

Bertram Zarins
Robert Śmigielski

Surgical Anatomy and Exposures of the Knee

A Surgical Atlas

 Springer

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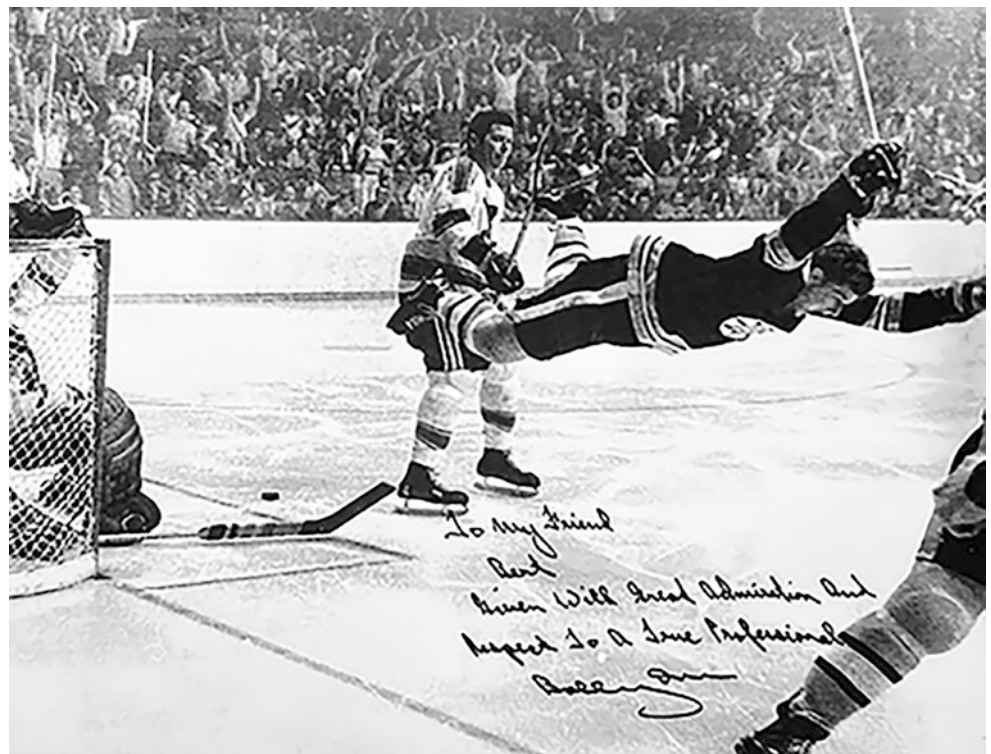
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This book is dedicated to Bobby Orr, the greatest hockey player of all time, whose brilliant career was cut short by knee injuries.



Foreword

I was so pleased to be asked to provide a Foreword for *Surgical Anatomy and Exposures of the Knee* by authors Bertram Zarins, MD, and Robert Śmigielski, MD, PhD, as this book represents a significant contribution.

The study of human anatomy, in this book dedicated to the knee joint, is an adventure in human creation, beauty, and function and the most rewarding endeavor.

“What spirit is so empty and blind, that it cannot recognize the fact that the foot is more noble than the shoe, and skin more beautiful than the garment with which it is clothed?” Michelangelo. 1475–1564

In the spirit of this quote, the same statement may be made for the human knee joint. Surgeons by necessity are required to be masters of anatomy; one questions, however, if we ever truly reach a master’s designation. Over the years of dissecting the human knee, in an academic setting, there has not been one time I have finished a dissection without an added appreciation and knowledge of anatomic structures. Over the years, many authors have published anatomic descriptions on the complexity of knee anatomic structures and this book builds on this knowledge base. I had the opportunity to publish our anatomic dissections on the human knee and hopefully added additional insights [1, 2].

It has been said that no anatomic rendering of the human body, in this case the knee joint, is ever finished or able to be described in a single textbook. The authors of this book have selected a logical flow in the contents by providing structural knee renderings, proceeding through anatomy by regions of the knee and then providing a perspective of knee anatomy related to surgical procedures. The photographic dissections of knee anatomy are truly beautiful and enjoyable to review. The knee arterial structures utilize a novel dissection technique that is among the most revealing and remarkable ever published.

The anatomic photographs and illustrations are highly artistic and noteworthy. A special mention of the professional medical illustrator for this book. The authors were prized to engage Joe Chovan from Cincinnati. I worked closely with Joe Chovan for over 2 years as the medical illustrator for the *Noyes’ Knee Disorders* textbook, producing many anatomic renderings and illustrations, and I am so grateful for his contribution. I remember a number of times he attended anatomic dissections to understand and provide precise anatomical illustrations. In this book, the anatomic illustrations and photographic presentations are outstanding and a tribute to Joe and the authors.

I congratulate the authors in producing this very fine work of art as the study of human knee anatomy is truly an art form. The expert surgical dissections produced in this book take an enormous amount of time, talent, and dedication. I know orthopaedic surgeons will enjoy the anatomic dissections and take away an added perspective and knowledge of anatomy that will be applied to their surgical practice.

On a personal note, I have had a close friendship with Bert Zarins for over four decades and have marveled at all his professional achievements. I have respected his enormous talents and professional appointments: a gifted surgeon providing expert care for his patients for decades, a teacher, educator, and Chief of the Sports Medicine Service at the Massachusetts General Hospital, Professor at Harvard Medical School, Head Team Physician for three Boston professional teams and the US Olympics, first Consulting Editor for Sports Medicine of the *Journal*

of *Bone and Joint Surgery*, and a mentor to students and residents for these many decades. He was awarded the *Order of the Three Stars* medal of honor for his volunteer work in Latvia. Bert set his professional aims at the highest level and how satisfying it is to see his achievements. He also set his personal aims to be a caring and devoted husband and father that are among his most cherished achievements.

Again, thank you for the honor of reviewing this most noteworthy contribution to our understanding of knee anatomy.

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Preface

This book was written for orthopaedic surgeons, radiologists, vascular surgeons, and other health professionals to demonstrate surgically important knee anatomy.

Operations come and go, but anatomy does not change. Recent trends in medical education have reduced the teaching of anatomy. Minimally invasive surgical techniques, such as arthroscopic surgery, have largely replaced open knee operations. This book addresses the knowledge gap.

“Surgical anatomy” is not the same as “anatomical anatomy.” Anatomical anatomy is presented in the “anatomical position” with the body upright, feet flat and facing forward, and the arms by the sides of the body with the palms facing forward. However, the relative positions of various anatomical structures change as the knee goes from flexion to extension. In this book, we demonstrate knee anatomy in the position in which surgery is typically performed. Since medial and lateral surgical approaches to the knee are usually performed with the knee in the flexed position, we show anatomy in the flexed as well as in the extended knee.

Most anatomy books give equal weight to all structures, regardless of clinical significance. Tissues can be dissected into minor parts and shown out of context, distorting their importance. We emphasize structures that are surgically important. Anatomical details that have little clinical bearing are mentioned, but not stressed.

In the third part of this book, we apply this anatomical knowledge to demonstrate surgical exposures of the knee.

We use standard medical terminology. *Gray’s Anatomy* [1] and *Terminologia Anatomica II (TA2)* [2] are our references. Muscles have “origins” (proximal) and “insertions” (distal). Ligaments have “attachments.”

We hope the reader will use the information in this book to safely navigate through the knee.

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The meticulous dissections of the knee were done by Dr. Robert Śmigielski in Warsaw, Poland. Drs. Bartosz Kargol and Jongmin Chai assisted him. Professor Bogdan Cizek (Medical University of Warsaw) injected the arteries and veins to demonstrate vascular anatomy and assisted in the dissections.

A special thanks to Władysław Śmigielski, who supported the team and made photographs for the book himself. Dr. Beata Ciszewska-Łysoń demonstrated the anatomy with radiographic images. Jakub Piękoś (MedDev Engineering) created three-dimensional images from CT scans of anatomic specimens. Jānis Savlovskis and Kristaps Raits in Latvia [*Anatomy Standard*] created three-dimensional models of the bones from CT scans.

Piotr Wójcik (Picture Doc Foundation) and Maciej Śmiarowski captured the anatomy with spectacular photographs and videos. Artist Joseph Chovan in Cincinnati drew beautiful medical illustrations to accompany the photographs.

Aleksandra Zielińska provided the editorial and technical expertise to pull everything together. She assisted both Robert Śmigielski and Bogdan Cizek in dissections and organized the space and resources.

MIRAI Clinic in Otwock (<https://miraclinic.pl>) granted access to their radiology department. Medical Education Centre a.k.a CEM in Warsaw (<https://www.cem-med.pl>) provided space at their laboratory for cadaver dissections.

Financial resources to create the book came from Dr. Zarins' Massachusetts General Hospital Research and Education Fund and the Latvian Medical Foundation. Contributions came from the Joseph M. Hamilburg Fund, the Muriel GS Lewis Fund for Sports Medicine, the Edythe/Paul Mannos Endowment Fund, Bobby Orr, Michael Grossman, Madeline and Edward Redstone, Andronico Luksic, and other grateful patients.



Professors Bogdan Cizek and Bertram Zarins (left) assist Robert Śmigielski (right) dissect a knee specimen

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Part I

Anatomical Features

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1.1 Layers and Superficial Structures (also Refer to Chap. 5)

The layers of the body are as follows:

- Skin.
- Subcutaneous fat.
- Subcutaneous loose connective tissue (superficial fascia).
- Deep fascia.

The **skin** is composed of the epidermis, dermis, and hypodermis.

Below the skin is **subcutaneous fat** (adipose tissue). There are two layers of subcutaneous fat: superficial and

deep. The skin receives neurovascular bundles from below. The subcutaneous fat is intertwined with fine retinacular fibers (*retinacula cutis superficialis*) (see Fig. 1.1a).

The popliteal fossa has an extra layer of fibrous connective tissue within the subcutaneous fat that separates the superficial subcutaneous fat from the deep subcutaneous fat: the **stratum membranosum** (see Fig. 1.1b). The stratum membranosum is continuous throughout most of the body and is sometimes called superficial fascia. In the abdominal wall, it is called Scarpa's fascia. The stratum membranosum is present in the popliteal fossa, but not in the anterior, medial, or lateral aspects of the knee.

Below the superficial subcutaneous fat is **subcutaneous loose connective tissue**. It is not really an anatomical layer but thin fibrous tissue that connects the superficial subcutaneous fat to the deep fascia. It becomes a space (or a layer) when the surgeon separates the superficial subcutaneous fat from the deep fascia. When this loose connective tissue is stretched, it becomes areolar tissue and it is referred to as the **superficial fascial layer** (see Fig. 1.2). **Dissecting within this subcutaneous loose connective tissue plane (superficial fascia) is the easiest way to develop skin flaps for surgical exposure.**

The **deep fascia** is a dense inelastic fibrous layer that covers almost the body. In the extremities, the deep fascia forms sheaths around muscles and expands into broad surfaces (aponeuroses) for attachments of muscles. The deep fascia gives off septae to compartmentalize groups of muscles that have similar function and innervation. The deep fascia around the knee, especially the anterior, medial, and lateral aspects, is thick. The cutaneous nerves, superficial nerves, arteries, veins, and lymphatics tend to be loosely attached to the deep fascia together with deep subcutaneous fat (see Fig. 1.3).

The deep fascia of the thigh that invests all the thigh muscles as a stocking is called the **fascia lata**. Distally the fascia lata attaches to all the prominent bony prominences around the knee, forms the patellar retinacula, and blends with the expansions of the vastus lateralis, vastus medialis, and

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sartorius muscles. The thickness of the fascia lata varies. Medially the deep fascia is thin, and it covers the adductor muscles. Laterally the fascia lata is thick and is called the **iliotibial tract (ITT)**, or interchangeably, **the iliotibial band (ITB)**. Posteriorly, the fascia lata covers the hamstring muscles and tendons and the popliteal fossa. The upper third of

the iliotibial tract laterally encloses the **tensor fascia lata muscle**. Anteriorly and medially, the fascia lata splits to enclose the **sartorius muscle** (see Fig. 1.4).

The deep fascia of the leg is the **fascia cruris** (see Fig. 1.5).

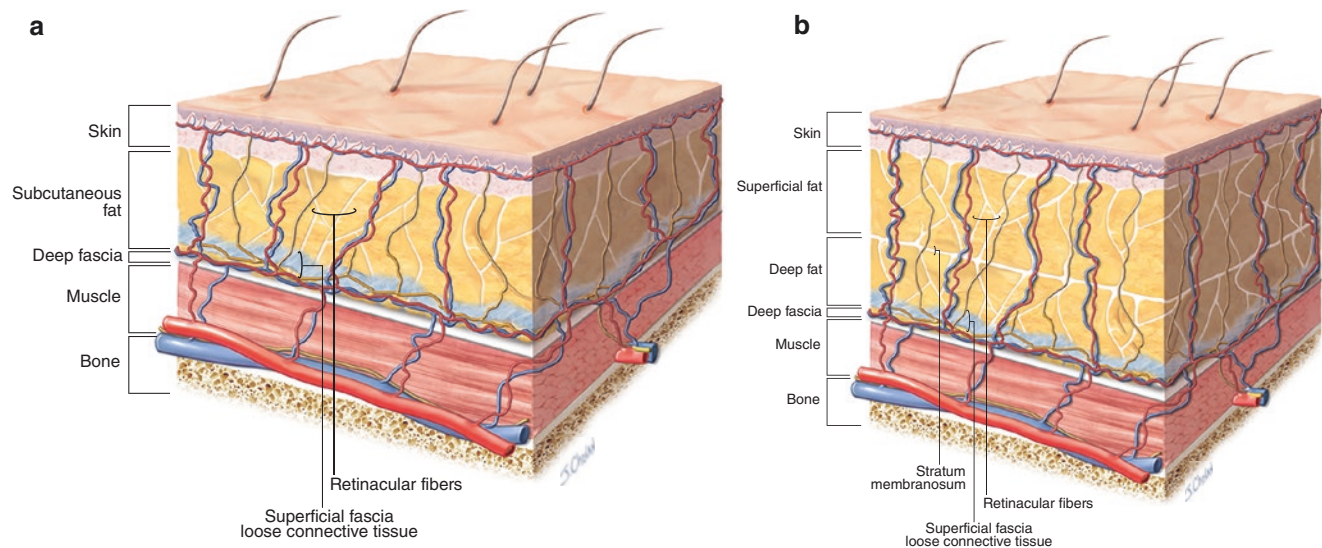


Fig. 1.1 (a). Diagrammatic representation of the integument of the anterior, medial, and lateral aspects of the knee. (b). In the popliteal fossa, there is an additional layer within the subcutaneous fat—the **stratum membranousum**.

