identification and isolation of major tendons and ligaments.
3. Removal of surrounding musculature to reveal the joint capsule.
4. Observation of the bony articulations and ligamentous attachments.
5. Photography and labelling of all visible structures using digital imaging tools.

Comparative observations were recorded under identical conditions for both specimens.

B. Documentation
High-resolution photographs were taken at various stages (anterior, posterior, medial, and lateral views). These images were labelled using Adobe Photoshop software and stored as comparative figure sets (Rabbit–Human pairs).

C. Data Analysis
Qualitative comparative analysis was employed. Structural similarities and differences were described in anatomical terms. Observations were supported by relevant literature (2020–2025) and interpreted in light of biomechanical function.

III. FINDINGS

A. General Morphology
Both the rabbit and human knee joints comprise three major bones: femur, tibia, and patella. However, the proportional dimensions and articular contours differ. The human femoral condyles are larger and more rounded, while the rabbits' are relatively elongated and flattened posteriorly.

B. Observation 1: Patella Structure

- The rabbit patella presents an elongated rectangular shape with a concave posterior surface.
- The human patella, by contrast, is triangular with a concave posterior surface.

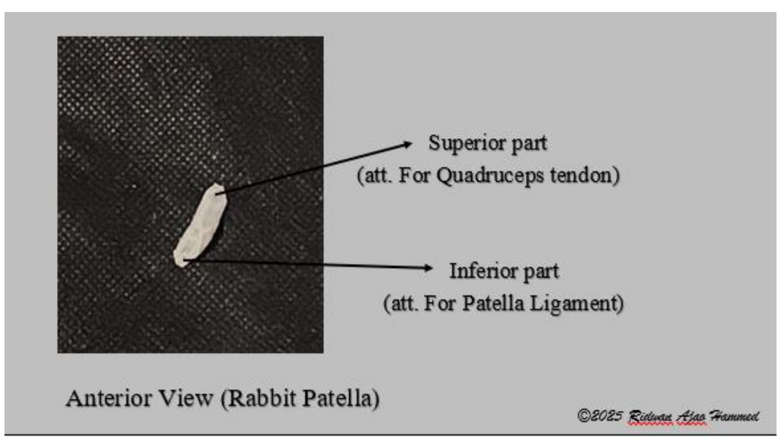

Fig. 1A

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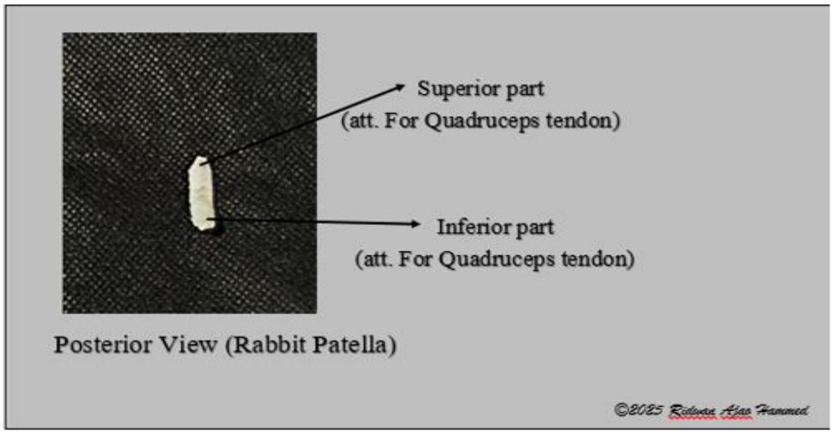

Fig. 1B

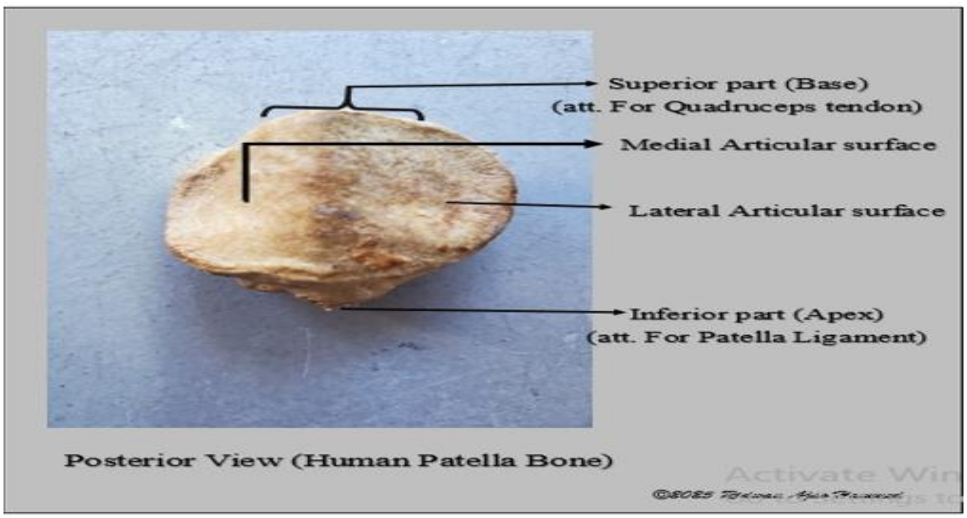

Fig. 1C

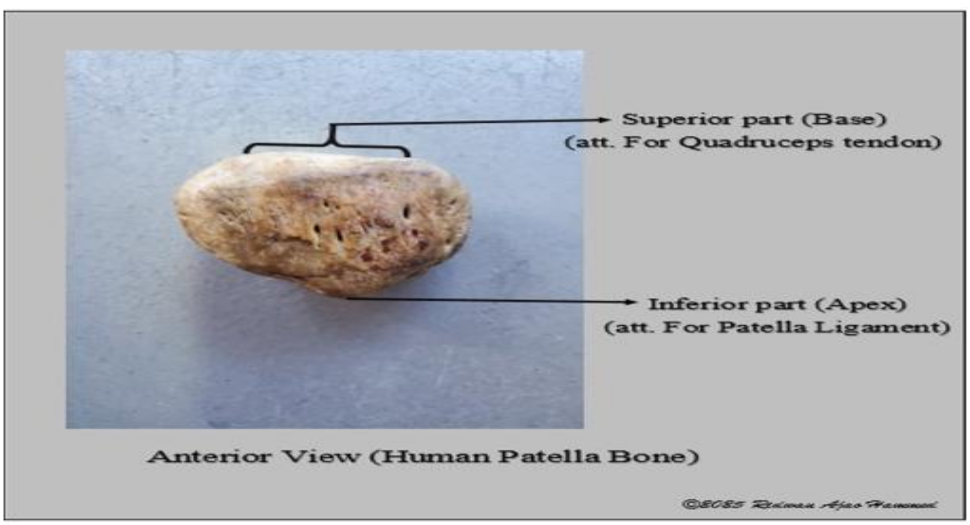

Fig. 1D

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The distinct patellar morphology observed between the rabbit and human knees may contribute to differences in the mechanical behaviour of the extensor mechanism between the two species.7,4,5

C. Observation 2: Femoral Patellar Surface

- In the rabbit, the patellar surface on the distal femur is rectangular and extends further superiorly.
- In humans, it exhibits a triangular outline corresponding to the patella's shape.

