

Article

The Human Knee Joint: An Anatomical and Histological Study Using a Cadaveric Approach

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Abstract: The knee joint is a complicated synovial joint that plays an important role in locomotor function and weight-bearing capacity of the body. The current study reports on the structure of knee joint tissues of humans by macrodissection and by histology in order to demonstrate the gross anatomy and histological organization of bones, ligaments, menisci, bursae, blood supply, and innervation of the knee joint. In this study, the gross anatomy and histological structure of 24 human cadaveric knees of adults (17 males and 7 females aged between 24 and 65 years old) were studied with regard to patellar measurements, arrangement of ligamentous and capsular fibers, and zonal organization of hyaline and fibrocartilaginous tissues. The study report is provided only in descriptive terms because no inferential statistical analyses are provided in the study record supplied.

Keywords: Knee joint; Cadaveric dissection; Histology; Patella; Menisci.

Introduction

The knee joint is the largest synovial joint in the human body and is typically classified as a modified hinge joint. This joint is formed by the distal femur, proximal tibia, and patella, allowing for flexion and extension, as well as rotation to some extent depending on the position of the joint. It consists functionally of the medial and lateral tibiofemoral joint and the patellofemoral joint. The heavy load and complexity of the structure make it prone to injuries and degenerative diseases [1], [2], [3], [4], [5], [6], [7].

The development of the knee joint starts at the time of embryogenesis due to the formation of condensations of mesenchyme within the limb bud. Further differentiation and cavitation lead to the formation of the articular surfaces, menisci, ligaments, and joint cavity. These processes happen chronologically and cannot be treated as a result achieved at once; hence, it needs to be taken into account that all structures are mature by the 20th week of gestation [2], [3], [8].

Materials and Method

Objectives of the Research

The objective of the research was to provide an account of the gross anatomy of the human knee joint in terms of the attachment of the ligaments, muscle arrangement, morphology, and topographic relationship, along with histology of the joint capsule, articular cartilage, and menisci.

Sample Collection

Twenty-four cadaveric knee-joint specimens of humans (17 male and 7 females; 24–65 years old) were collected from the forensic medicine departments of Tikrit and Baghdad in Iraq during the period between October 2020 and July 2021. In addition, dry human skeletons were used for osteological analysis. The authors are required to include the information about the side and number of knee joint samples per individual donor along with ethics/authorization details of the institution prior to submission of the manuscript.

Anatomical Dissection and Histological Techniques

Anatomical Dissection

A sequential layer-by-layer dissection was done using conventional surgical instruments to reveal the structures of interest, ligamentous attachments, topography, and neurovascular bundles that run adjacent to the structures. The notes in the original paper did not give a standard dissection technique and any measurements; these should be included if available.

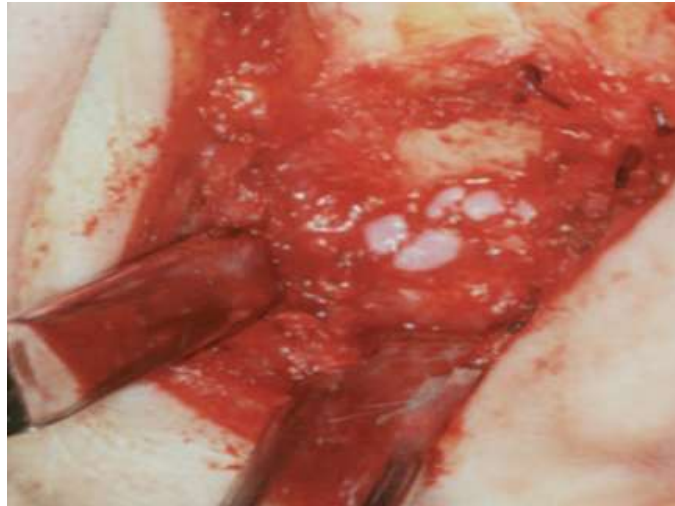


Figure 1. Initial skin incision to expose the superficial anatomical structures of the knee.



Figure 2. Knee-joint structures following removal of the overlying skin and deep fascia.