Note the superficial fascia (loose connective tissue) at the base of the subcutaneous fat overlying the deep fascia

Fig. 1.2 The subcutaneous fat is connected to the deep fascia by **subcutaneous loose connective tissue**. When this loose connective tissue is stretched, it becomes areolar tissue and it is referred to as the **superficial fascial layer**

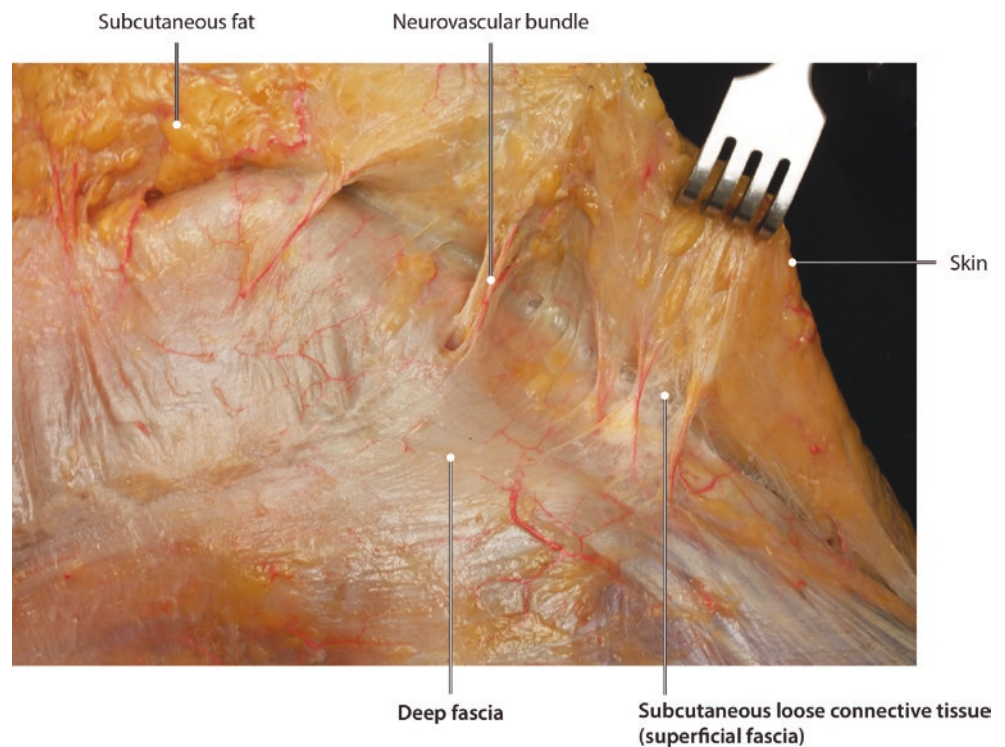


Fig. 1.3 The skin and superficial subcutaneous fat have been lifted exposing the **deep fascia**. The cutaneous nerves, superficial nerves, blood vessels, and lymphatics tend to remain loosely attached to the deep fascia, together with deep subcutaneous fat

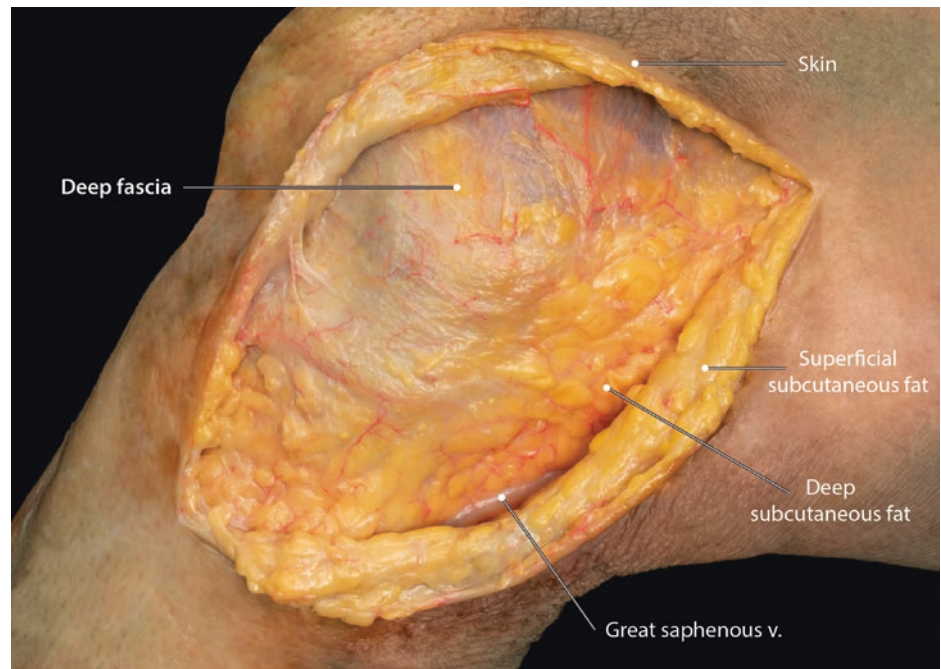


Fig. 1.4 The deep fascia of the thigh is the **fascia lata**

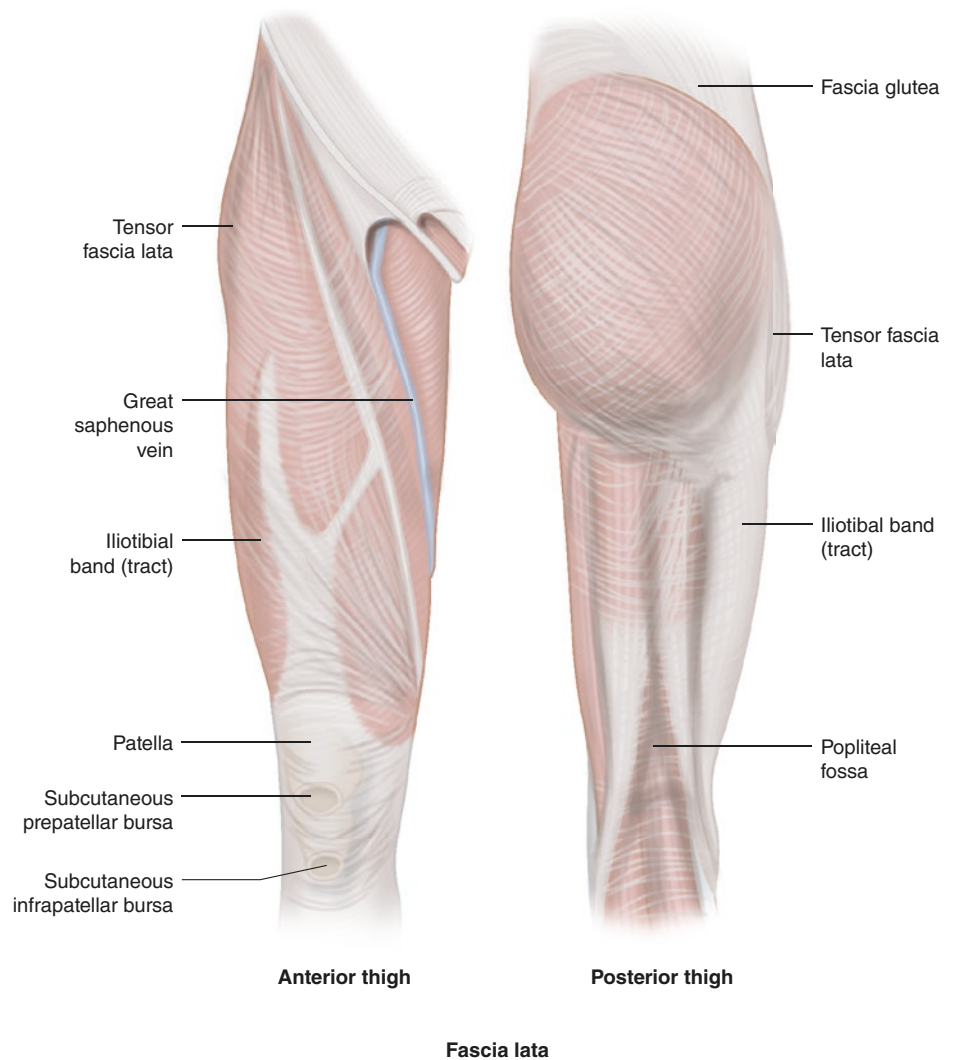
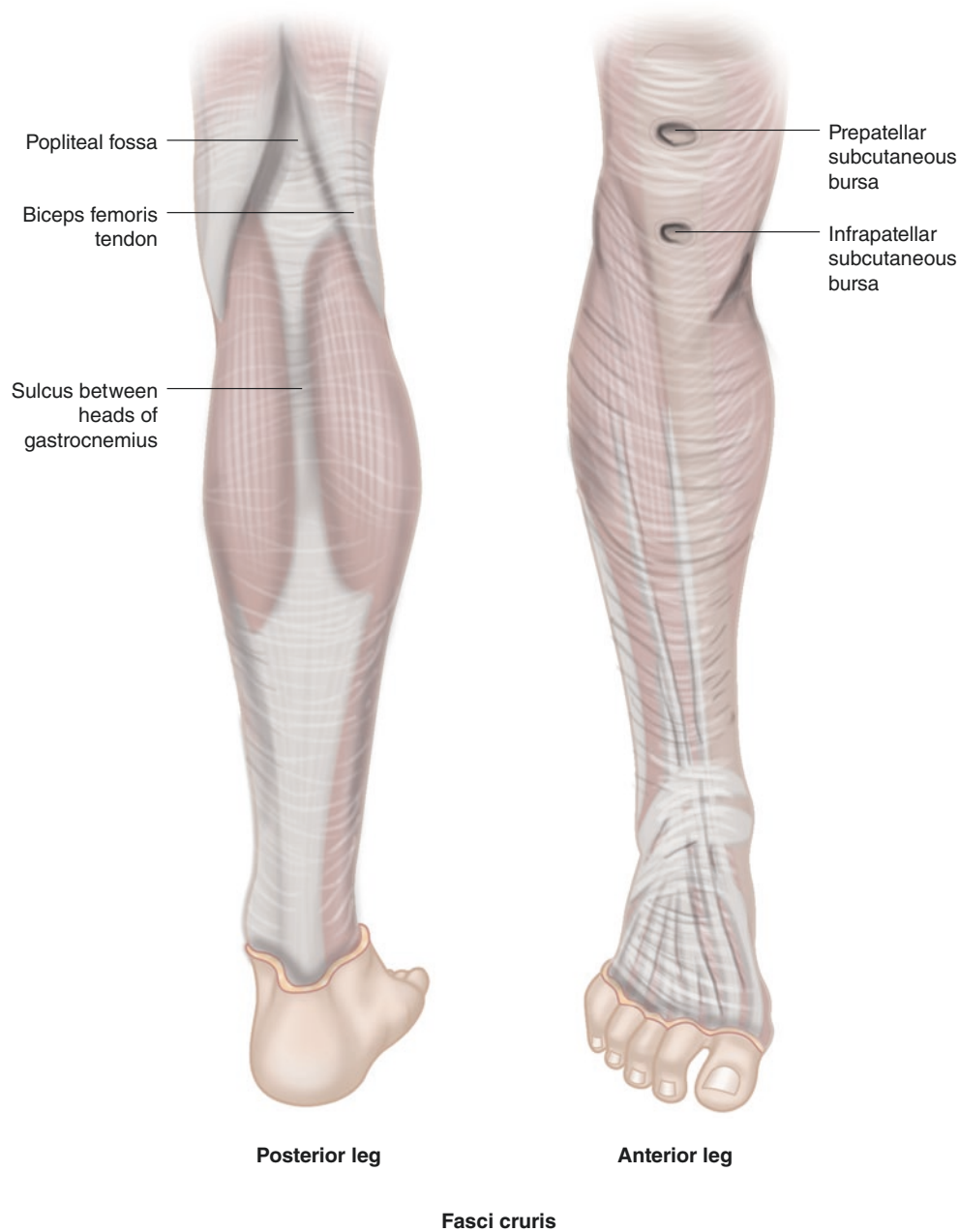


Fig. 1.5 The deep fascia of the leg is the **fascia cruris**



1.2 Bones

The osseous components of the knee are as follows:

- Patella.
- Distal femur.
 - Medial and lateral femoral condyles.
 - Patellar surface of femur—trochlea.
- Proximal tibia.
 - Medial and lateral tibial condyles (plateaus).
- Proximal fibula.

1.2.1 Patella (*also Refer to Chap. 4*)

The patella is a somewhat triangular shaped bone in front of the knee joint. Its broad proximal pole is the **base** and the distal pole, the **apex**. The anterior surface is convex and has numerous longitudinal striae. The middle third of the anterior surface has small perforations for the passage of blood vessels, which are supplied by an anastomotic arterial ring formed by the four genicular arteries and the anterior tibial recurrent artery (*see Figs. 1.6a and 1.41*). The posterior surface of the patella consists of articular cartilage. It is divided

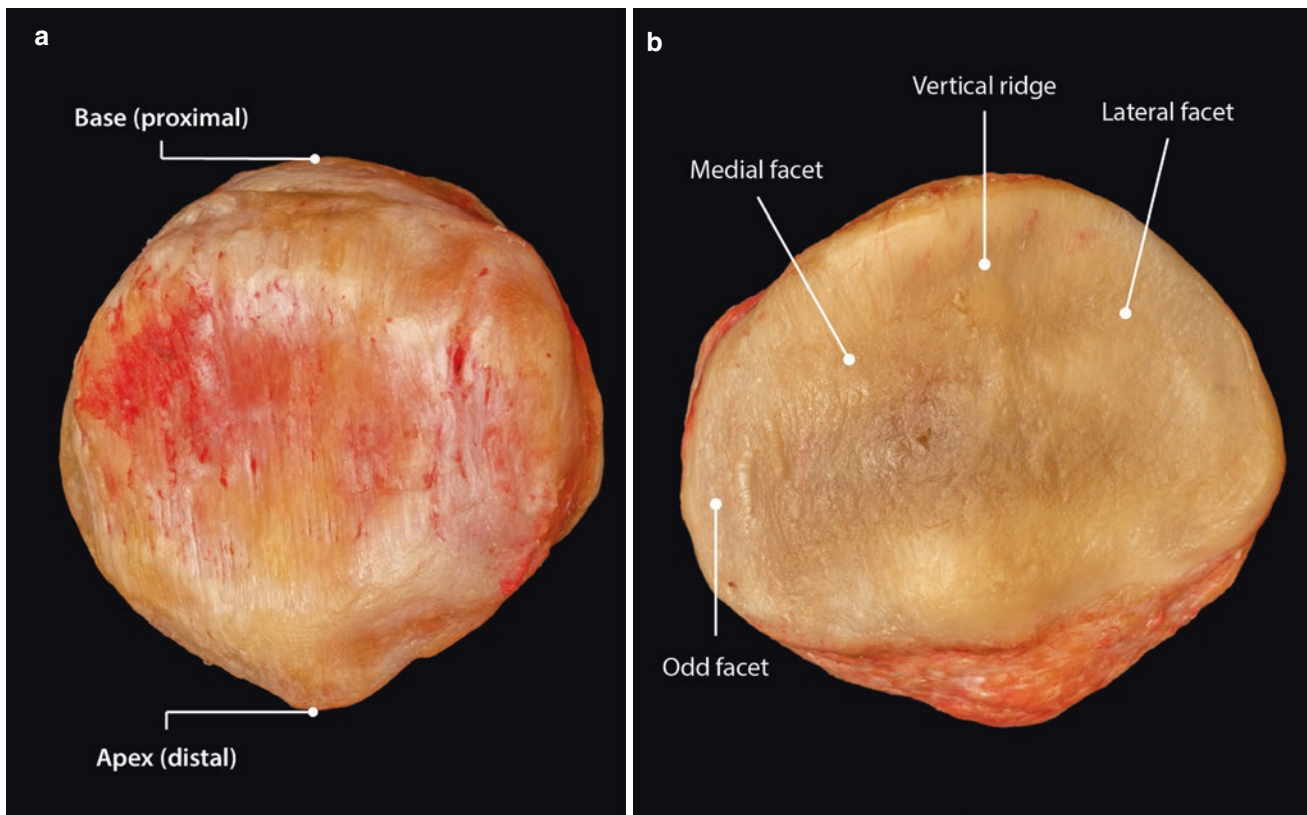
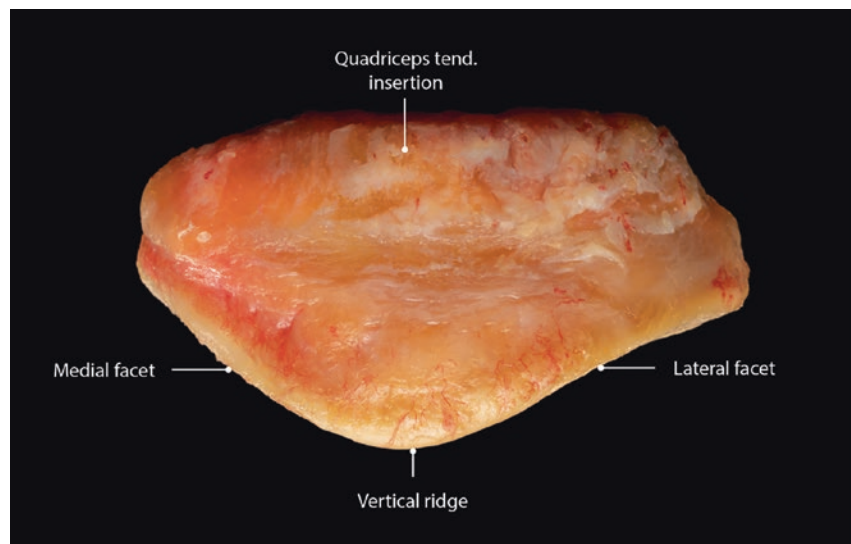


Fig. 1.6 Right patella. (a). Anterior aspect. Note convex anterior surface, numerous longitudinal striae and entry of the arterial blood supply to the patella in the anterior middle third. (b). Posterior aspect. The articular surface of the patella is divided by a vertical ridge creating a

small medial and a larger lateral articular facet. The two halves can be further sub-divided indistinctly into three horizontal pairs: upper (superior), middle and lower (inferior) pairs of facets. There is a seventh facet, the medial vertical (or odd) facet

Fig. 1.7 Right patella base (proximal)—view from above. Note broad insertion of quadriceps tendon



by a vertical ridge creating a small medial and a larger lateral articular surface, or facet. The two halves can be further sub-divided indistinctly into three horizontal pairs: upper (superior), middle and lower (inferior) pairs of facets. There is a seventh facet, the medial vertical (or odd) facet (see Fig. 1.6b).