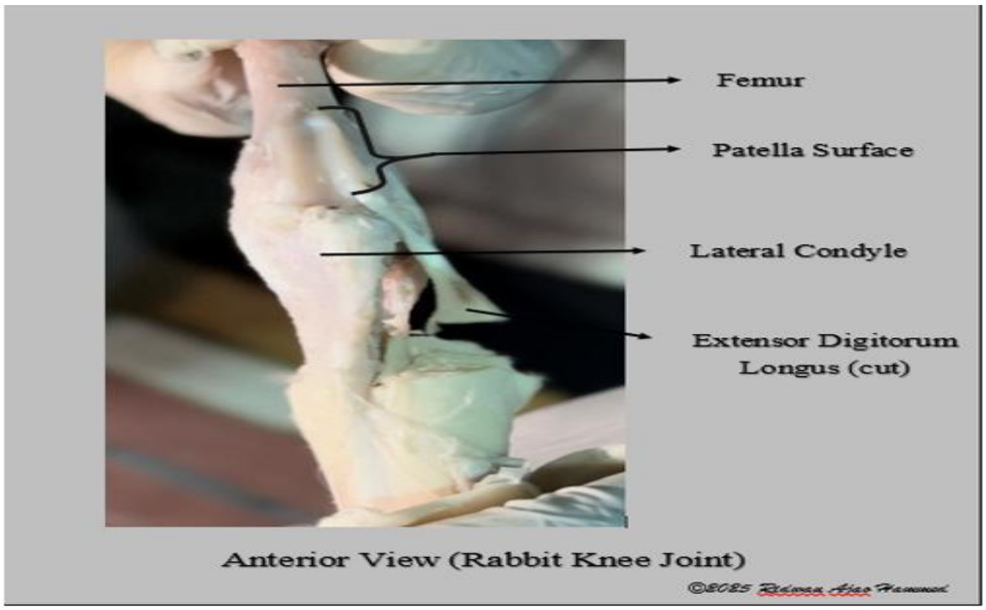

Fig. 2A

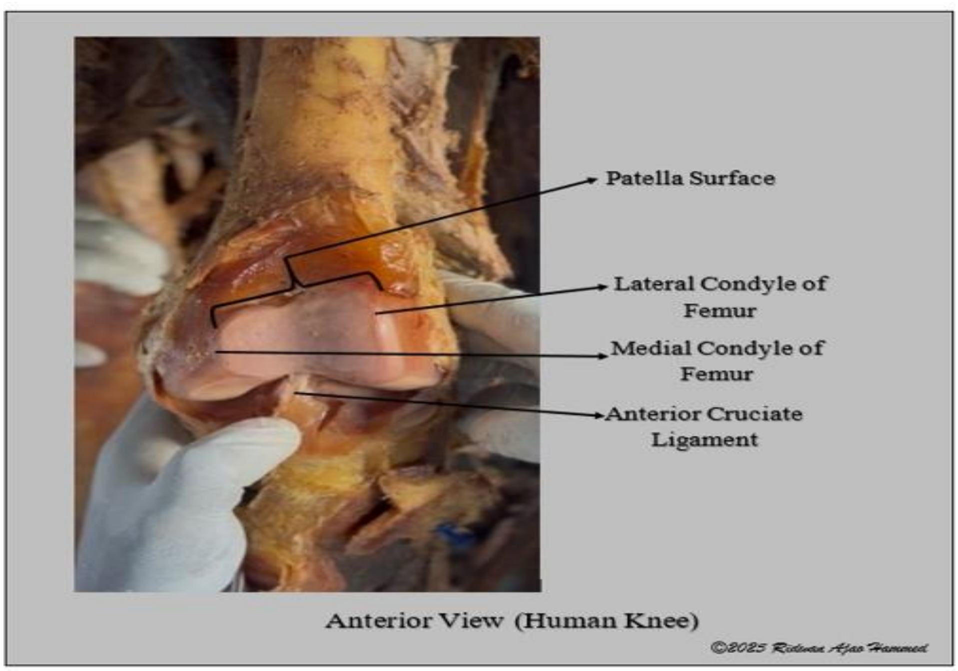

Fig 2B.

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D. Observation 3: Ligamentous Arrangement

The rabbit and human knees share homologous major ligamentous structures, including the cruciate and collateral ligament complexes; however, species-specific differences in ligament morphology, attachment and mechanical behaviour must be considered.4,5

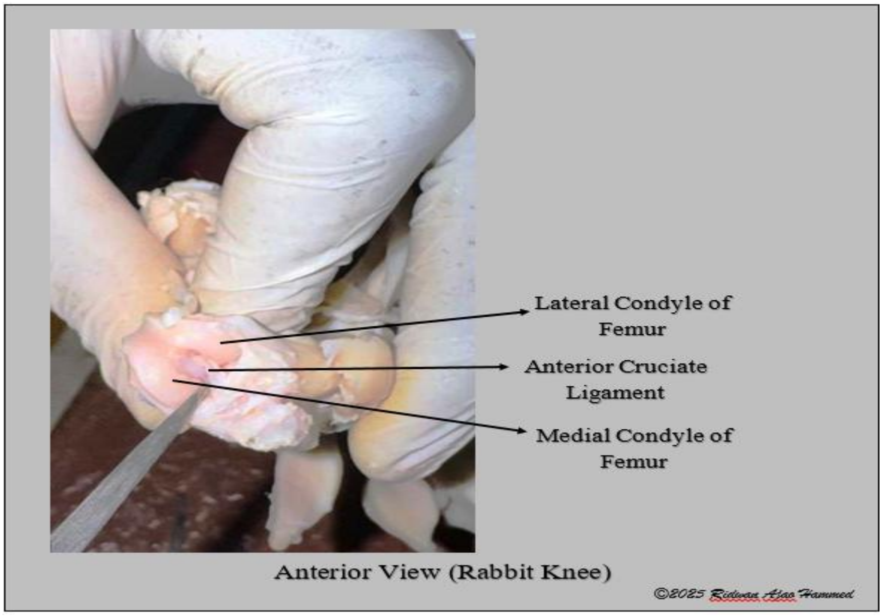

Fig. 3A

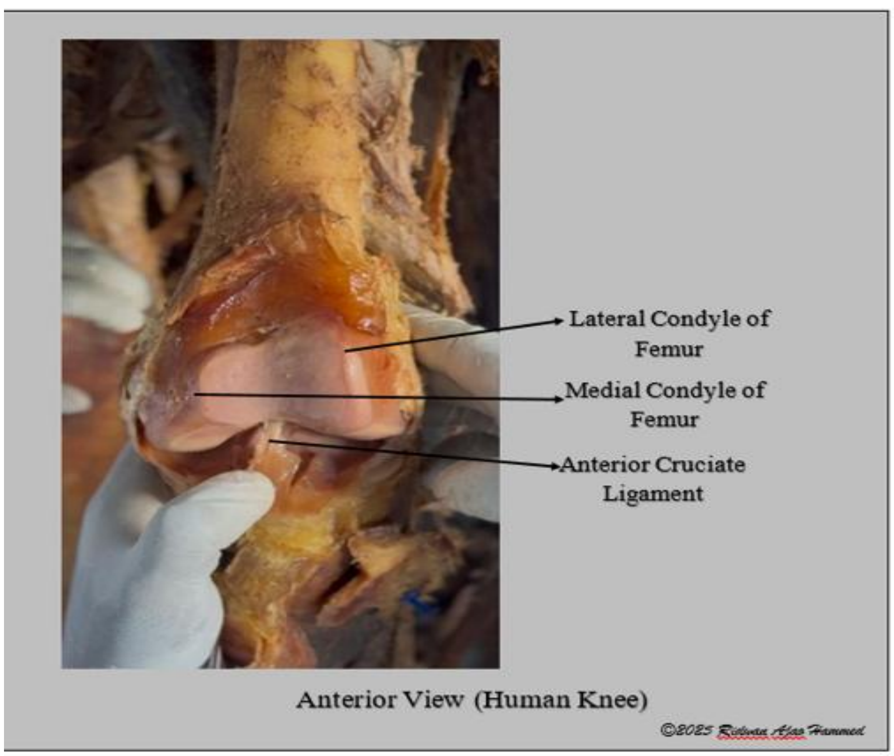

Fig. 3B

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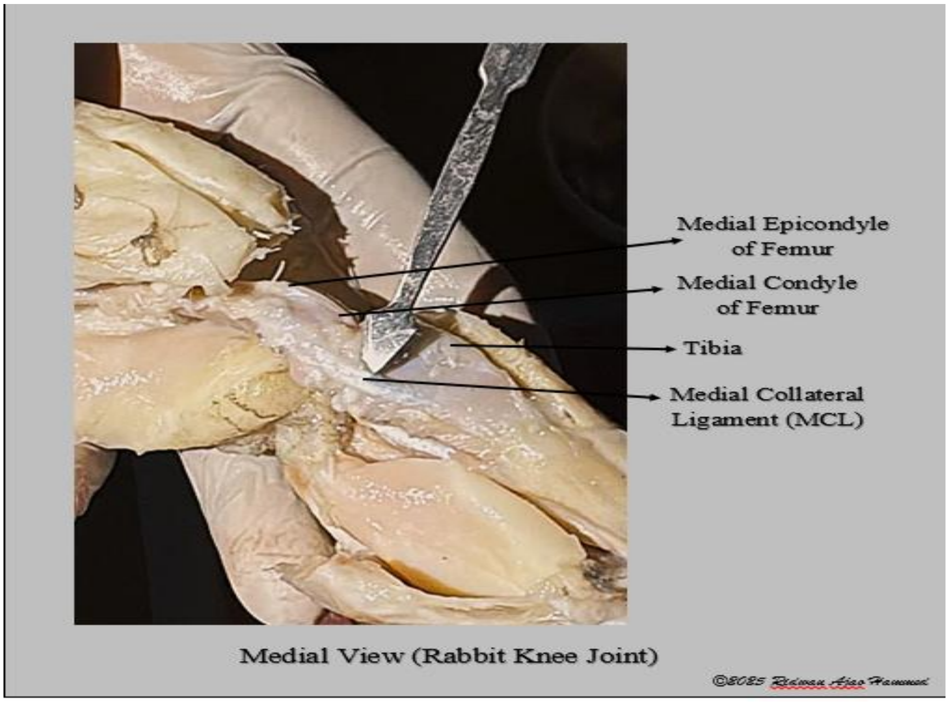