Histological Processing

Samples of tissues obtained from the joint capsule, articular cartilage, and menisci were fixed in 10% neutral-buffered formalin for 24-48 hours. Osteological specimens were decalcified with dilute nitric acid, neutralized, and extensively rinsed. Tissues were subjected to dehydration in ethanol, cleared in

a proper clearing agent, and embedded in paraffin wax. The concentration of the decalcifying agent and time of decalcification, if known, should be stated.

Sectioning and Staining

Sections of 4-7 μm thickness were cut with a rotary microtome, placed on glass slides, and stained with hematoxylin and eosin (H&E) and Masson's trichrome in order to study the tissue structure, cell distribution, and arrangement of collagen fibers. These details concerning staining, microscope/camera equipment, magnification factors, and histological evaluation criteria should be included in the manuscript if available.

Result

Gross Anatomical Features

Patella and Patellofemoral Joint

Patella is the biggest sesamoid bone and is situated in the quadriceps femoris tendon [9], [10], [11], [12], [13].



Figure 3. Dissection and isolation of the patella for anatomical examination.



Figure 4. Exposure of the knee joint after removal of surrounding soft tissues.

The patella was found to be triangular in shape, with its vertical length measuring 5.0 to 7.0 cm and its transverse width ranging between 4.5 to 6.0 cm. The posterior articulating surface of the patella is made up of medial and lateral facets, which are lined with hyaline cartilage and articulate with the trochlear groove of the femur [9], [10], [11], [12], [13], [14].

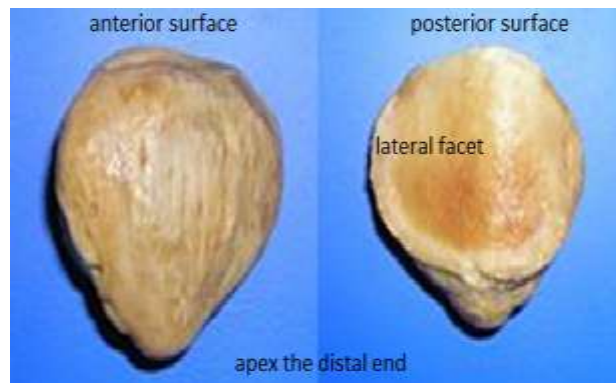


Figure 5. Left patella in anatomical orientation, showing the anterior and posterior surfaces, lateral facet, and apex. (Confirm figure numbering against the original image sequence before submission.)

The patellar ligament stretches from the top part of the patella to the tibial tuberosity [2], [3], [15], [16].



Figure 6. Patellar ligament (infrapatellar tendon) demonstrated during dissection.



Figure 7. Infrapatellar fat pad and deep infrapatellar bursa.

Collateral Ligaments

The medial collateral ligament (MCL) runs from the medial femoral epicondyle to the medial tibia. It has deep fibers that lie close to the joint capsule and the medial meniscus. The length mentioned in the source manuscript is 8.5–13.0 cm; landmarks and measurement techniques need to be specified [3], [6], [17], [18].

The lateral collateral ligament (LCL) runs from the lateral femoral epicondyle to the head of the fibula. The length mentioned in the source manuscript is 8.0–12.0 cm. In contrast to the deep MCL, the LCL is situated away from the lateral meniscus and joint capsule [3], [6], [17], [18].



Figure 8. Medial collateral ligament exposed during dissection.



Figure 9. Lateral collateral ligament exposed during dissection.