The anterior surface is covered by the pre-patellar bursa (see Fig. 4.11).

The tendons of the various portions of the quadriceps muscle unite to insert at the superior surface (base) of the patella (see Fig. 1.7).

The infrapatellar fat pad attaches to the apex of the patella (distal). The patellar tendon (lig. patellae) does not attach to the apex but continues along the anterior surface of the patella (*see* Figs. 1.8 and 1.9).

The articular cartilage of the patella can be up to 7 mm thick (*see* Fig. 1.10).

The patella is composed of thick trabecular bone (*see* Fig. 1.11).

Bipartite patella—a secondary ossification center of the patella can remain unfused and persist into adult life. The separate fragment is usually in the upper outer quadrant (75%) (*see* Figs. 1.12 and 1.13). It can occur at the lateral margin (20–25%) or inferior pole (1%). A bipartite patella occurs in approximately 2% to 6% of the population and is nine times more common in males than in females. A bipartite patella occurs bilaterally in about 43% of people [1].

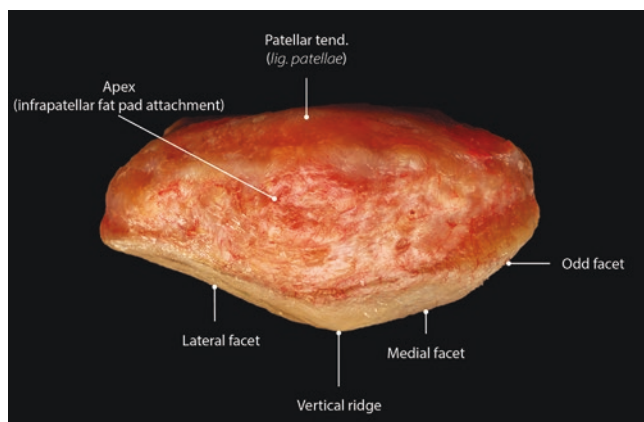


Fig. 1.8 Right patella apex (distal)—view from below. Note large surface area for attachment of infrapatellar fat pad

1.2.2 Distal Femur

The distal femur has three contiguous articular surfaces: medial femoral condyle, lateral femoral condyle, and patellar surface (trochlea) (*also refer to* Chap. 3).

1.2.2.1 Trochlea—Patellar Surface of Femur

Anteriorly the femoral condyles are separated by a shallow depression, the **patellar surface** or **trochlea** for articulation with the patella. The lateral facet of the trochlea is about twice as large as the medial surface. This matches the larger lateral facet of the patella. The lateral facet also projects further anteriorly than the medial. The lateral facet is a bony buttress that helps prevent lateral displacement of the patella (*see* Fig. 1.14) (*refer to* Chap. 4).

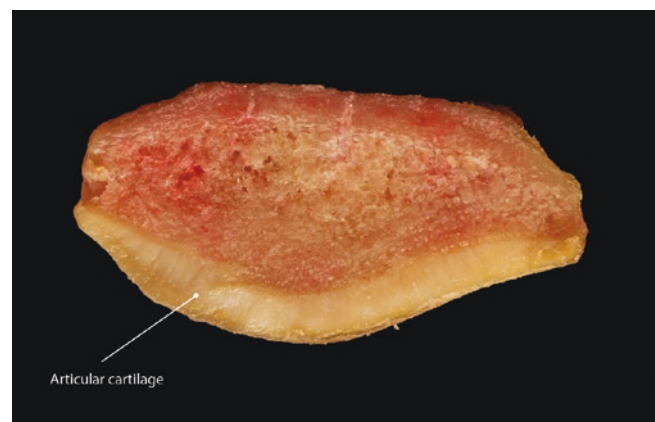


Fig. 1.10 Right patella, cross-section. The articular cartilage can be up to 7 mm thick

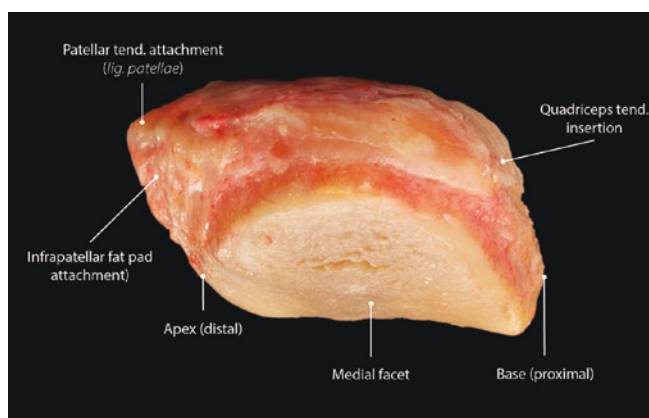


Fig. 1.9 Right patella, medial aspect. Note the large attachment of the infrapatellar fat pad to the apex and the insertion of the quadriceps tendon to the base

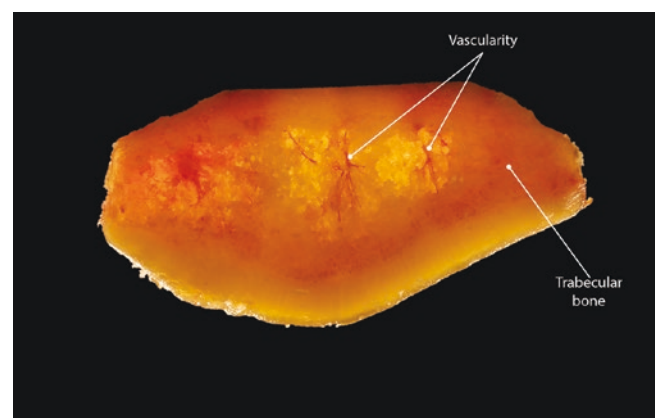


Fig. 1.11 Right patella, thin cross-section. Note the vascularity and thick trabecular bone



Fig. 1.12 A bipartite patella is an unfused secondary ossification center of the patella that occurs in approximately 2% to 6% of the population. It is usually (75%) located in the upper outer quadrant of the patella



Fig. 1.13 Right knee MRI—bipartite patella

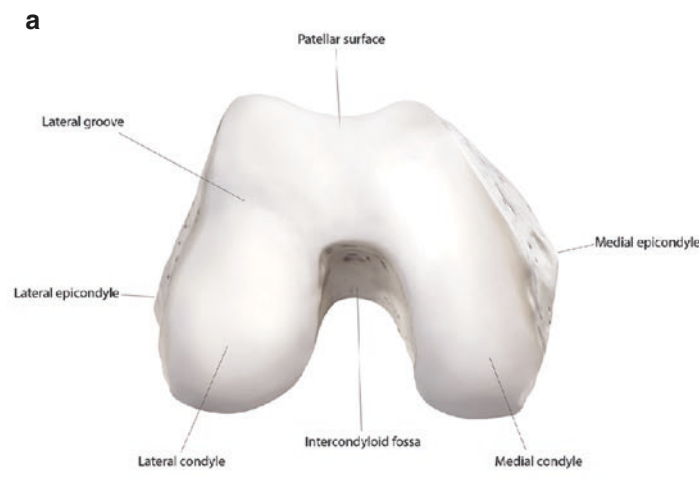


Fig. 1.14 Right femur, inferior aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

1.2.2.2 Medial and Lateral Femoral Condyles

The **distal femur** consists of two rounded oblong eminences, the **medial** and **lateral femoral condyles**. They are eccentrically curved, with the anterior portion being part of an oval and the posterior portion, a section of a sphere. The articular surface of the medial condyle is longer than the lateral con-

dyle, but the lateral condyle is wider. Posteriorly, the femoral condyles project considerably and are separated by a deep notch, the intercondylar notch (or intercondyloid fossa) (see Figs. 1.15, 1.16, 1.17, and 1.18).

The posterior superior part of the lateral femoral condyle has been referred to as the “over-the-top” location in anterior cruciate ligament reconstruction [2] (see Fig. 12.40).

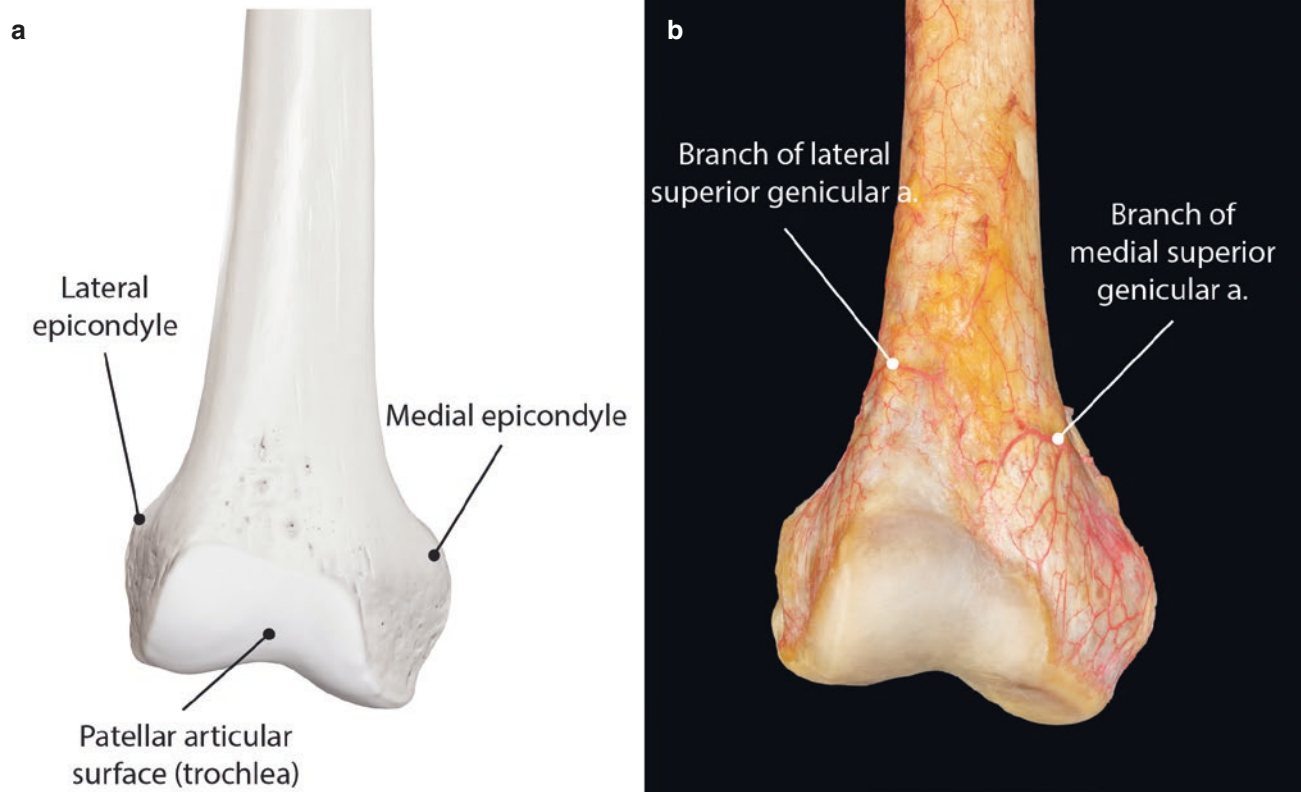


Fig. 1.15 Right femur, anterior aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

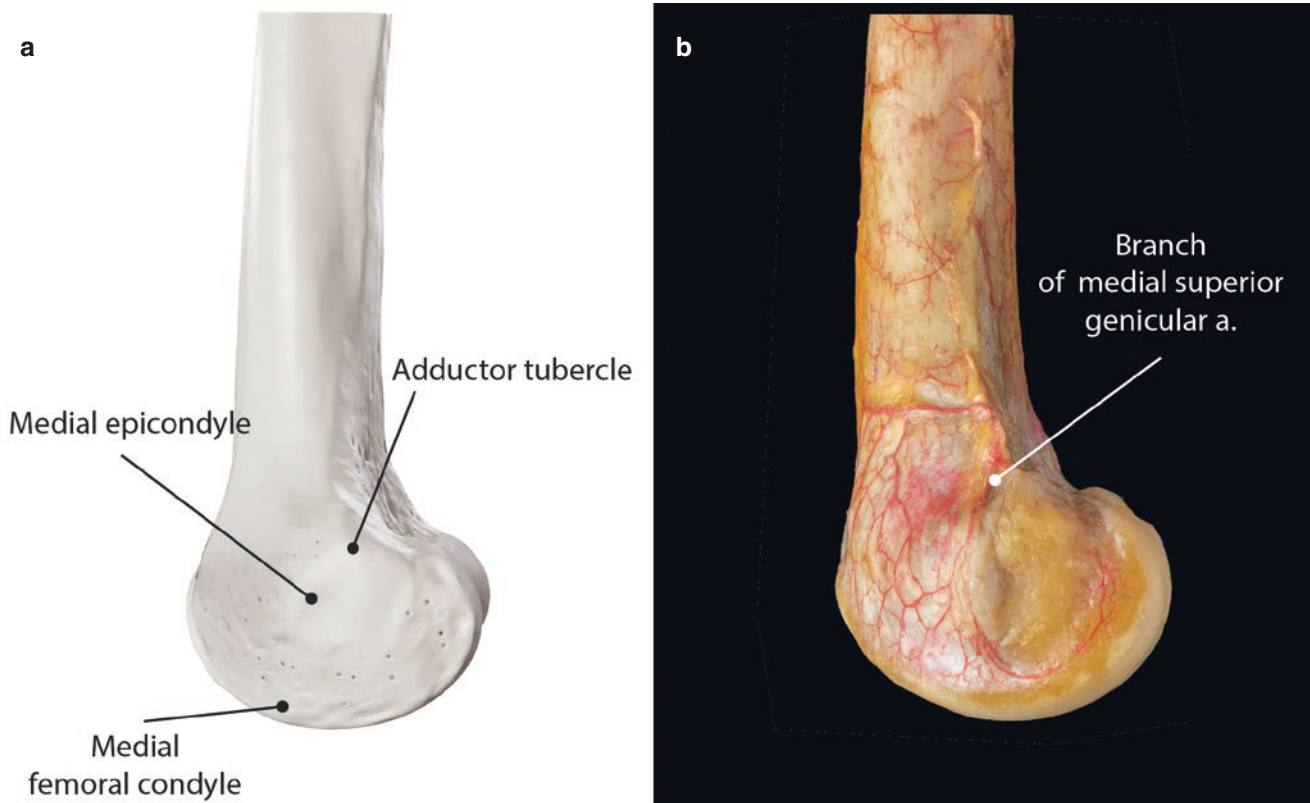


Fig. 1.16 Right femur, medial aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