Fig. 4A

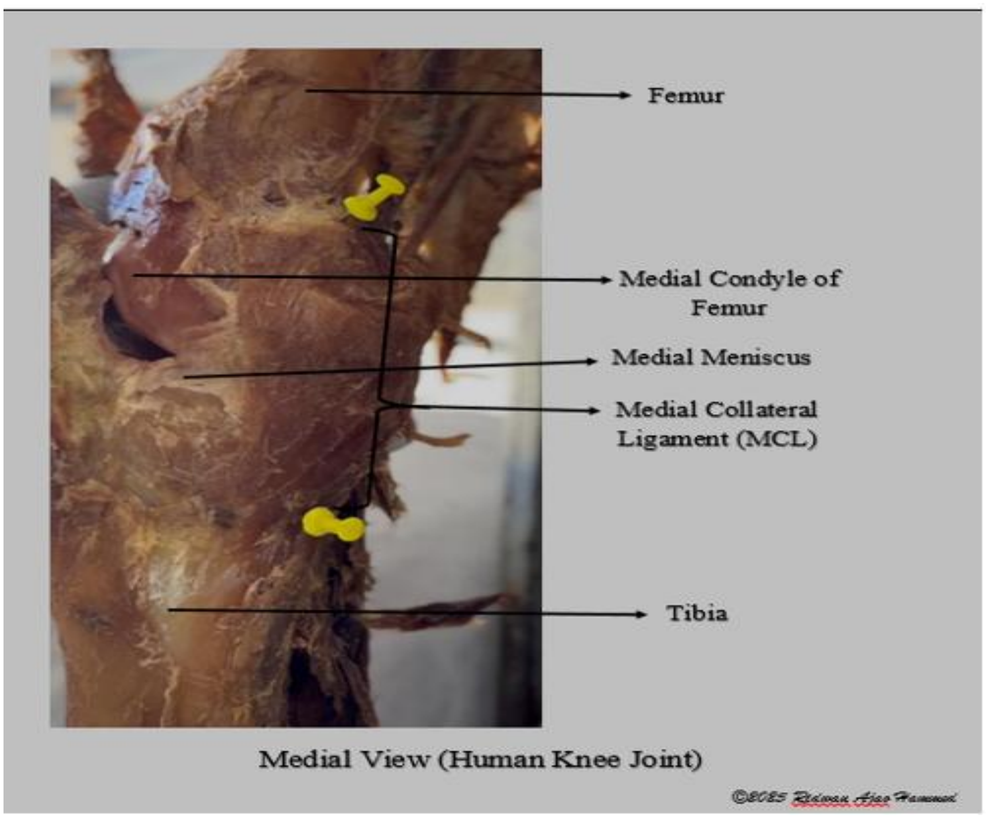

Fig. 4B

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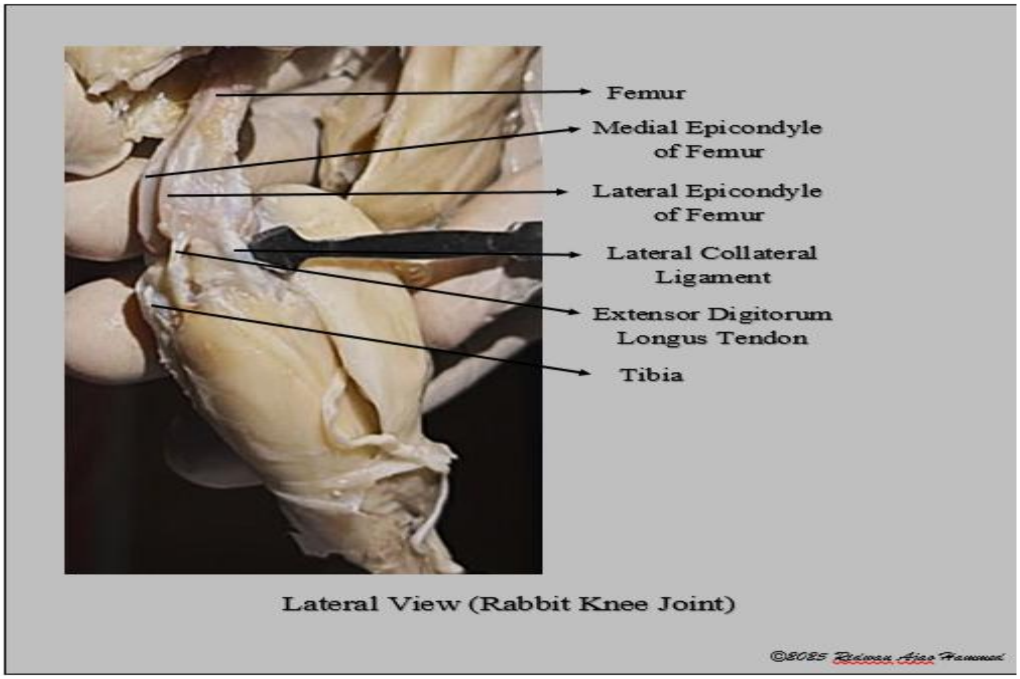

Fig.5A

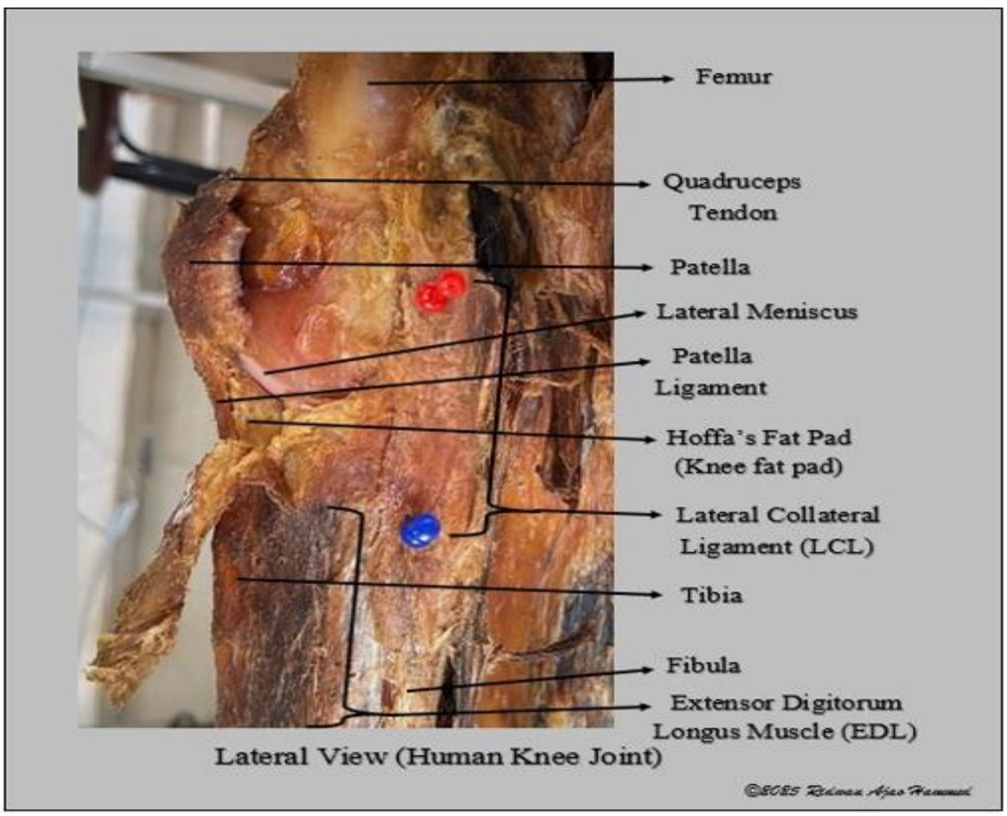

Fig. 5B

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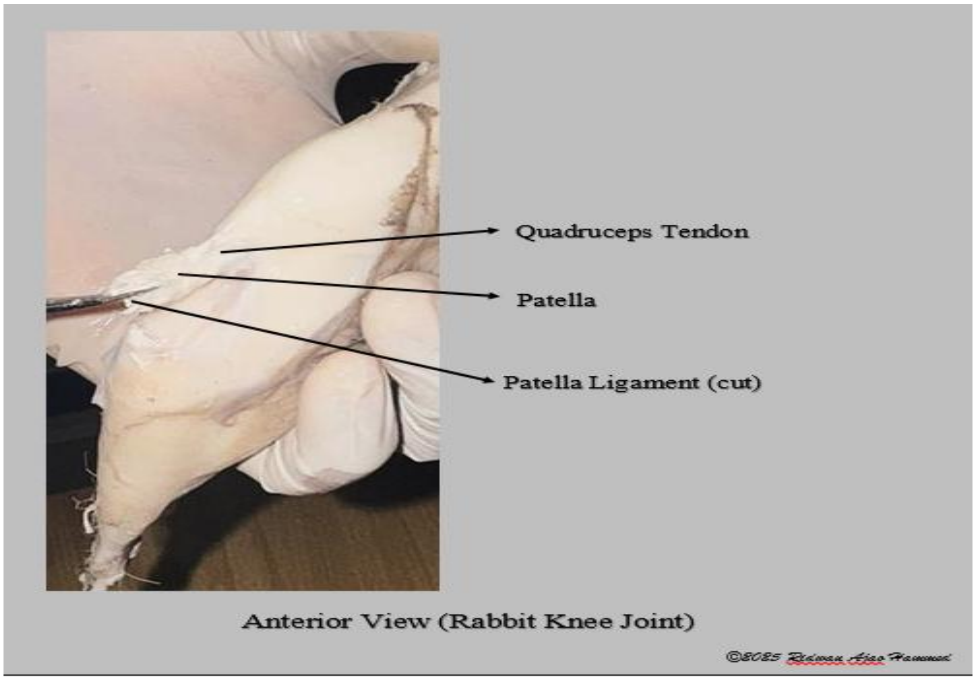