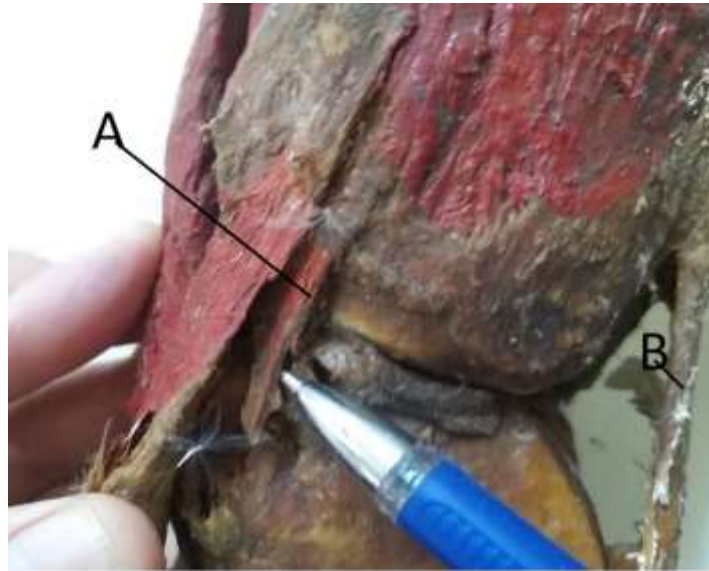


Figure 10. Comparative view of the medial collateral ligament (A) and lateral collateral ligament (B).

Cruciate Ligaments and Joint Surfaces

The anterior cruciate ligament (ACL) and posterior cruciate ligament (PCL) intersect within the intercondylar area and help in providing anteroposterior and rotational stability of the knee joint [2], [3], [17], [19], [20].



Figures 11–12. Intra-articular adipose tissue and the suprapatellar bursa in relation to the knee-joint cavity. (Verify image-to-caption correspondence.)



Figure 13. Internal cavity of the knee joint showing the intra-articular structures.

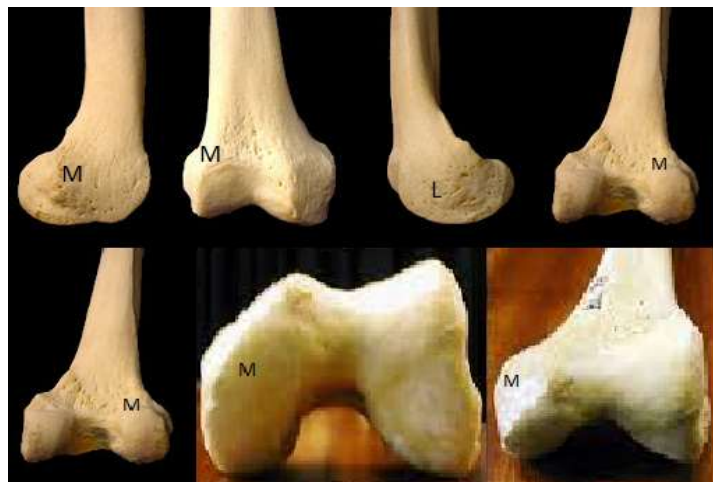


Figure 14. Distal femur showing the medial and lateral condyles.

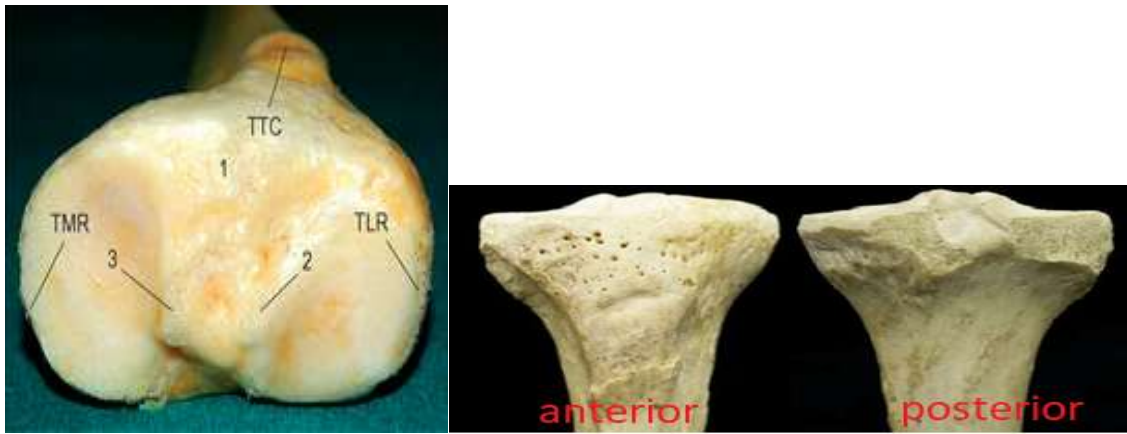


Figure 15. Superior view of the tibial plateau and intercondylar eminence. (Confirm labels and orientation against the image.)