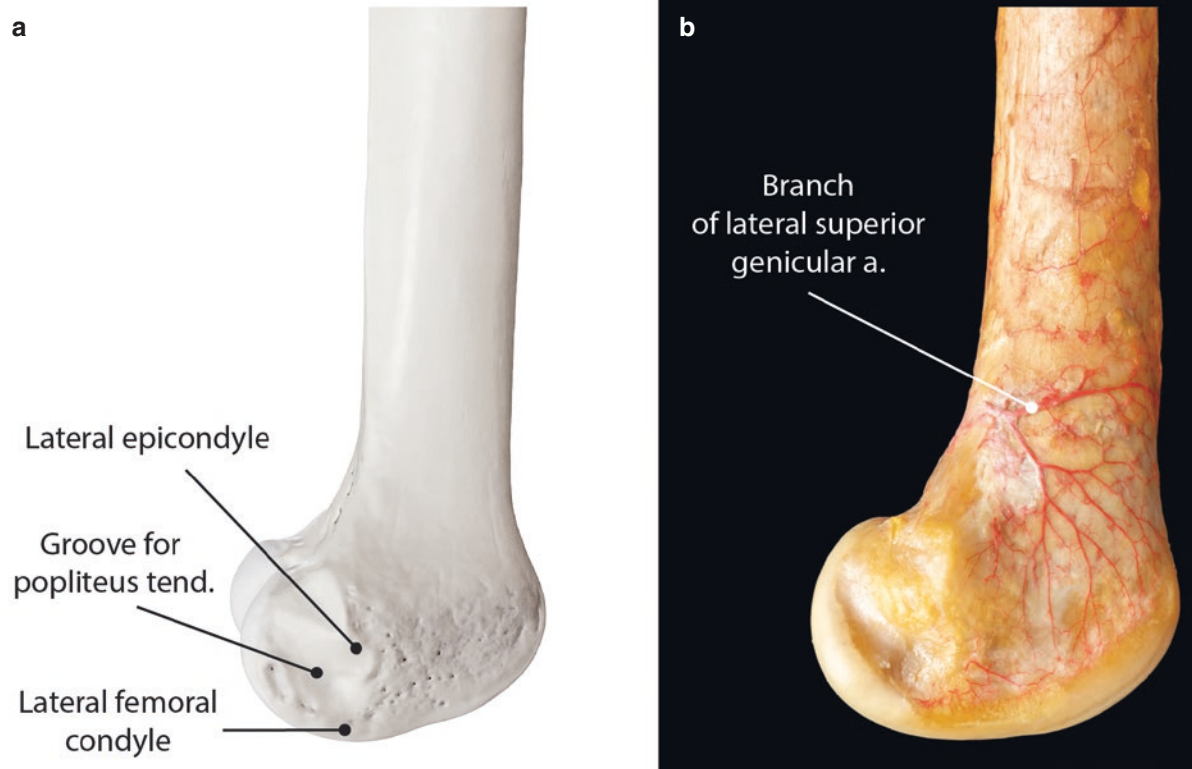


Fig. 1.17 Right femur, lateral aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

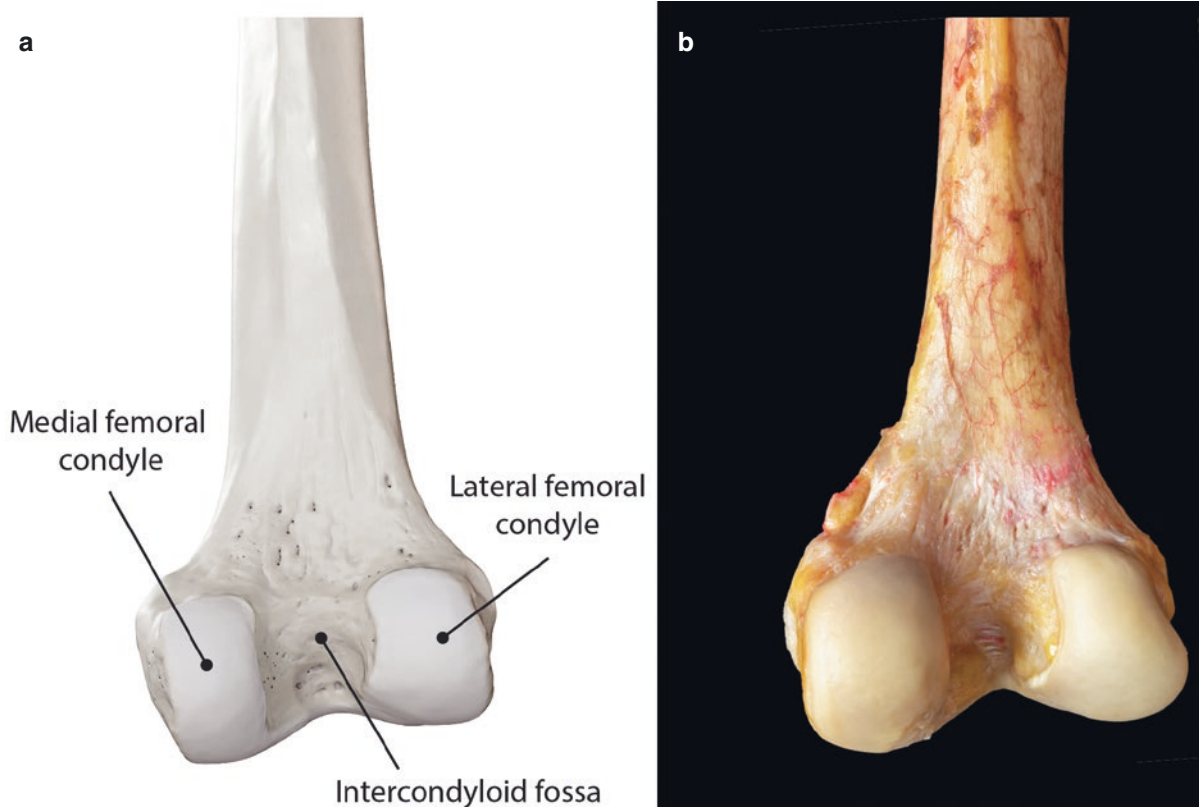


Fig. 1.18 Right femur, posterior aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

1.2.3 Proximal Tibia—Medial and Lateral Tibial Condyles (Tibial Plateau)

The superior articular surface of the tibia (tibial plateau) is formed by two smooth, rather flat surfaces, or condyles (medial and lateral), which articulate with the femoral condyles. They are separated in the middle by the intercondylar eminence, which is composed of the **medial and lateral intercondylar tubercles** (also called **tibial spines**). The anterior cruciate ligament and anterior horns of the medial and lateral menisci attach to the anterior intercondylar area. The posterior intercondylar area serves as attachment sites for the posterior horn of the medial meniscus and part of the posterior cruciate ligament (see Fig. 1.19).

The posterior lip of the lateral tibial condyle is rounded off where the lateral meniscus slides posteriorly in flexion of the knee. The medial tibial condyle is large, oval in shape, and concave from side to side, and from front backward. The lateral tibial condyle is small, nearly circular, and convex from side to side, but slightly convex from before backward.

The large oblong elevation of the proximal tibia anteriorly is the **tibial tuberosity**. It is the attachment site of the patellar tendon (*lig. patellae*). **Gerdy's tubercle** is a bony prominence slightly lateral and proximal to the tibial tuberosity. It is the attachment site of the iliotibial tract (see Figs. 1.20, 1.21, 1.22, and 1.23).

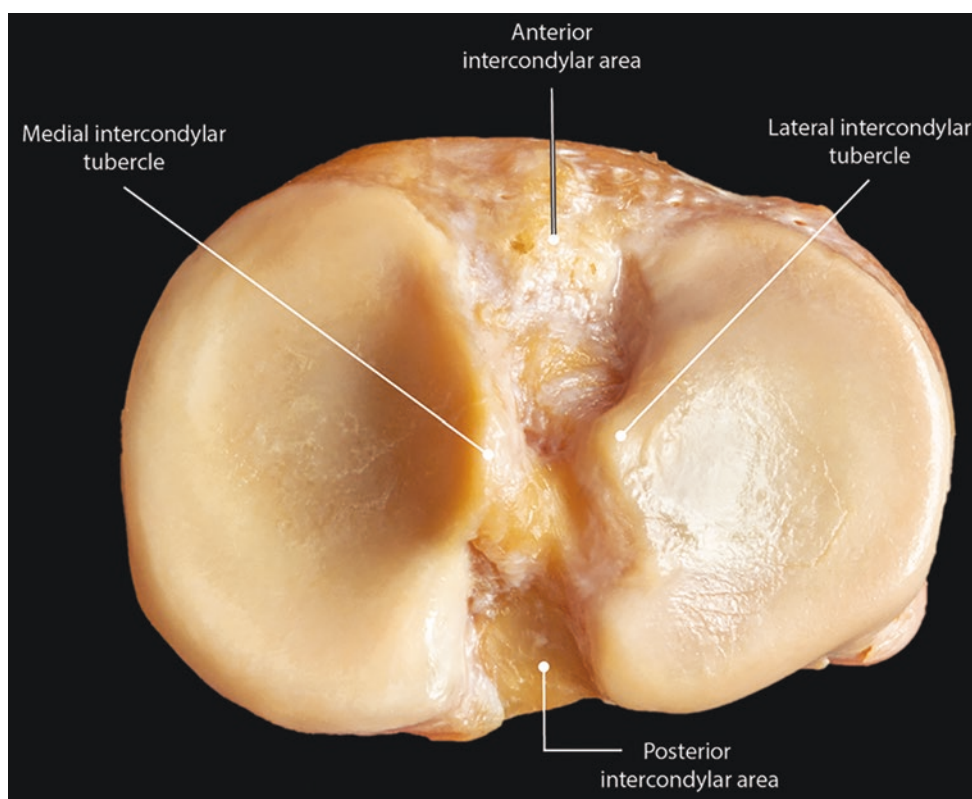


Fig. 1.19 Right tibia, superior articular surface (tibial plateau). The intercondylar eminence is composed of the **medial and lateral intercondylar tubercles** (also called **tibial spines**)

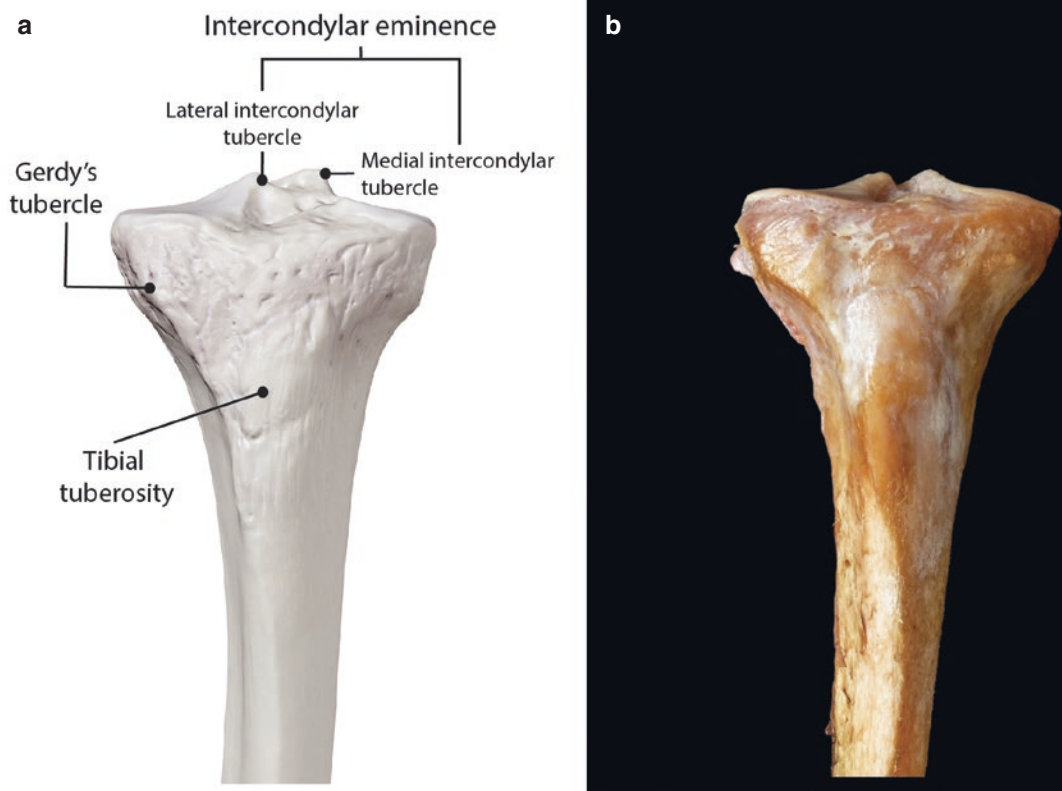


Fig. 1.20 Right proximal tibia, anterior aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

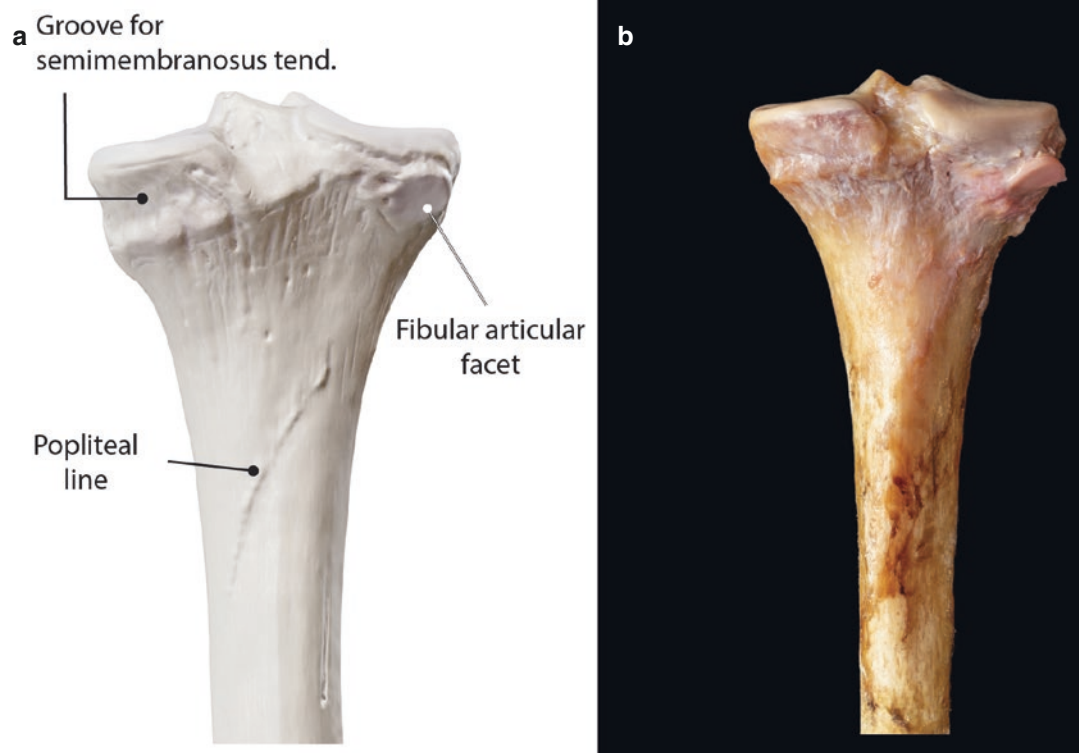


Fig. 1.21 Right proximal tibia, posterior aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

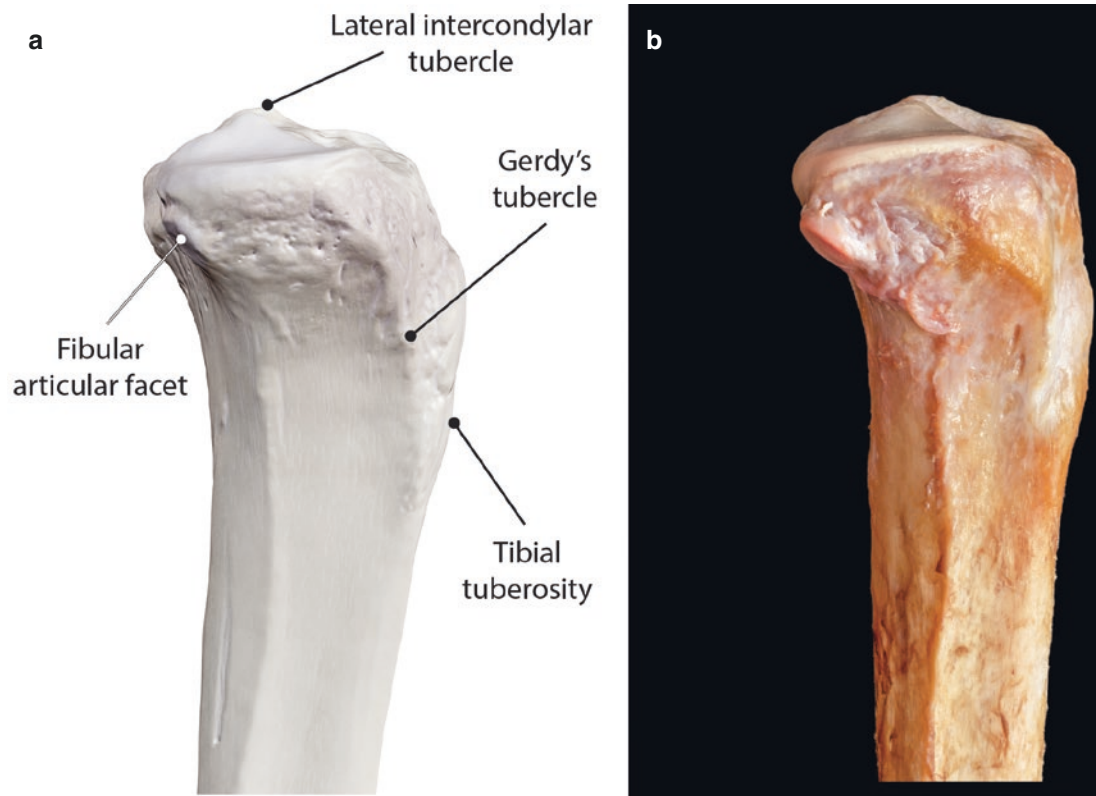


Fig. 1.22 Right proximal tibia, lateral aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