Fig. 6A

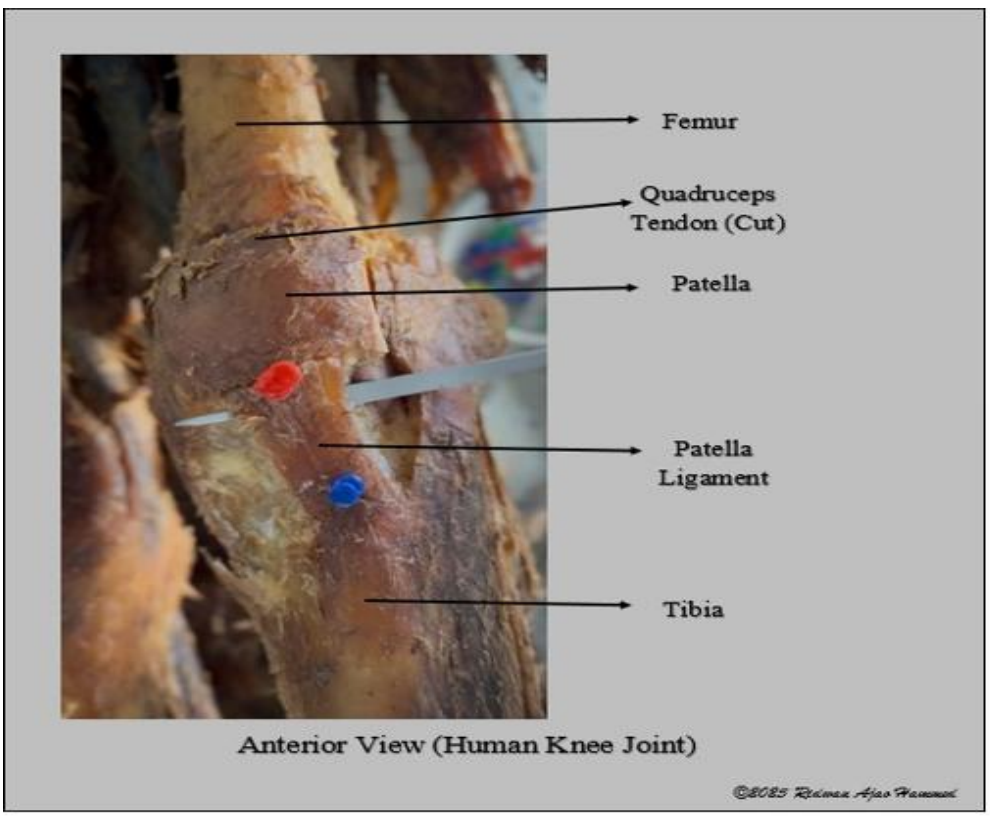

Fig. 6B

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E. Observation 4: Extensor Digitorum Longus Muscle Attachment

- In the rabbit, the Extensor Digitorum Longus (EDL) originates from the lateral condyle of the femur. It extends inferiorly behind the extensor retinaculum, dividing into four tendons to the 2nd–5th toes.
- In humans, the EDL originates from the lateral condyle of the tibia and anterior surface of the fibula, dividing into tendons to the 2nd–5th toes.

This difference may be associated with the restricted knee extension in rabbits (≈ 90°) compared with full extension (≈ 180°) in humans.

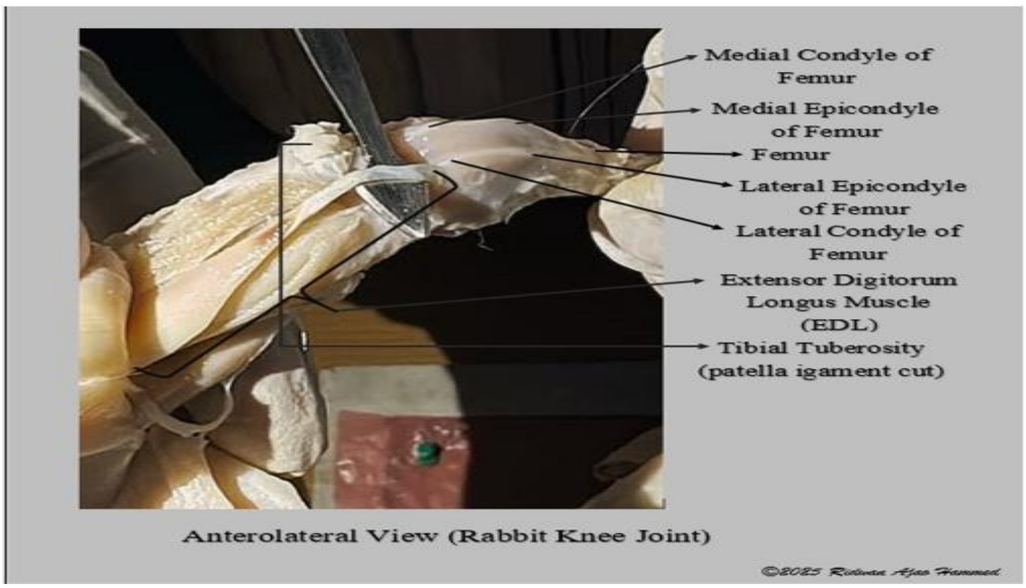

Fig. 7A

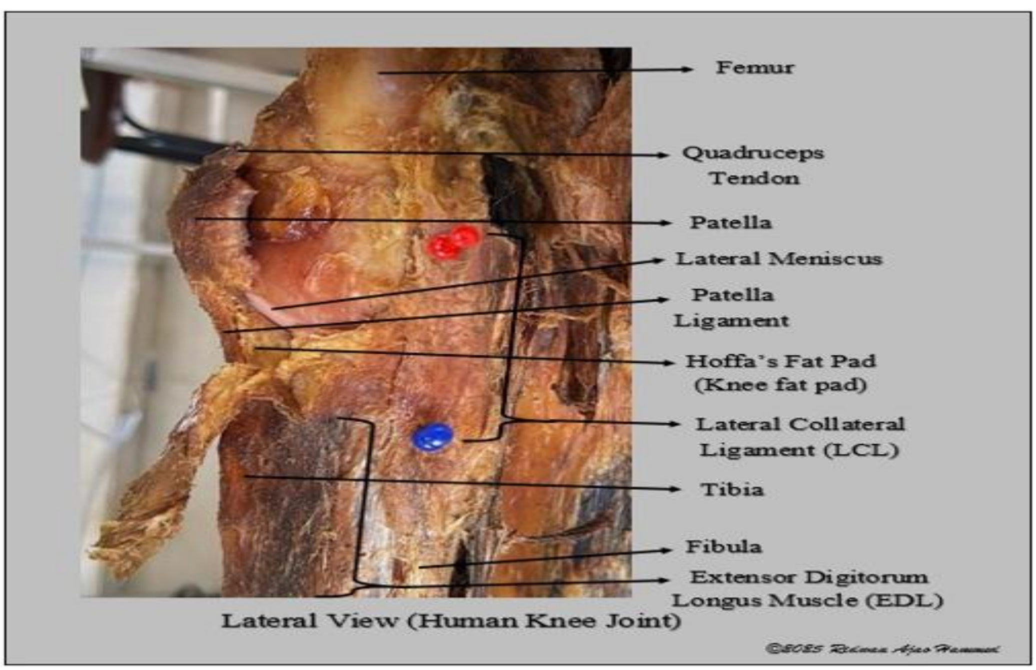

Fig. 7B

IV. DISCUSSION

A. Comparative Overview

The comparative gross anatomy of the rabbit and human knee joints demonstrates that, while both structures share the same fundamental organization, the morphological adaptations of each reflect their unique locomotor patterns. The human knee is designed for bipedal locomotion, demanding complete extension, greater weight-bearing capability, and stability in an upright posture. In contrast, the rabbit knee exhibits adaptations for saltatorial (hopping) movement, which prioritizes flexion power over extension stability.

These findings align with earlier biomechanical studies (Oláh et al., 2021; Hall et al., 2022; Xue et al., 2023) suggesting that species' postural orientation directly influences knee joint configuration. The elongated femoral trochlea and concave patellar surface in rabbits enable efficient flexion-extension cycles during hopping, whereas the broader human patella and deeper trochlear groove provide stability during bipedal stance.4,5,2,8

B. Functional Implications of Patellar Morphology

The observed shape differences between the rabbit's rectangular patella and the human's triangular one (see Figure 1A–1B) reveal divergent biomechanical roles. The triangular human patella acts as a mechanical pulley, increasing the lever arm of the quadriceps tendon, thereby enhancing knee extension power.7 The rectangular elongated rabbit patella, by contrast, serves more as a gliding surface during repetitive flexion, minimizing friction in fast, cyclical movements.

This suggests that evolutionary modifications in the patellofemoral interface represent functional responses to locomotor demands rather than mere structural divergence.