Menisci

The medial meniscus usually has a C-shape and is less mobile because of its capsular and ligamentous attachments. The lateral meniscus is more circular in shape and is more mobile. They are fibrocartilage structures that enhance joint congruity and distribute joint load [2], [3], [16], [21], [22].



Figure 16. Superior view of the menisci of the right knee.



Figure 17. Posterior surface of the patella in relation to the quadriceps tendon complex.

Popliteal Fossa

The popliteal fossa is located behind the knee joint and consists of the popliteal artery and vein, tibial nerve, common fibular nerve, and their branches [1], [3], [23], [24], [25].



Figures 18–19. Boundaries of the popliteal fossa, including the sural nerve and small saphenous vein.



Figure 20. Deep neurovascular contents of the popliteal fossa.



Figure 21. Muscular relationships in the posterior popliteal region.

Histological Features

Joint Capsule and Synovial Membrane

The fibrous layer of joint capsule is made up mostly of dense connective tissue with collagen fibers. It is lined on its inner side by synovial membrane – a vascularized connective tissue membrane with cells called synoviocytes that participate in the formation of synovial fluid. Fibrous capsule should not be regarded as dense regular connective tissue everywhere [2], [3], [4], [7].

Articular Hyaline Cartilage

Articular surfaces are covered with hyaline cartilage. According to the source manuscript, the thickness is 2.0–4.0 mm. This value depends on the location. Articular hyaline cartilage can be subdivided into superficial, transitional, deep, and calcified layers. Shape of chondrocytes and their arrangement, as well as the structure of matrix, differs between these layers [2], [3], [4], [11].

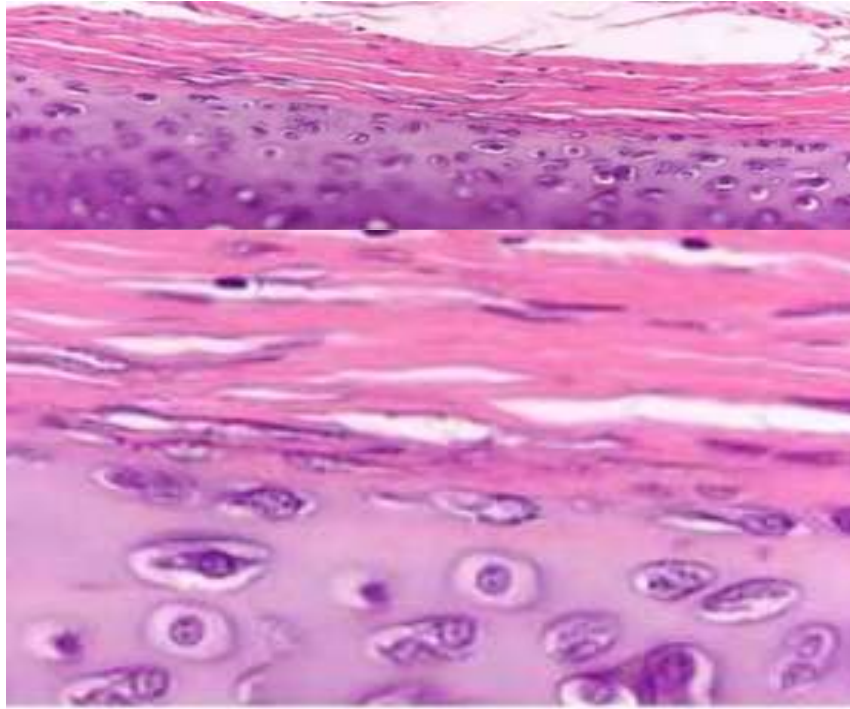


Figure 22. Hyaline articular cartilage and adjacent capsular tissue (H&E; ×10 and ×40).

Meniscal Histology

The histological structure of the meniscus is regional in terms of vascularity and composition. The periphery is highly vascularized, containing dense collagenous connective tissue. However, the interior is mostly avascular, consisting of fibrocartilage that is capable of taking up compressive and shear forces. There is difference in collagen fiber alignment and cell shapes [2], [4], [21], [22].