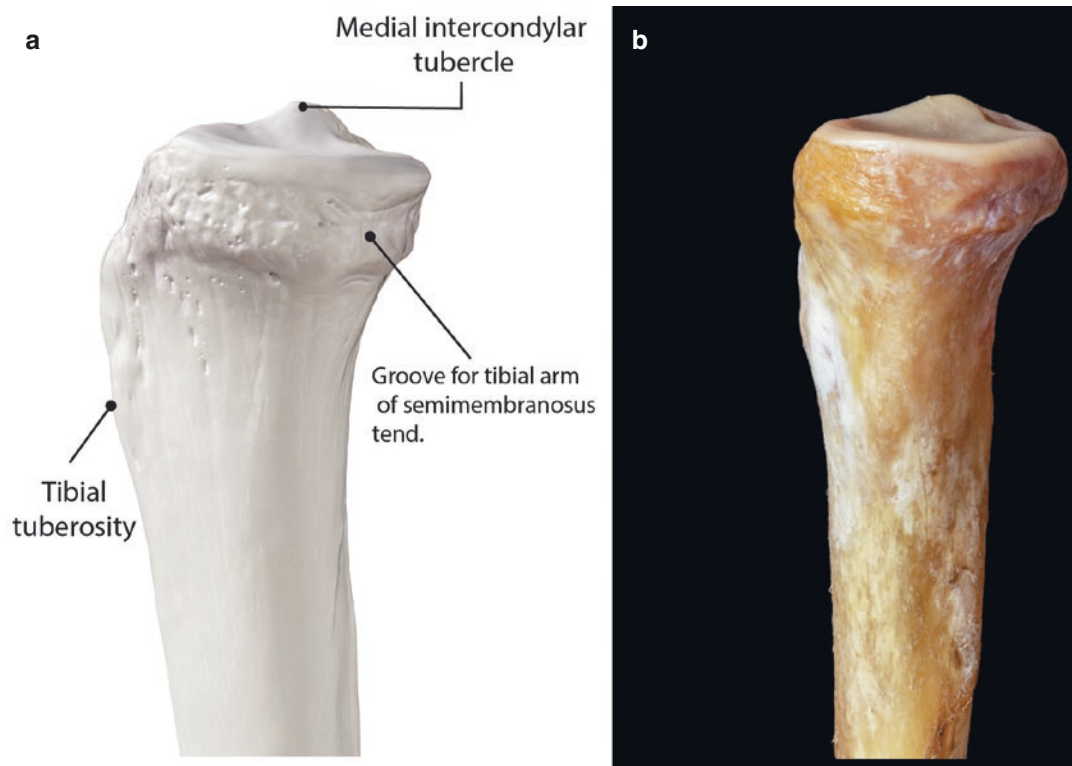


Fig. 1.23 Right proximal tibia, medial aspect. (a). 3D reconstruction from CT scan (From Anatomy Standard; <https://www.anatomystandard.com>; with permission). (b). Anatomical specimen

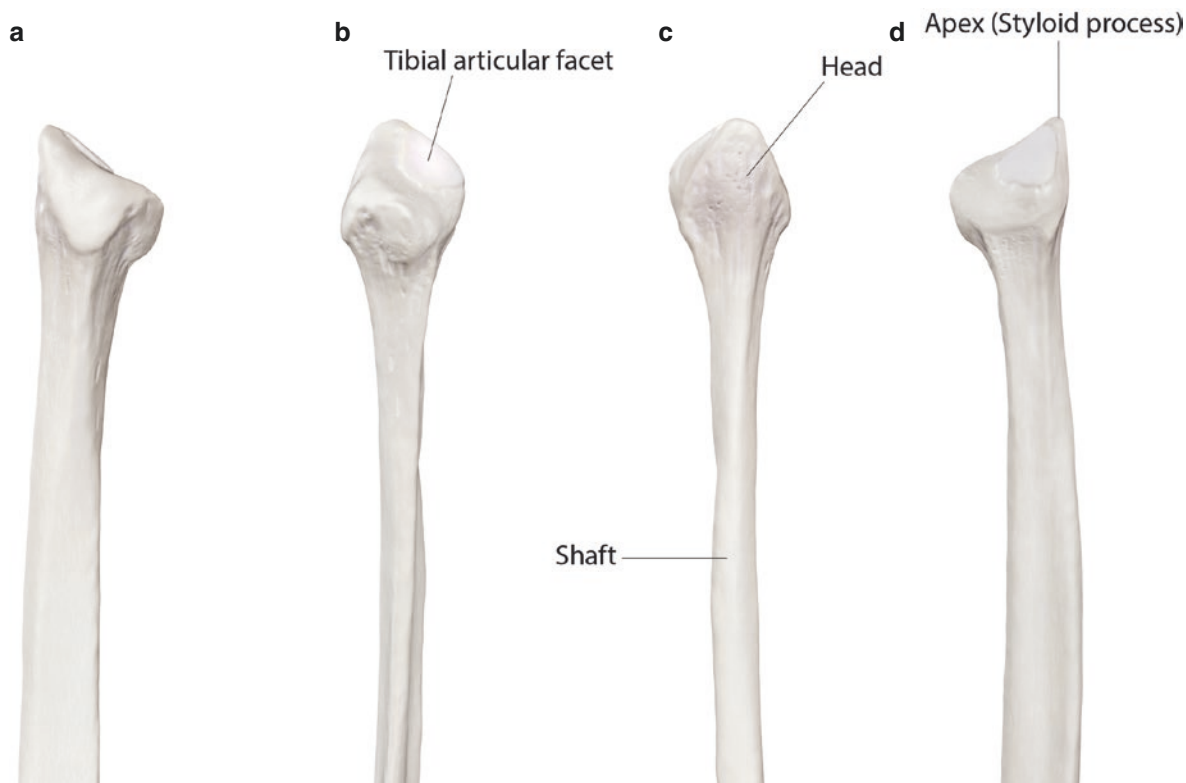


Fig. 1.24 Right fibular head, 3D reconstruction from CT scan. (a). Lateral; (b). Anterior; (c). Posterior; and (d). Medial view (From Anatomy Standard; <https://www.anatomystandard.com>; with permission)

1.3 Proximal Fibula (Head of Fibula)

The head of the fibula (*capitulum fibulae*; *proximal extremity*) has a flattened superior articular surface angled upward, forward, and medialward. The styloid process (apex) on its lateral side is the site of insertion of the biceps femoris tendon and the attachment of the fibular collateral ligament (see Fig. 1.24).

1.4 Articulations

Anatomically, the knee consists of two joints that share a common synovial layer:

1. Patellofemoral.
2. Tibiofemoral.

From a clinical standpoint, however, there are three distinct articulations to the knee joint:

1. Patellofemoral.
2. Medial compartment (tibiofemoral).
3. Lateral compartment (tibiofemoral).

There is a third synovial joint, or fourth articulation the **tibiofibular joint**, which is occasionally significant to the surgeon. It does not communicate with the knee joint (see Fig. 1.25).

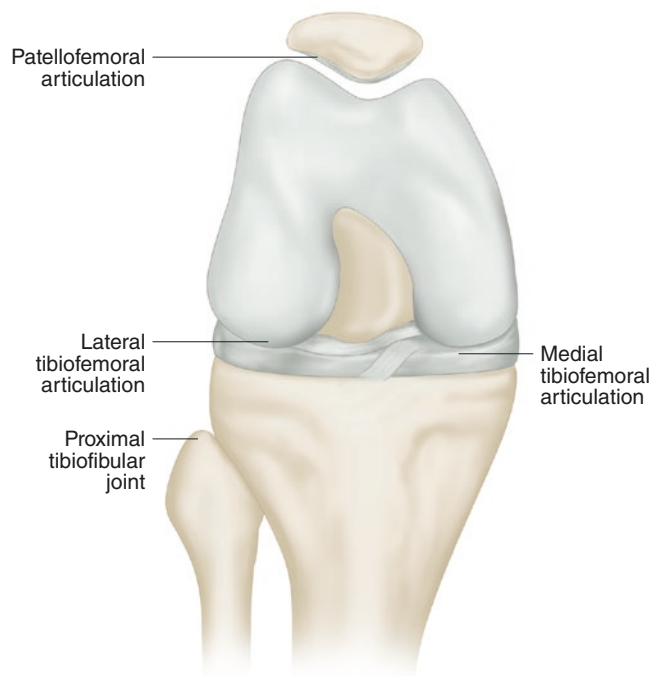


Fig. 1.25 From a clinical standpoint, the knee has three distinct articulations: **patellofemoral**, **medial tibiofemoral**, and **lateral tibiofemoral**. A fourth articulation is the **tibiofibular joint**

1.4.1 Patellofemoral Articulation (Refer to Chap. 4)

The articular surfaces of the patella and trochlea that come into contact change as the knee flexes (see Fig. 1.26). At 120° flexion, only the lateral and odd facets of the patella contact the corresponding inner portions of the distal femur (see Fig. 1.27). As the knee flexes, the position of the patella in relation to the distal femur changes (see Fig. 1.28).

1.4.2 Tibiofemoral Articulation—Medial and Lateral Compartments

The **tibiofemoral joint** is formed by two articulations: one between the **medial** femoral and tibial condyles, and the other between the **lateral** femoral and tibial condyles. The femoral condyles are convex. The medial tibial condyle is convex. The lateral tibial articular surface is somewhat flat. The incongruity is filled by two menisci, one

medially and the other laterally, which increase the articular congruity. The actual areas of contact between the femoral and tibial condyles are relatively small because of the intervening fibrocartilaginous menisci (see Fig. 1.29) (refer to Chap. 3).

1.4.3 Proximal Tibiofibular Joint

The **superior tibiofibular joint** (*articulatio tibiofibularis; superior tibiofibular articulation*) is a synovial joint between the proximal tibia and the head of the fibula. It is located toward the posterior aspect of the tibia (see Fig. 1.30). It has an articular capsule (*capsula articularis; capsular ligament*). The anterior ligament (*anterior superior ligament; ligamentum capitis fibulae ant.*) passes from the head of the fibula to the front of the lateral condyle of the tibia. The posterior ligament (*posterior superior ligament; ligamentum capitis fibulae post.*) goes from the back of the head of the fibula to the back of the lateral tibial condyle (see Fig. 1.31).

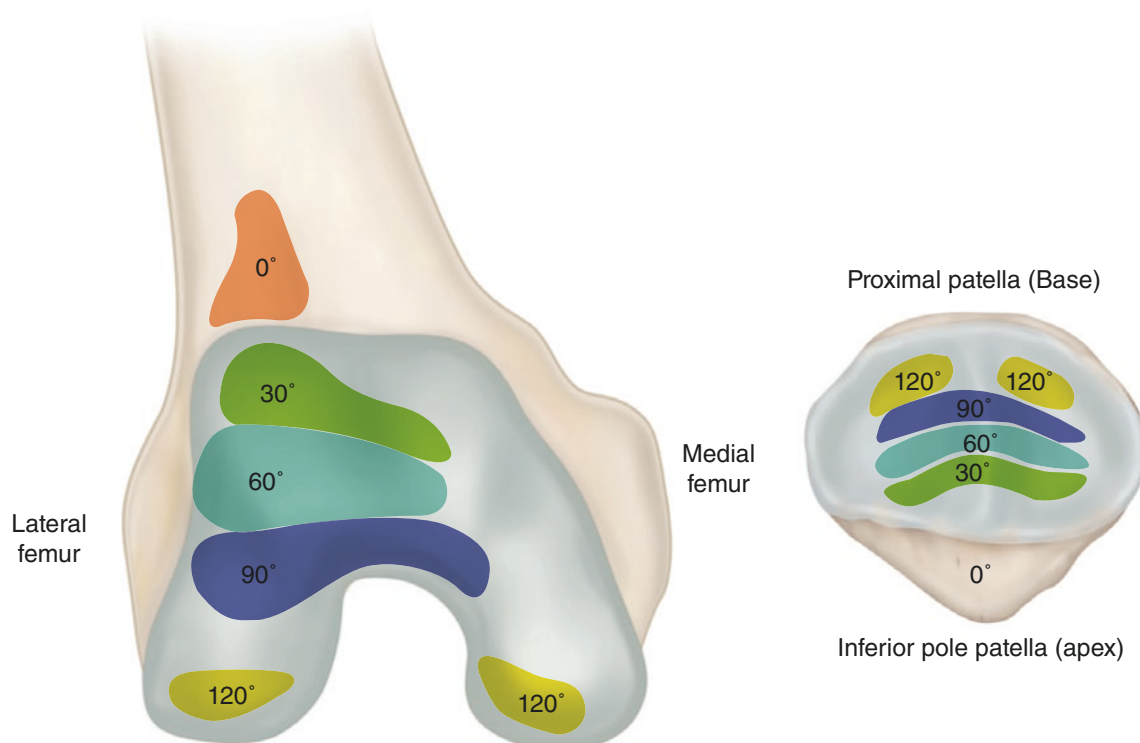


Fig. 1.26 Right knee patellofemoral joint. The articular surfaces of the patella and trochlea that come into contact change as the knee flexes

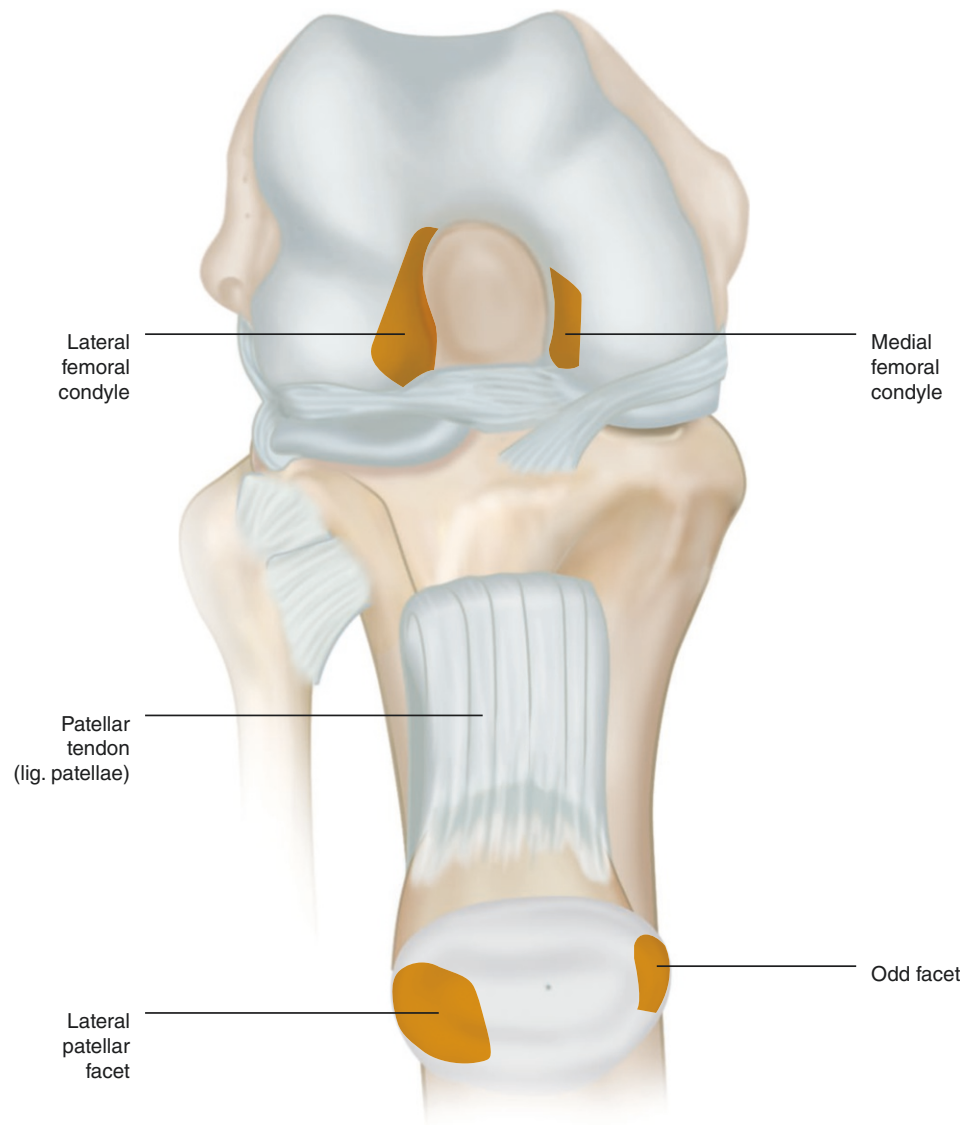


Fig. 1.27 At 120° flexion, only the lateral and odd facets of the patella contact the corresponding inner portions of the intercondylar areas of the distal femur

The superior tibiofibular joint is important to the surgeon because of its proximity laterally to the common peroneal nerve. The common peroneal nerve has been hugging the undersurface of the biceps femoris tendon as far distally as the head of the fibula. The nerve then wraps around the neck of the fibula between the peroneus longus and the fibula. The common peroneal nerve is superficial in this area and is easily injured (see Chap. 7).