C. Ligamentous Homology and Biomechanical Correlation

Despite morphological differences, the ligamentous arrangements of both species are remarkably similar. The anterior and posterior cruciate ligaments intersect within the intercondylar notch, while the collateral ligaments provide mediolateral stability. The positional conservation of these structures supports the theory of functional homology among mammalian knees.4,5,9

However, differences in ligament thickness and tension may correlate with joint range of motion. The rabbit cruciate ligaments are proportionally thinner, accommodating more rapid flexion–extension cycles, while the human ligaments are denser, ensuring stability during upright load-bearing.

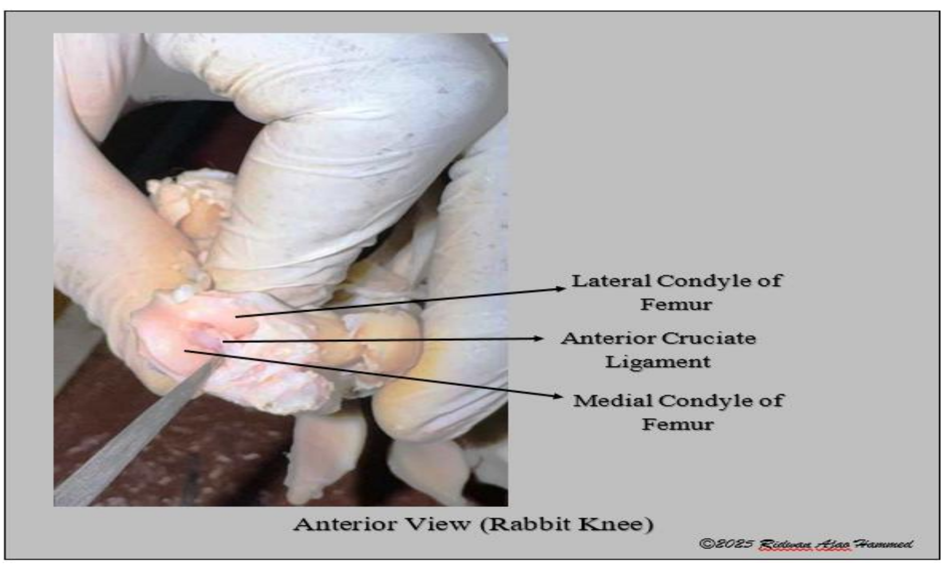

Fig. 8A

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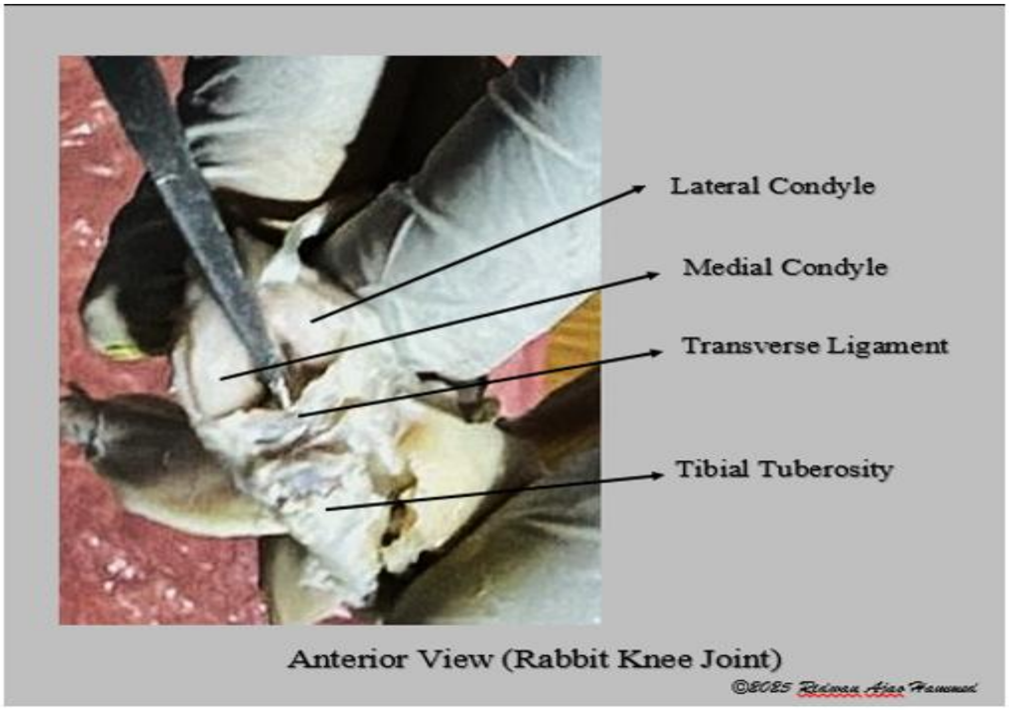

Fig. 8B

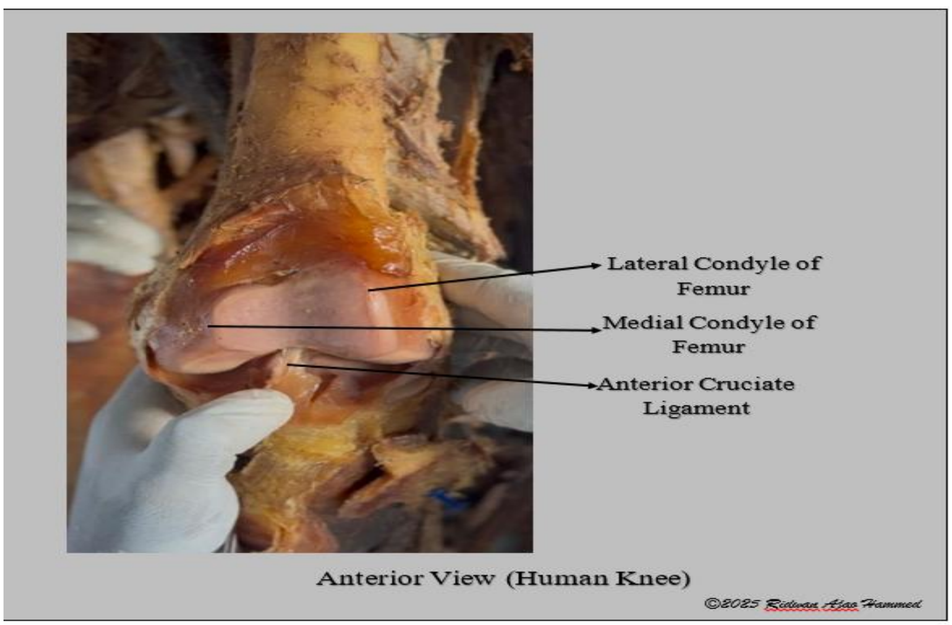

Fig. 8C

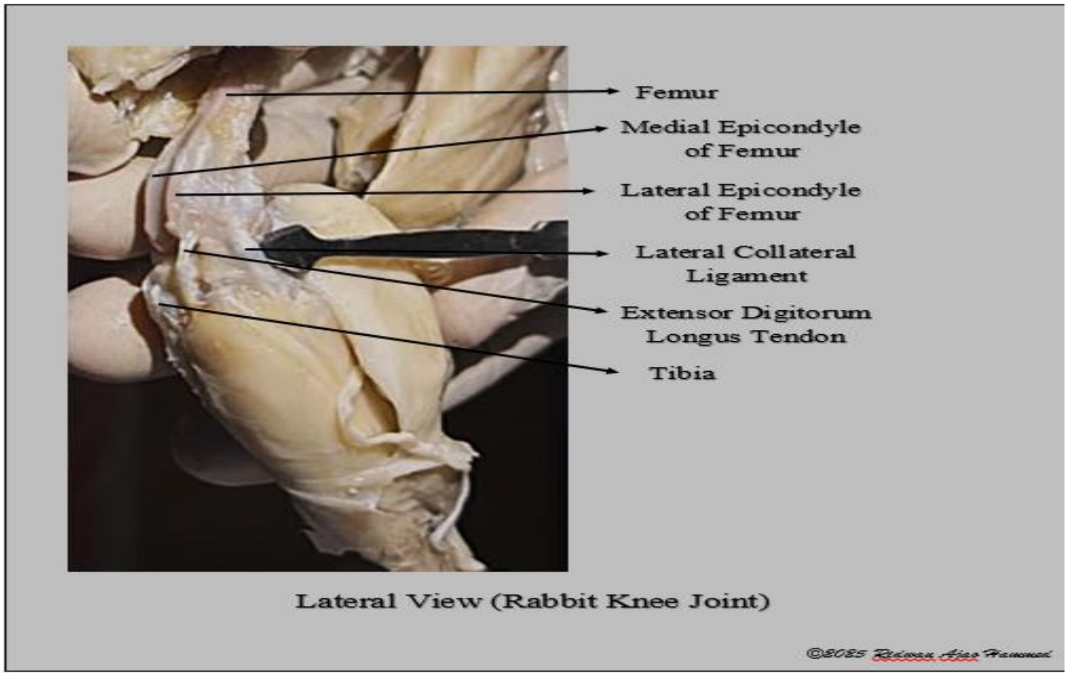
Femur
Medial Epicondyle of Femur
Lateral Epicondyle of Femur
Lateral Collateral Ligament
Extensor Digitorum Longus Tendon
Tibia
Lateral View (Rabbit Knee Joint)