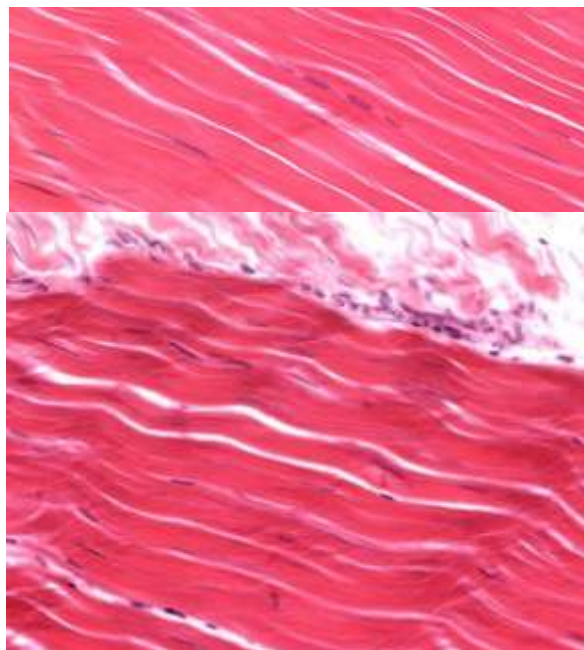


Figure 23. Meniscal histology showing collagen bundles and fibrocartilage cells (H&E; ×200).

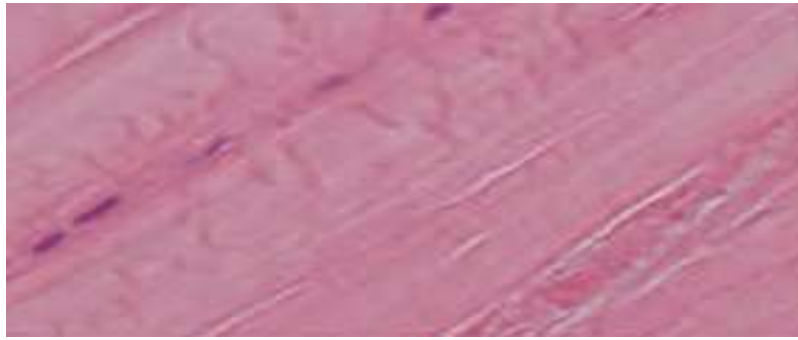


Figure 24. Horizontal section through the central meniscus showing densely organized collagen bundles (H&E; $\times 200$).

Discussion

The observations discussed in this study correlate with typical anatomical and histological descriptions of the knee. Cadaveric dissection allows a visual observation of the structure, whereas morphometric analysis requires well-defined landmarks and calibration of instruments. Therefore, the patellar measurements provided here should be taken into consideration with caution prior to the presentation of the actual measurements. The interactions among the collateral and cruciate ligaments, menisci, articular cartilage, and the capsule are crucial for joint stability and proper load distribution [2], [3], [4], [9], [10], [16], [17], [18], [26], [27], [24], [19], [20], [21], [22]. This manuscript is descriptive; there are no inferential statistics presented in this paper and, hence, no statistical significance or superiority of the technique compared to radiography can be claimed.

Conclusion

The described cadaveric dissection provides a description of patellar dimensions and the anatomical relationships of the knee-joint structures. Without presenting the actual measuring protocol and individual data, the patellar measurements can be regarded as preliminary descriptive values. The collateral and cruciate ligaments have their own specific attachments and different relationships that contribute to knee stability. The histological descriptions show the zonal organization of hyaline articular cartilage and the difference in peripheral fibrous tissue and inner fibrocartilage in the menisci. In future studies, injections of dyes or contrast materials should be considered, wherever feasible and ethical, to understand bursal-joint cavity communications and clinically significant variants. Anatomical and radiological correlation can be improved by using studies combining cadaveric dissection with magnetic resonance imaging (MRI). Histological and ultrastructural studies according to age can be used to study age-related changes in articular cartilage and menisci.

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