Terminology

The *superior tibiofibular articulation* is a **synovial joint**.

The *distal tibiofibular articulation* is a **fibrous joint**: the **tibiofibular syndesmosis**.

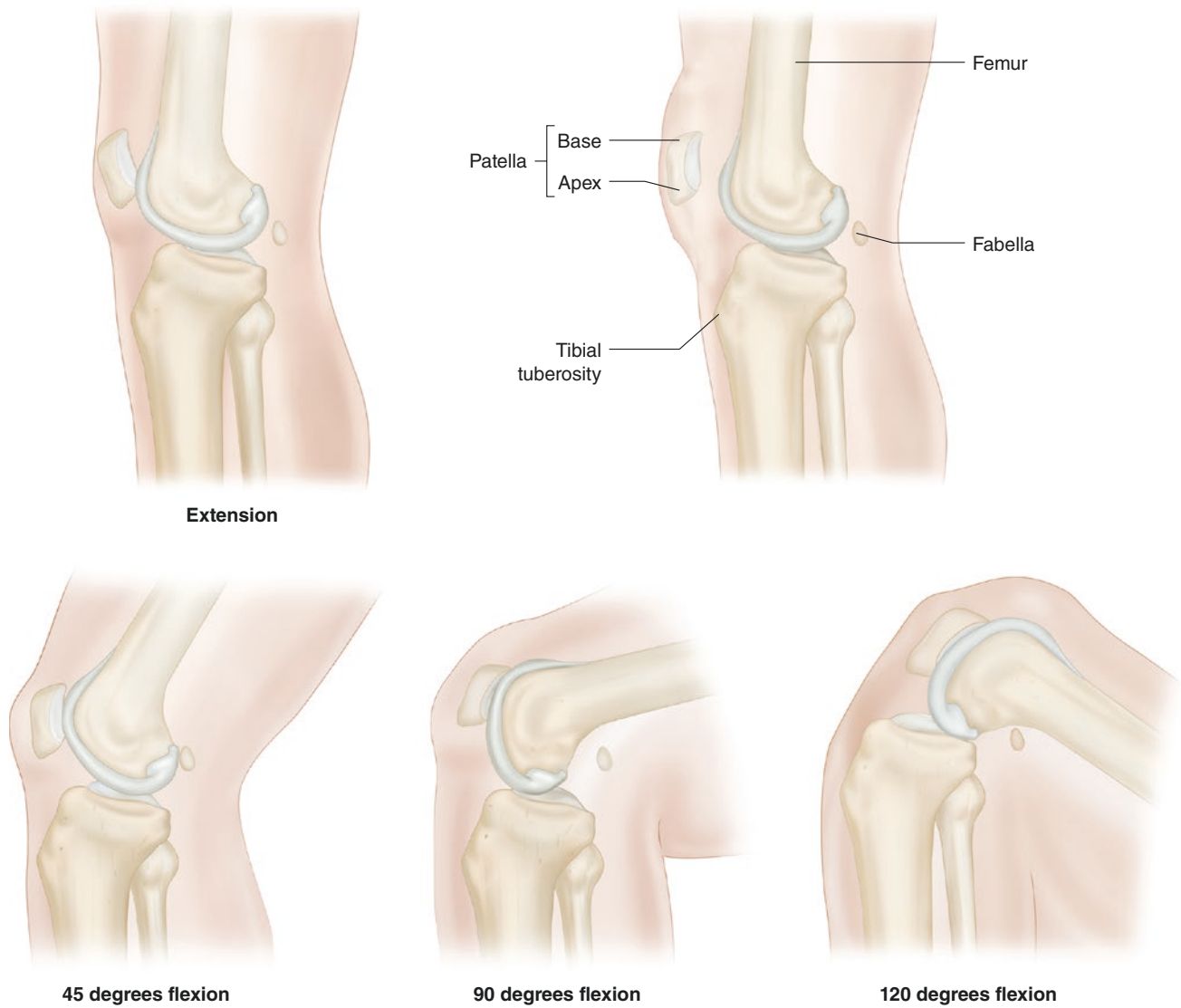


Fig. 1.28 As the knee flexes, the position of the patella in relation to the distal femur changes

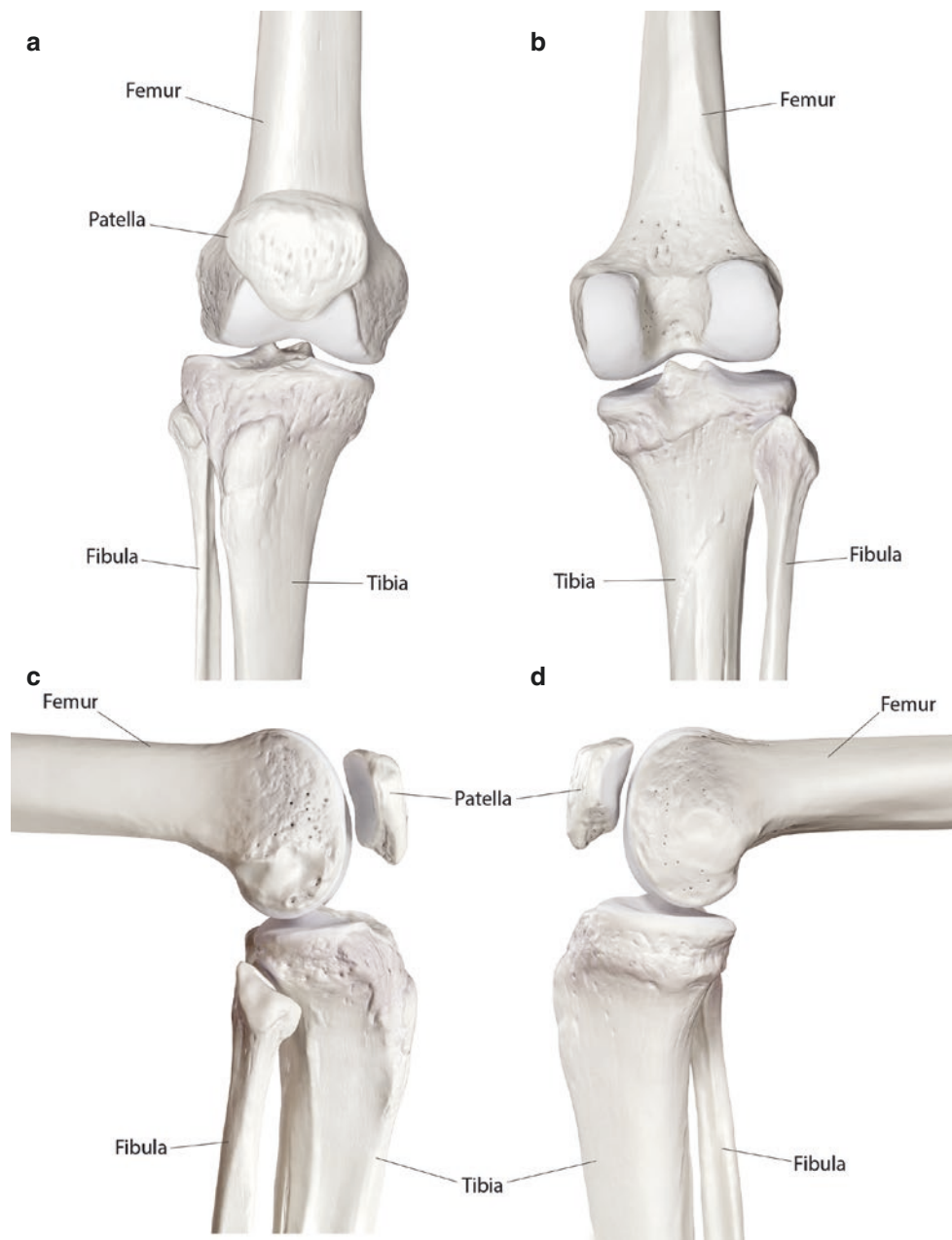


Fig. 1.29 Right knee articulations, 3D reconstruction from CT scan. (a) Anterior; (b) Posterior; (c) Lateral; and (d) Medial view (*From Anatomy Standard; <https://www.anatomystandard.com>; with permission*)

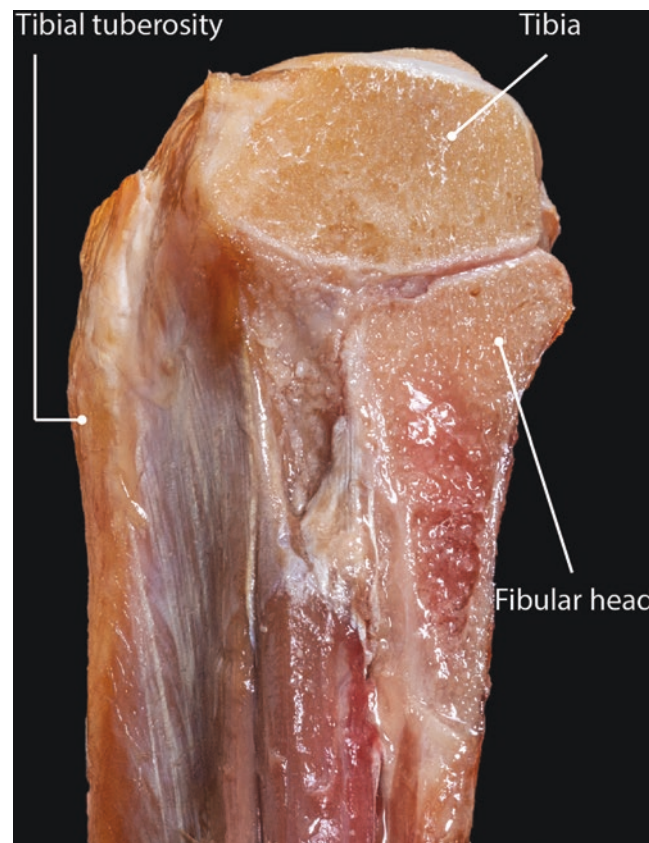


Fig. 1.30 Right knee, proximal tibiofibular articulation (*articulatio tibiofibularis*) is an arthrodiar joint. It is located toward the posterior aspect of the tibia

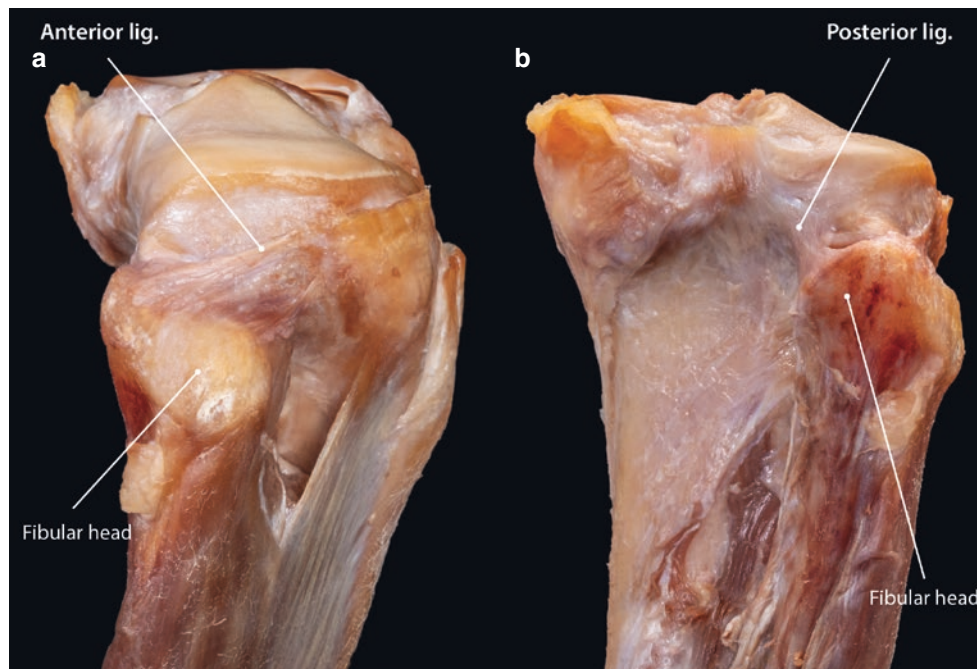


Fig. 1.31 Right knee, proximal tibiofibular articulation. (a). Anterior ligament passes from the fibular head to the front of the tibia. (b). Posterior ligament goes from the back of the fibular head to the back of the tibia

1.5 Muscles

The surface markings of muscles and tendons around the knee are shown in Figs. 1.32, 1.33, and 1.34. The origins and insertions of muscles and tendons and attachments of ligaments around the knee are shown in Figs. 1.35 and 1.36.

Terminology

Origin (proximal) and **insertion** (distal)—connection of the muscle or a tendon to a bone.

Attachment—connection of a ligament to a bone.

Aponeurosis—a broad flat sheet of dense connective tissue that covers and invests the origin or insertion of a muscle or tendon.

Retinaculum—a restraining band.