Fig. 9A

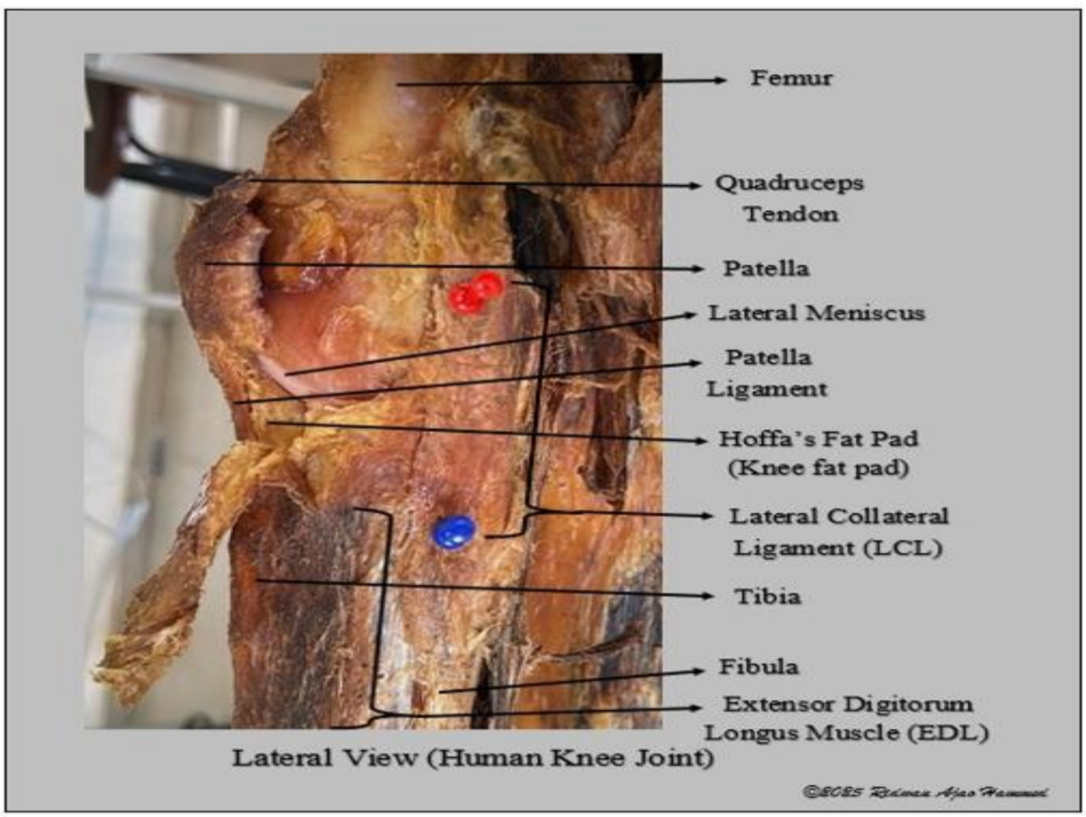
Femur
Quadruceps Tendon
Patella
Lateral Meniscus
Patella Ligament
Hoffa's Fat Pad (Knee fat pad)
Lateral Collateral Ligament (LCL)
Tibia
Fibula
Extensor Digitorum Longus Muscle (EDL)
Lateral View (Human Knee Joint)

Fig. 9B

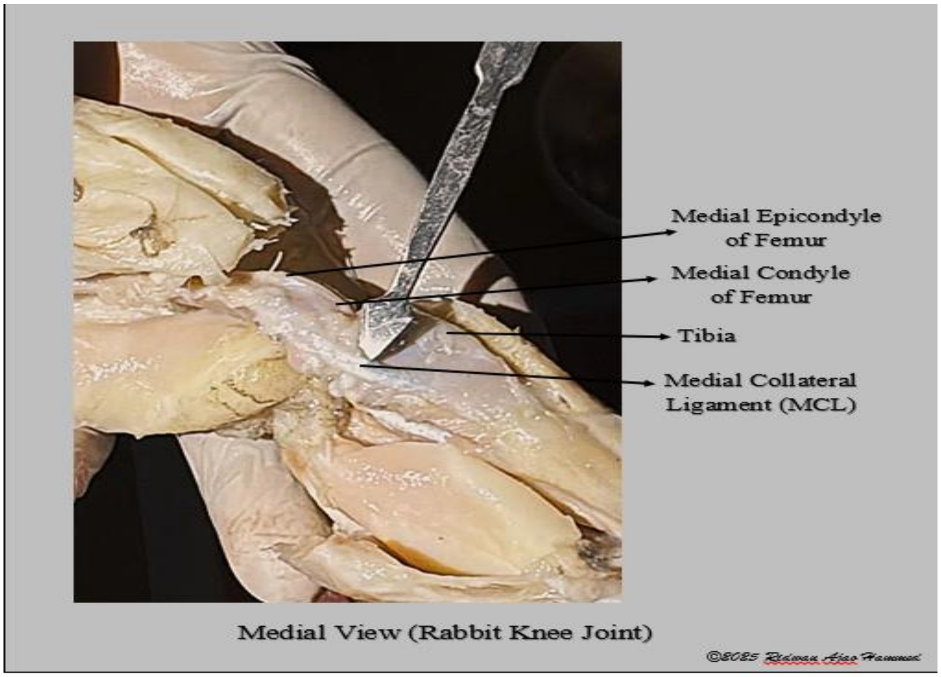

Fig. 10A

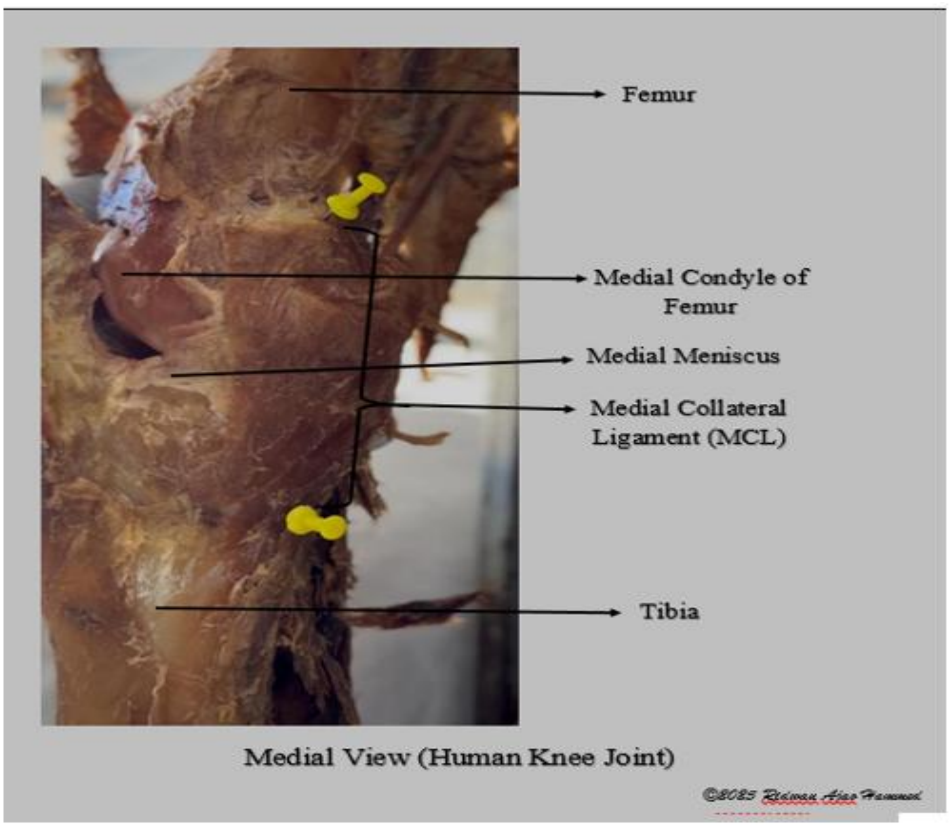

Fig. 10B

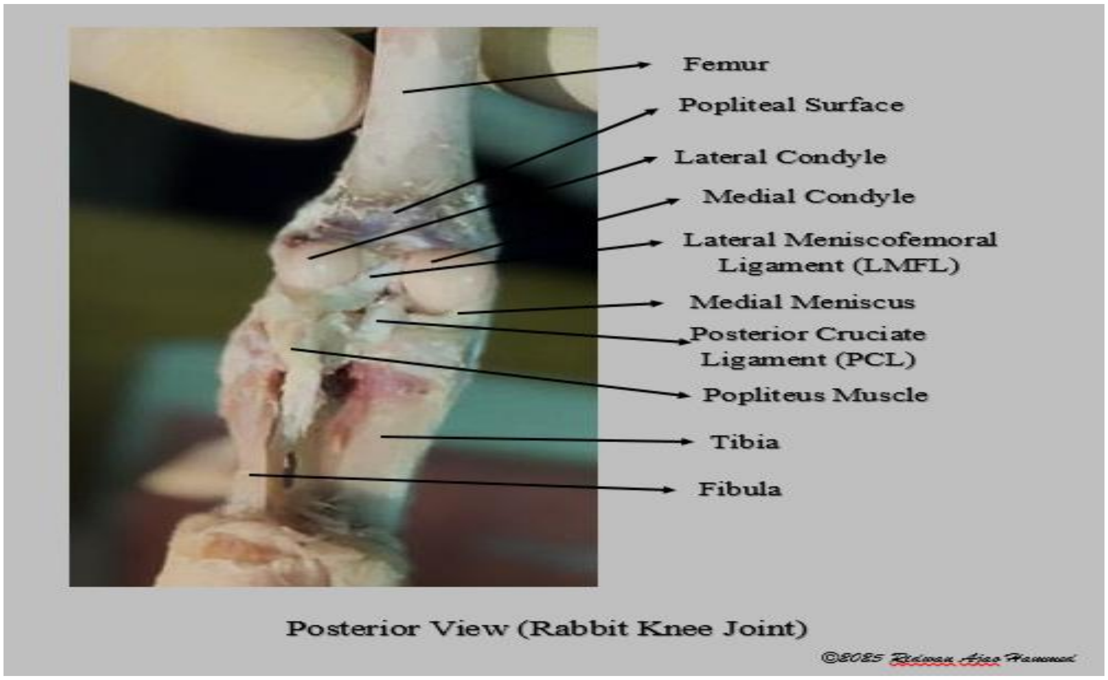

Fig. 11A

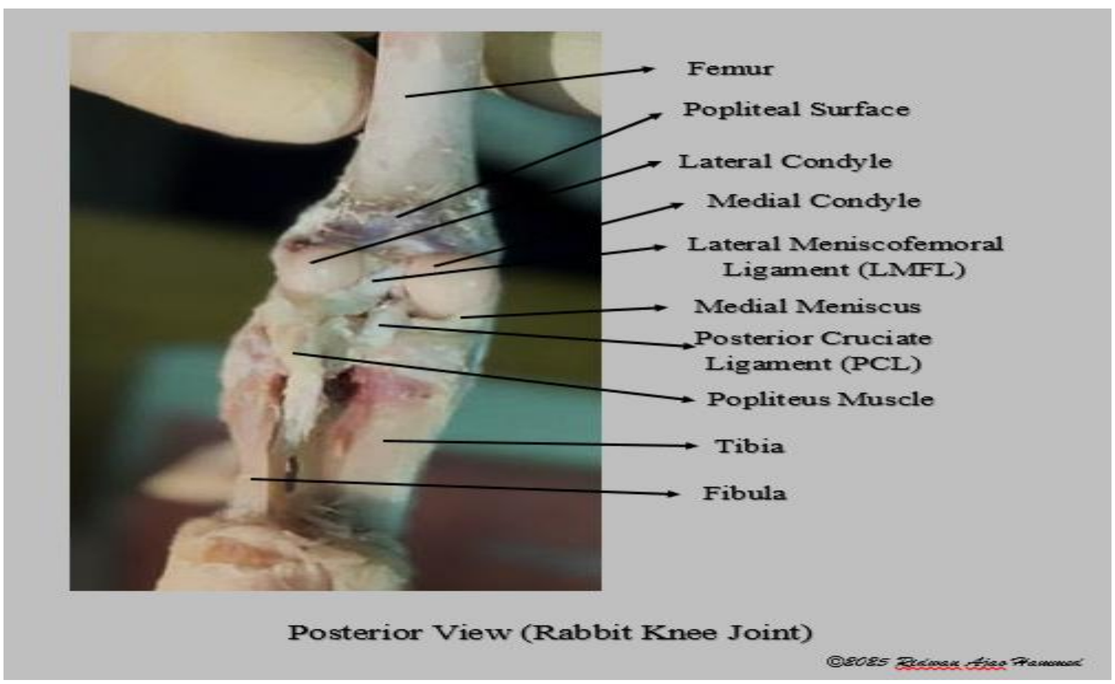

Fig. 11B

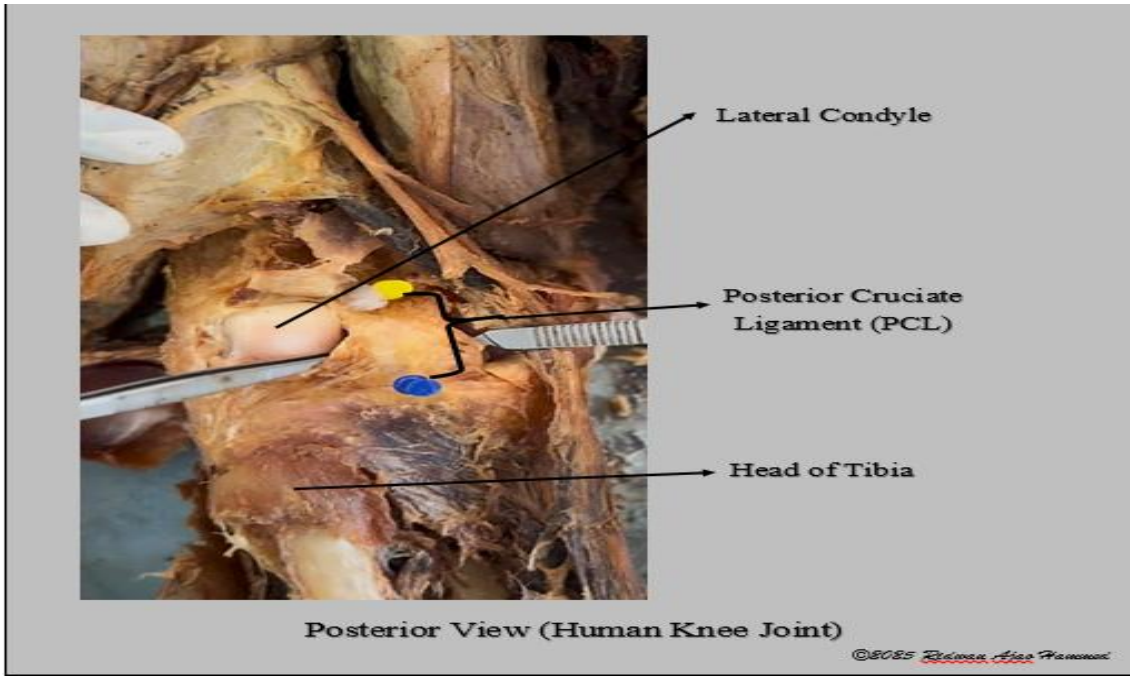

Fig. 11C

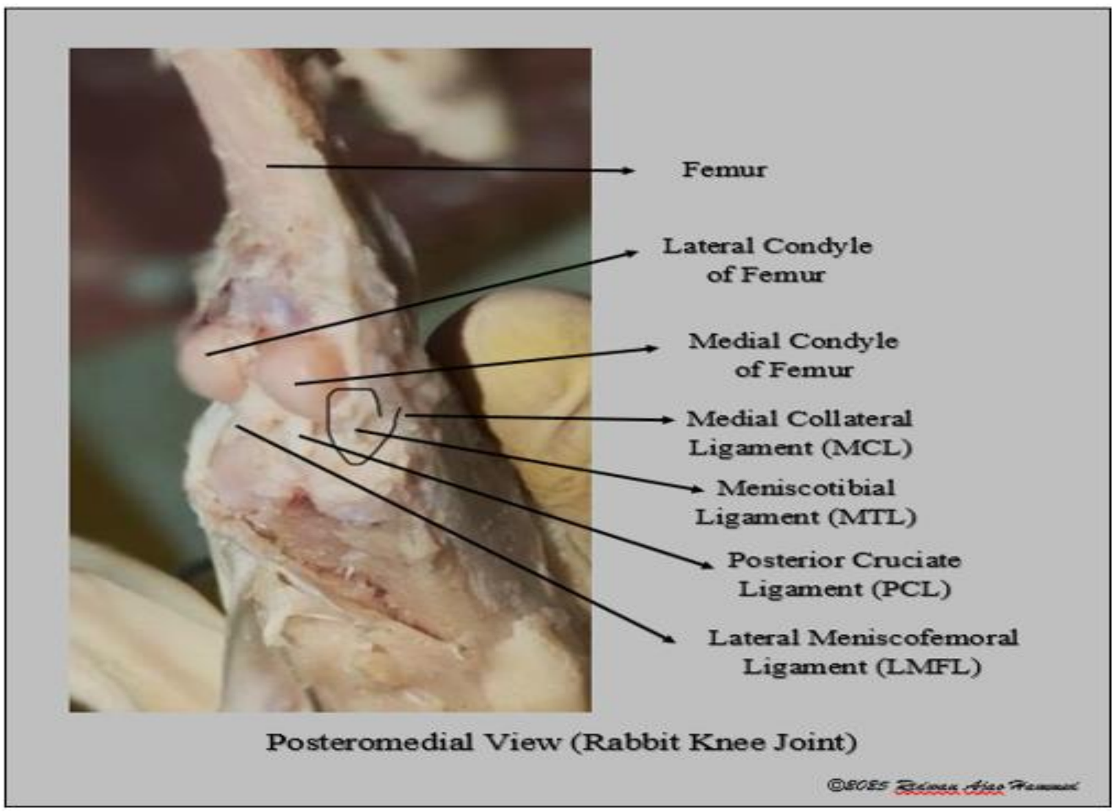

Fig. 12A

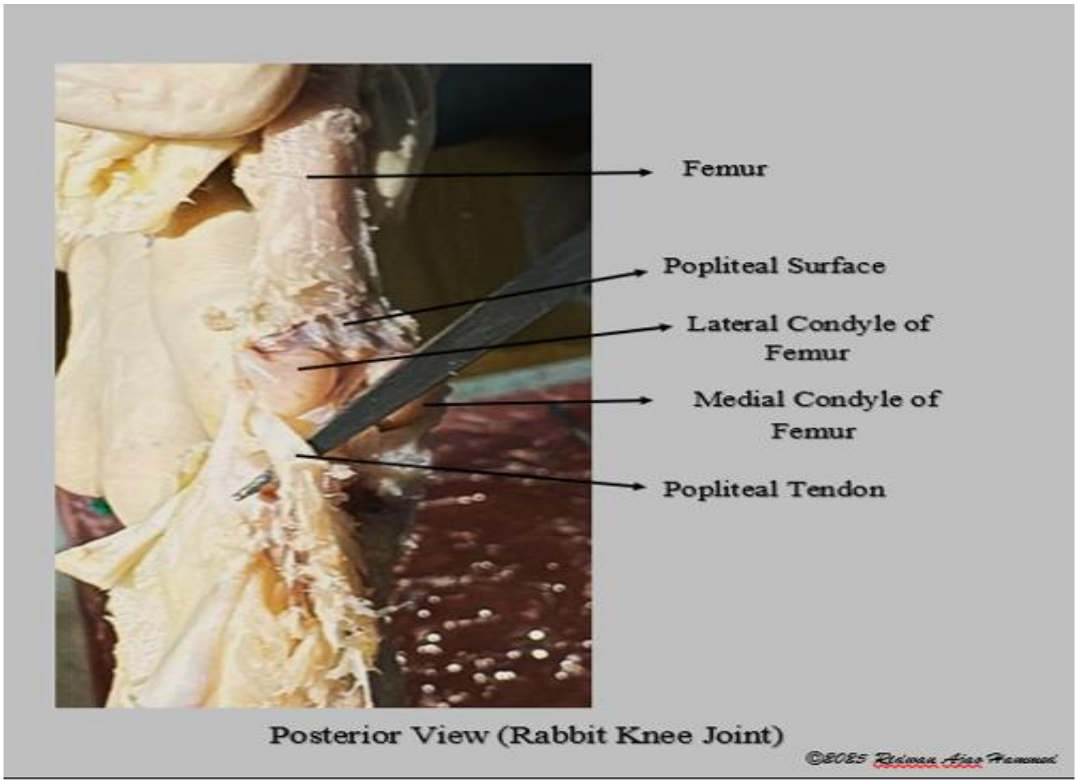

Fig. 12B

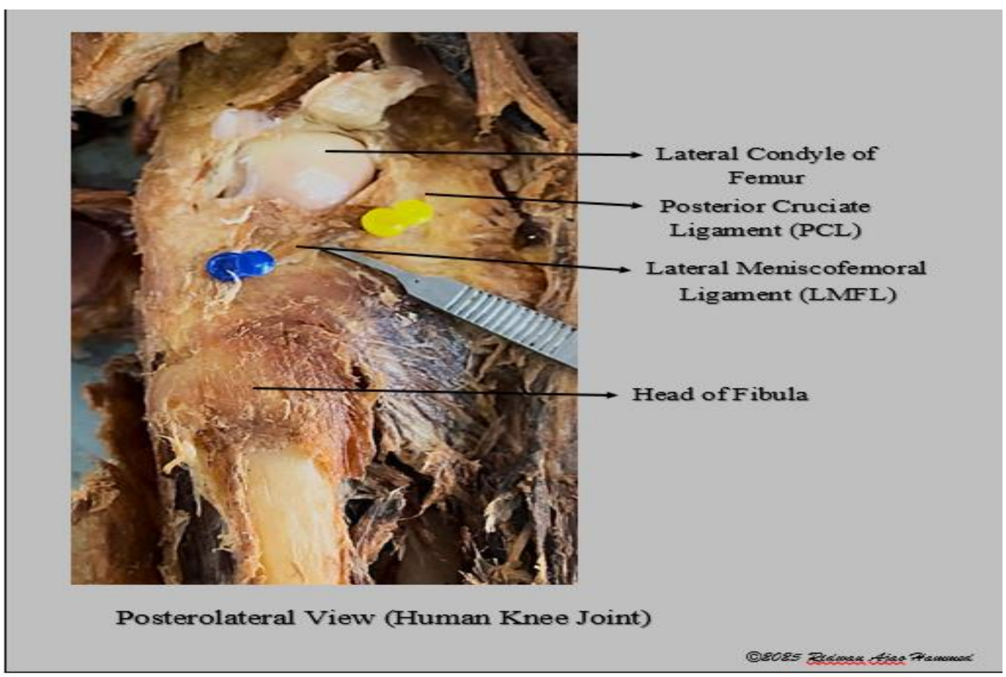

Fig. 12C

D. Extensor Digitorum Longus Muscle Variation

The distinct proximal attachment sites of the EDL muscle femoral origin in rabbits versus tibial origin in humans, provide key insights into locomotor adaptation. The femoral origin in rabbits shortens the functional length of the extensor chain, which may be associated with optimizing for rapid but limited extension, whereas the tibial origin in humans allows a longer lever for full extension and postural control. This finding is consistent with the observation that rabbit knee extension is limited to approximately 90°, corresponding with their crouched resting and hopping posture, while human knees achieve ≈ 180°, crucial for upright gait.

E. Muscular Arrangement and Load Distribution

Rabbit hindlimb muscle activity and morphology especially the hamstring group contribute substantially to the biomechanics of hopping and stance-phase locomotion.2,1

F. Biomechanical Considerations

The knee joint's ability to resist shear stress and compressive load is largely determined by bone alignment and ligament tension. The rabbit's femoral condyles and tibial plateau form a nearly horizontal articulation, suitable for distributing force during a crouched posture. In contrast, the human condyles are more vertically oriented, aligning with the mechanical axis of the leg to facilitate upright locomotion and shock absorption.4,5,8,3

These variations reinforce that joint orientation and articular congruence are critical in defining locomotor mechanics.

G. Comparative Evolutionary Perspective

Functionally and biomechanically, both species share the same fundamental joint blueprint, but divergent functional pressures led to different morphologies. The rabbit's adaptation reflects speed and agility in horizontal motion, while the human knee evolved for balance and efficiency in vertical posture.4,5,2,3

This study therefore provides valuable evidence supporting the concept of adaptive morphological divergence, where the same anatomical components serve species-specific functions, illustrating evolutionary versatility within mammalian locomotor systems.

V. CONCLUSION