1.5.1 Anterior Thigh

The anterior thigh muscles are the quadriceps and sartorius. The **quadriceps** muscles are the **rectus femoris**, **vastus medialis** [*vastus internus*], **vastus lateralis** [*vastus externus*], and **vastus intermedius** [*crureus*]; they insert on the superior pole of the patella and extend the knee. The **rectus femoris** originates from the pelvis and crosses two joints, so it is also a hip flexor. The **vastus medialis obliquus (VMO)** is the most distal portion of the vastus medialis. It has a more oblique orientation (55°) than the rest of the muscles, and it inserts on the medial part of the patella but has the same innervation as the rest of the vastus medialis. The **sartorius** muscle originates at the anterior superior iliac spine. Before reaching its insertion to the medial surface of the tibia posterior to the tuberosity, the sartorius tendon forms an expansion which covers the insertions of the gracilis and semitendinosus tendons as a component of the **pes anseri-**

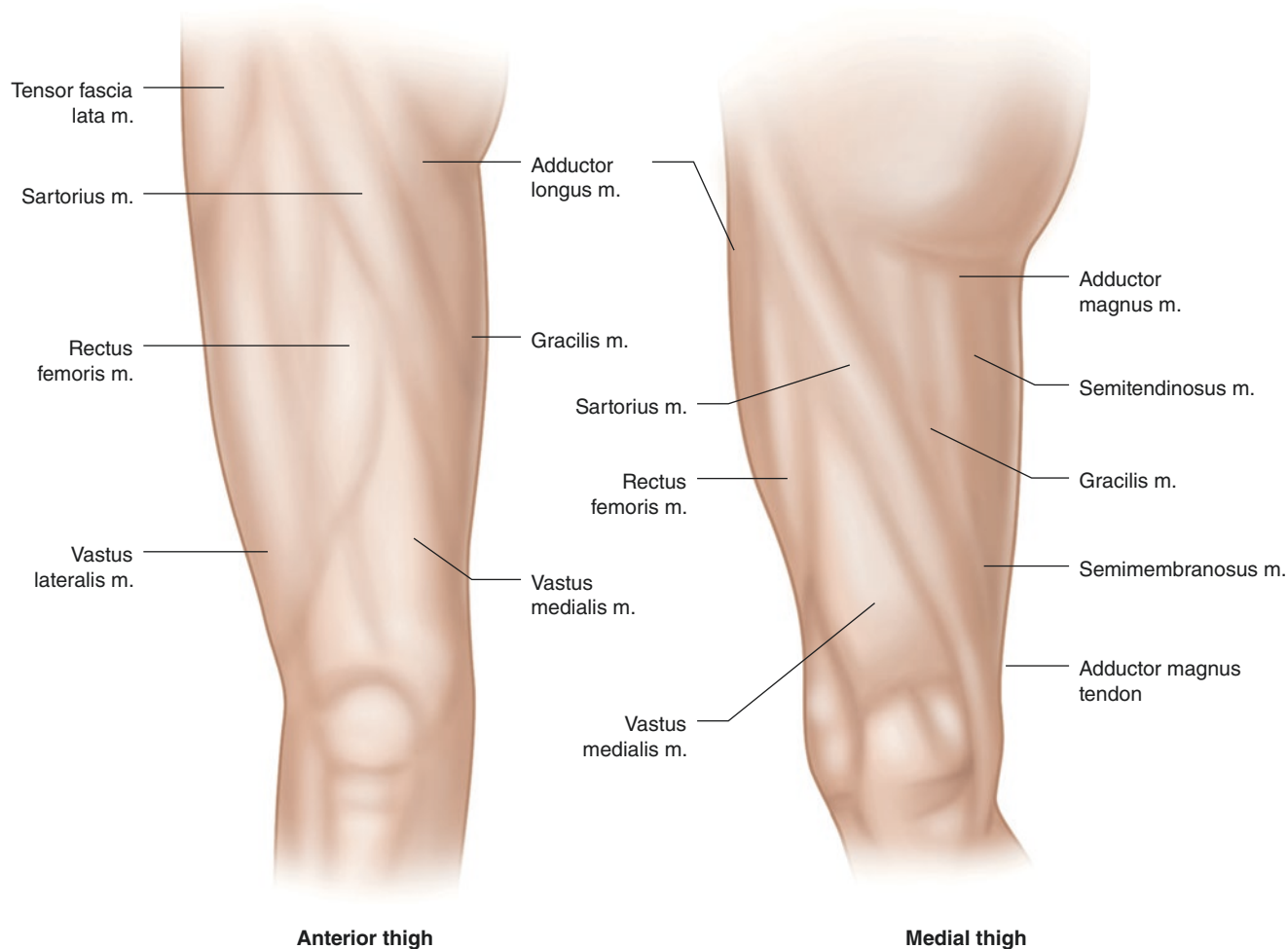


Fig. 1.32 Surface markings of anterior and medial thigh muscles

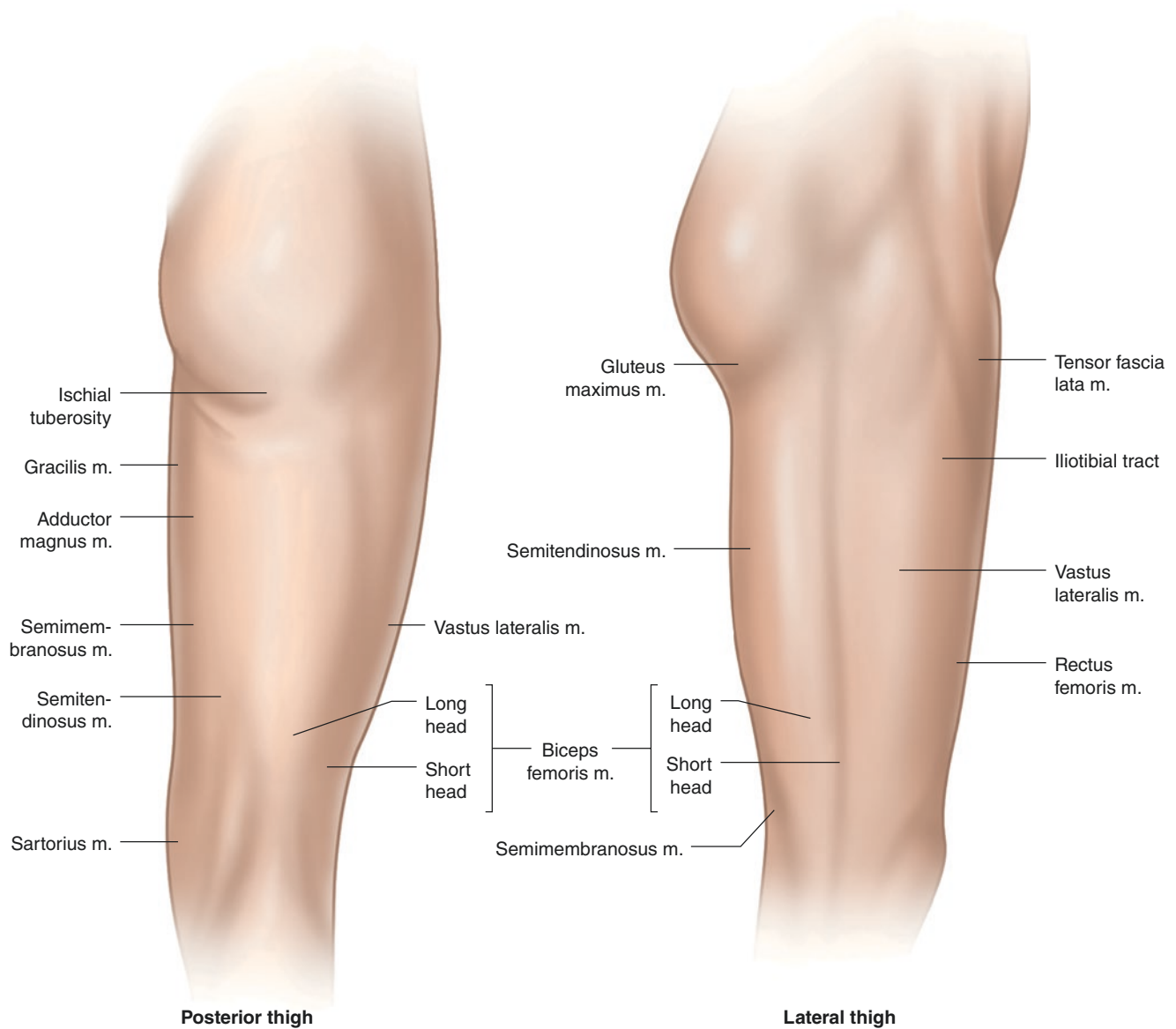


Fig. 1.33 Surface markings of posterior and lateral thigh muscles

nus tendons. It is a knee flexor and slight internal rotator (*see* Fig. 1.37).

Innervation of Pes Anserinus Muscles

Each of the three compartments in the thigh contributes a muscle/tendon to form the pes anserinus. Although they come from different compartments of the thigh, all three insert together. Each muscle is innervated by one of the three major nerves that supply the lower extremity. The **sartorius** muscle (anterior) is innervated by the femoral nerve. The **gracilis** muscle (adductor or medial) gets the obturator nerve. The **semitendinosus** (hamstring) has the sciatic nerve.

The articularis genus [*subcrureus*] is a part of the vastus intermedius. It is formed by several small muscle fibers that originate separately from the shaft of the femur and insert into the superior knee joint capsule. It is thought to take up the slack of the superior capsule during extension of the leg. It can frequently be seen at arthroscopy but has little clinical significance.

1.5.2 Medial Thigh

The only muscle in the medial compartment that acts across the knee is the **gracilis**. The **adductor magnus** inserts on the adductor tubercle of the femur.

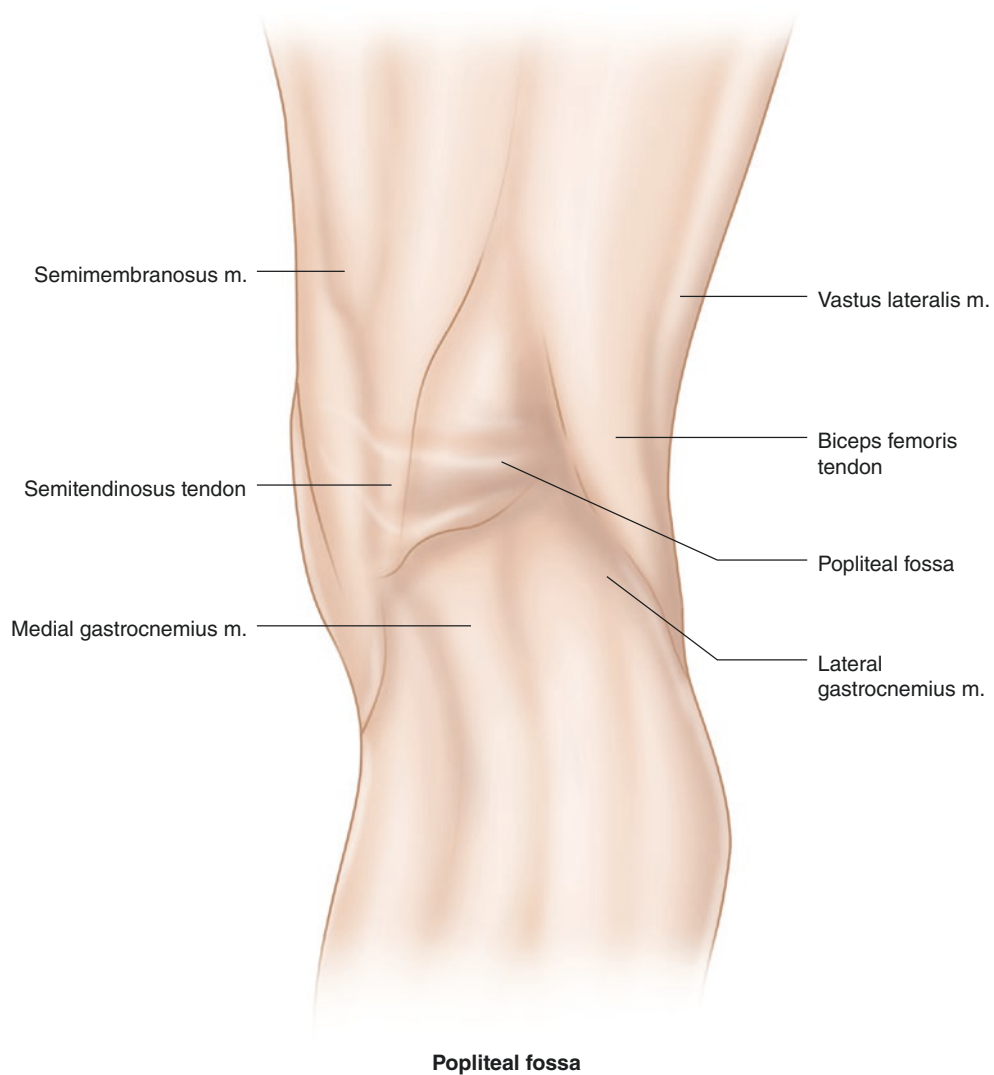


Fig. 1.34 Surface markings of popliteal fossa

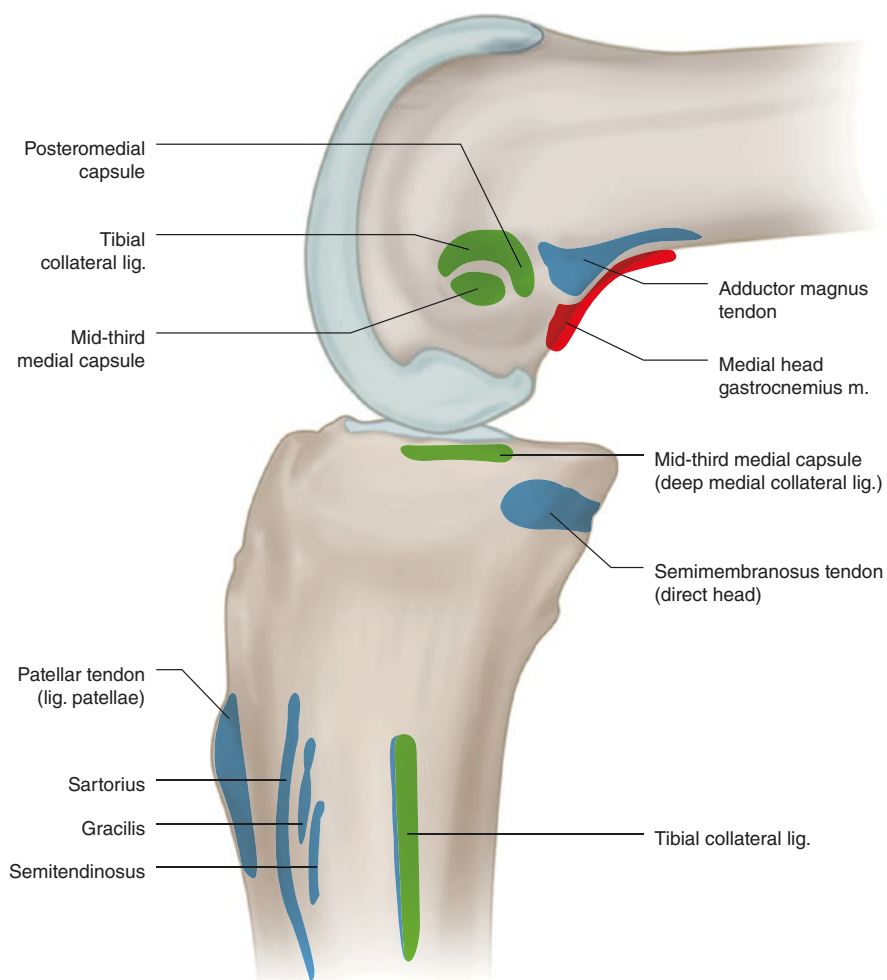


Fig. 1.35 Origins (red) and insertions (blue) of muscles and tendons and attachments (green) of ligaments (green) on medial knee

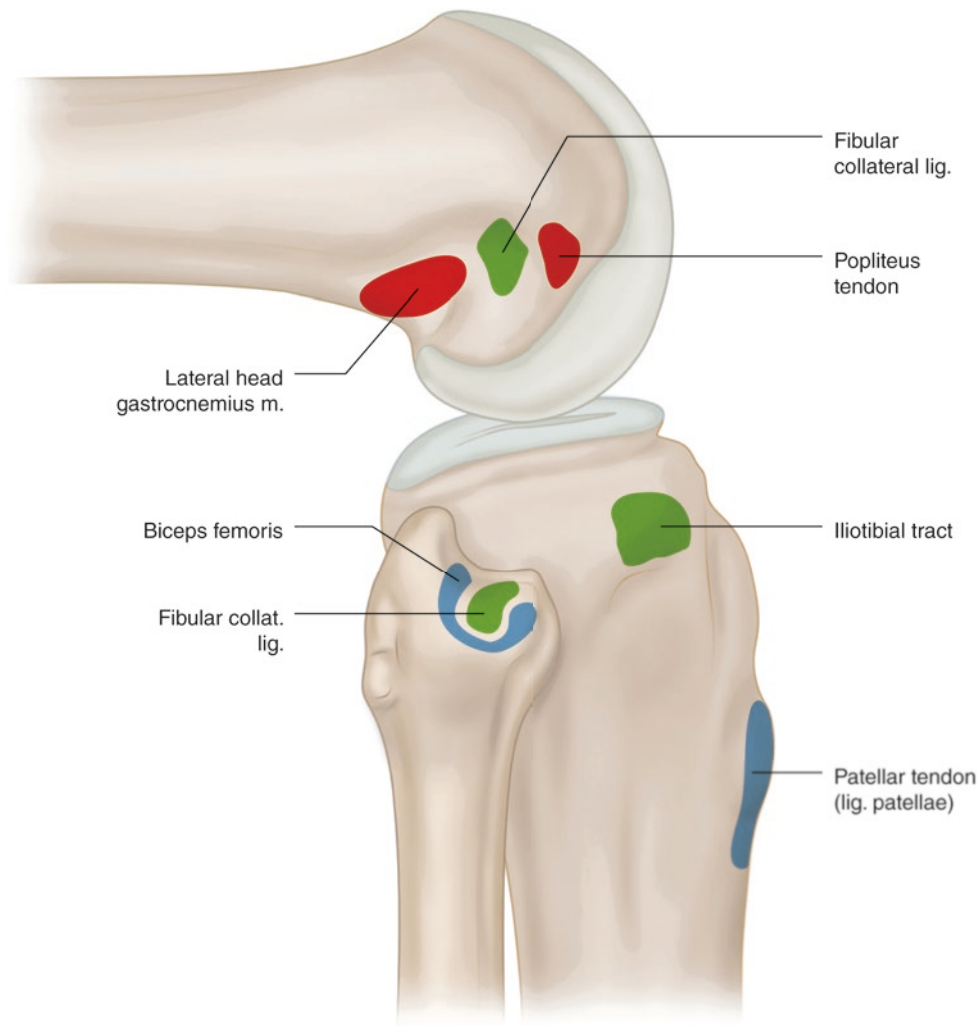


Fig. 1.36 Origins (red) and insertions (blue) of muscles and tendons and attachments of ligaments (green) on lateral knee

1.5.3 Posterior Thigh

The posterior thigh muscles that cross the knee are the hamstring muscles: long and short heads of the biceps femoris laterally, and the semitendinosus, and semimembranosus medially [3] (*see* Fig. 1.38).