The comparative anatomical assessment of the rabbit and human knee joints demonstrates substantial structural homology alongside distinct morphological and functional adaptations. Differences in patellar and distal femoral morphology, ligamentous characteristics, muscle attachments, and the origin of the extensor digitorum longus reflect species-specific biomechanical demands associated with locomotion, propulsion, and postural stability. These findings emphasise the importance of comparative anatomy in understanding musculoskeletal adaptation and in assessing the translational relevance of rabbit models to human knee research. Further studies incorporating histological and kinematic analyses are recommended to clarify species-specific soft-tissue specialisation and its relationship with joint movement and function.

APPENDIX

Below are the 29 labelled figure placeholders representing comparative paired views of rabbit and human knee joints. Each pair corresponds to anatomical orientations used in this study.

Figure 1A–1D: Comparative anterior and posterior view of rabbit and human patella.

Figure 2A and 2B: Comparative femoral patellar surface of rabbit and human knee joint anterior view.

Figure 3A and 3B: Anterior view showing ligamentous structures in rabbit and human knees.

Figure 4A and 4B: Medial view of rabbit and human knee joint displaying medial collateral ligament (mcl) and condyles.

Figure 5A and 5B: Lateral view of rabbit and human knee joint displaying lateral collateral ligament (lcl) and extensor digitorum longus muscle (edl).

Figure 6A and 6B: Anterior view of rabbit and human knee showing patella, patellar ligament and quadriceps tendon.

Figure 7A and 7B: Comparative anterolateral view of rabbit knee joint and lateral view of human knee joint.

Figure 8A–8C: Comparative anterior view of rabbit and human knee joint showing anterior cruciate ligament (acl), femoral lateral condyle and transverse ligament.

Figure 9A and 9B: Comparative lateral view of rabbit and human knee joint.

Figure 10A and 10B: Comparative medial view of rabbit and human knee joint.

Figure 11A–11C: Comparative posterior view of rabbit and human knee joint showing posterior cruciate ligament (pcl), condyles of femur and meniscus.

Figure 12A–12C: Posterior view of rabbit knee joint, posteromedial view of rabbit knee joint and posterolateral view of human knee joint.

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CONFLICT OF INTEREST
The authors declare no conflict of interest.

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