1.5.4 Leg

The muscles on the anterolateral aspect of the upper leg are the tibialis anterior, peroneus longus and brevis, extensor

digitorum longus, and extensor hallucis longus (*see* Fig. 1.39a). Posteriorly, the medial head of the gastrocnemius muscle originates from a depression just proximal to the articular surface of the medial femoral condyle. The lateral head of the gastrocnemius originates from the posterior distal femur just above the lateral femoral condyle. The plantaris muscle arises from the distal linea aspera and oblique popliteal ligament (*see* Figs. 1.39b and 8.3). The deep group of muscles are the popliteus, flexor hallucis longus, flexor digitorum longus, and tibialis posterior.

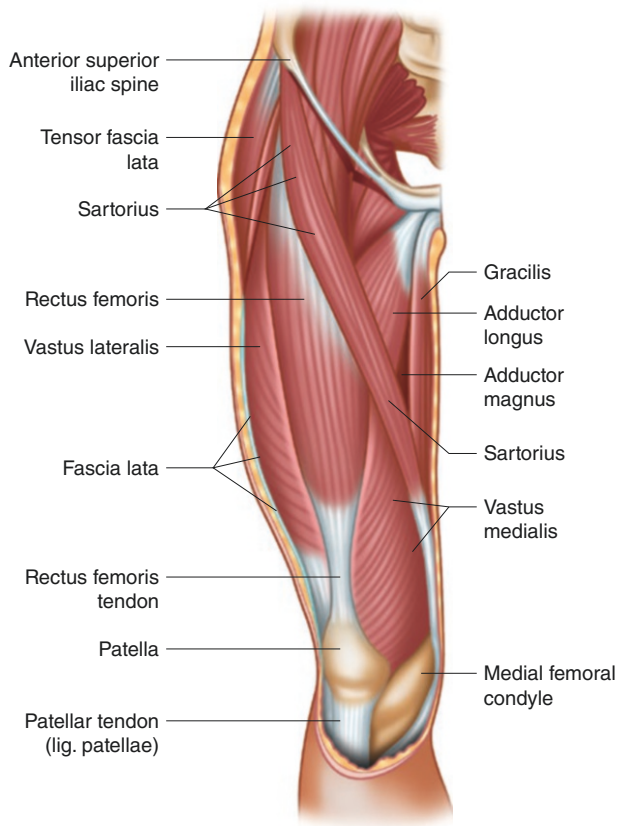


Fig. 1.37 Right thigh, anterior muscles

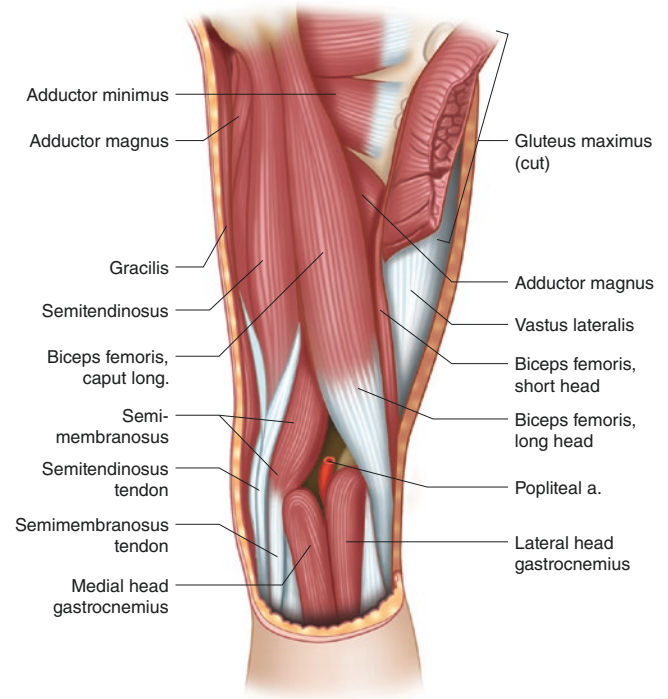


Fig. 1.38 Right thigh, posterior muscles

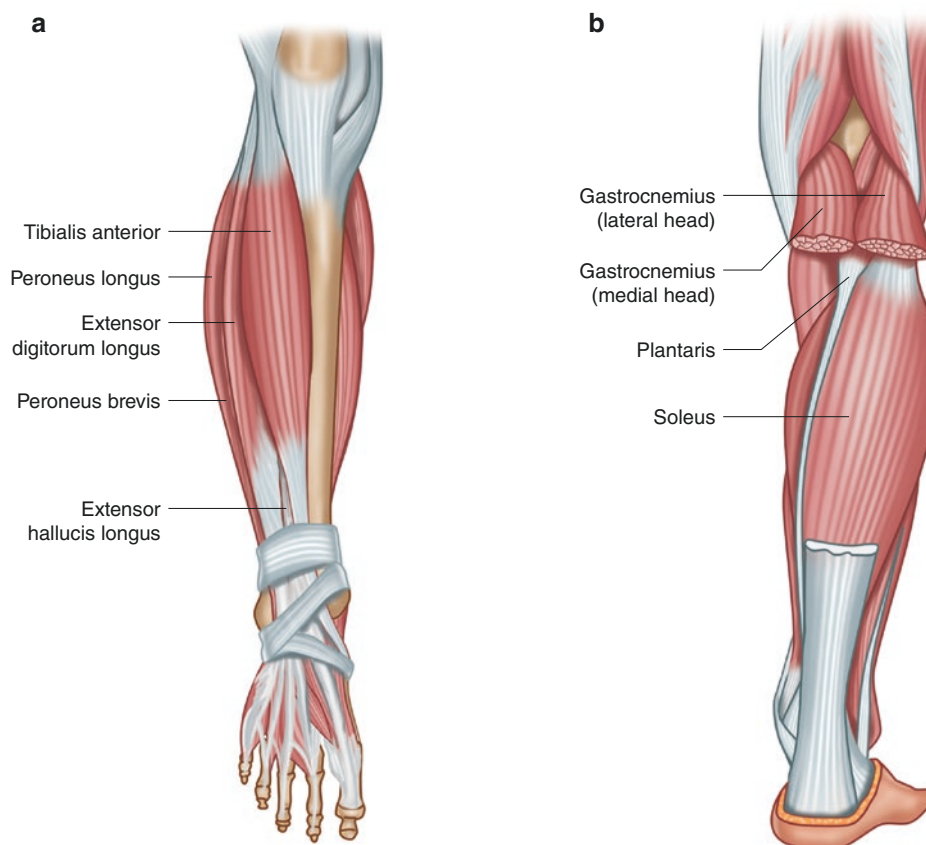


Fig. 1.39 Right leg, calf muscles. (a). Anterolateral view. (b). Posterior view

1.6 Arteries

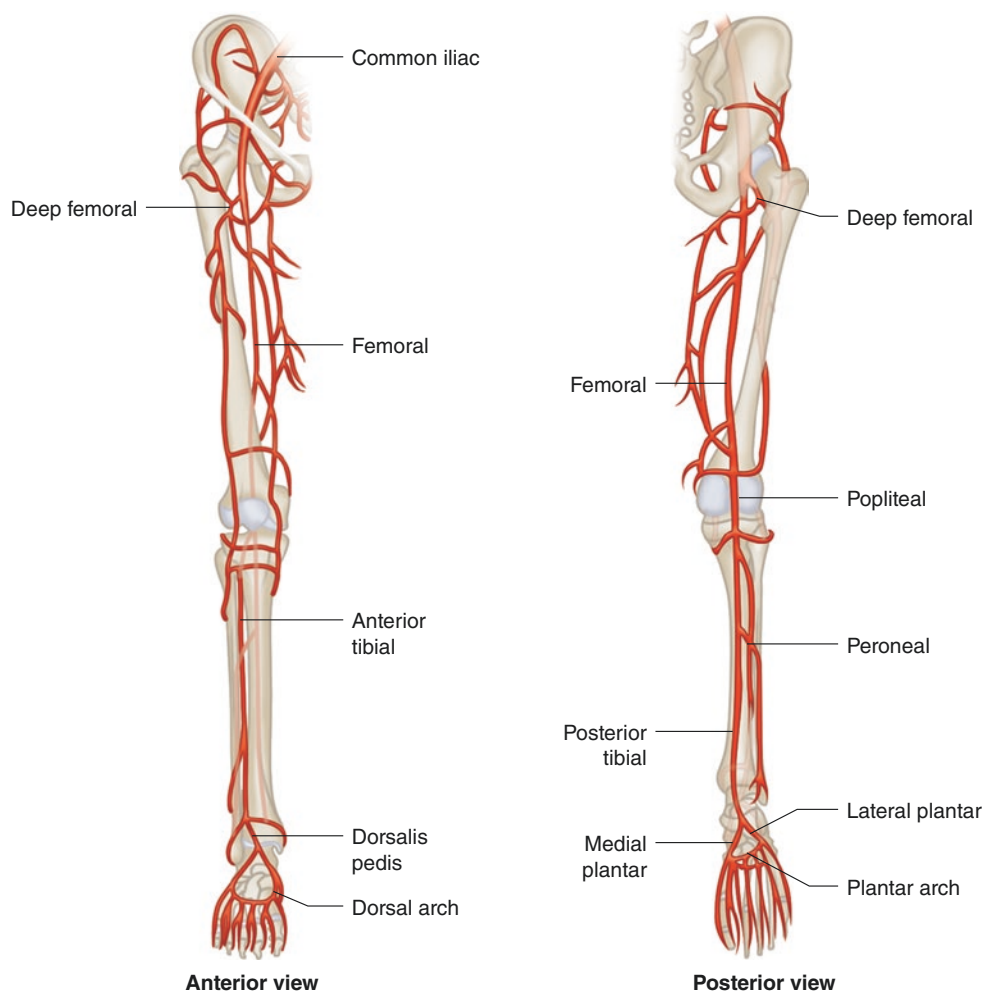
According to commonly used surgical nomenclature, the **common femoral artery** [according to TA2 – *a. femoralis*] gives off the **deep femoral artery** [according to TA2 – *a. profunda femoris*]. This is the main blood supply of the thigh. The continuation of the common femoral artery is the **superficial femoral artery**, which is still the **femoral artery** in official anatomical nomenclature. It continues down the thigh closely associated with the medial intermuscular septum and changes its name to the **popliteal artery** [according to TA2 – *a. poplitea*] below the adductor hiatus.

Before entering the hiatus, the femoral artery gives off the **descending genicular artery** (also known as the *highest genicular artery*) which divides into the **musculo-articular branch** and **saphenous branch**. In the popliteal fossa, the popliteal artery gives off branches: two superior genicular arteries [*a. genus suprema; anatomica magna artery*]: the **medial superior genicular artery** and the **lateral superior genicular artery**; the **middle genicular**

artery [*a. genus media; azygos articular artery*]; and two inferior genicular arteries [*aa. genus inferiores; inferior genicular arteries*]: the **medial inferior genicular artery** and the **lateral inferior genicular artery**. Near the lower border of the popliteus muscle, the popliteal artery normally splits into the **anterior tibial artery** [*a. tibialis anterior*] and the **posterior tibial artery** [*a. tibialis posterior*]. The anterior tibial artery passes through an opening of the interosseous membrane between the tibia and fibula to enter the anterior compartment of the leg. The posterior tibial artery sends off the fibular artery. The popliteal artery provides blood not only for the knee, including the joint capsule and ligaments, but also for areas of the leg and foot. Around the knee there is an extensive arterial network of anastomotic vessels that form a deep and superficial plexus. These provide collateral circulation to the knee and to the leg when the knee is fully flexed (see Figs. 1.40 and 1.41).

The arteries, unlike the nerves, do not belong to specific compartments.

Fig. 1.40 Major arteries of lower extremity



In the popliteal space, the artery is the deepest of the neurovascular structures and is close to the posterior capsule. The vein lies between the popliteal vein and the nerves. The nerves are most superficial.

Three-dimensional postmortem angio-CTs of the knee with gelatin and barium sulfate injection of arterial system are shown in Figs. 1.42, 1.43, 1.44, 1.45, 1.46, and 1.47. It is important to note that the popliteal artery is close to the posterior capsule in extension and further away when the knee is in flexion.

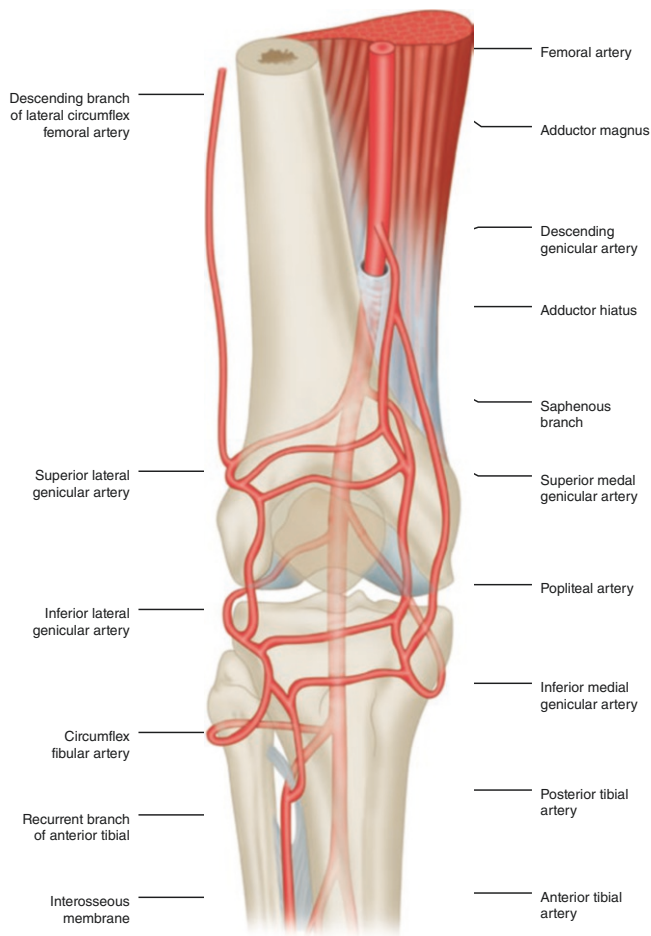


Fig. 1.41 Arterial anastomoses around the knee

In about 10% of knees, there are anatomic variants of the main branches of the popliteal artery [4, 5] (see Fig. 1.48) (refer to Chap. 8). These can be of concern to the orthopaedic surgeon performing total knee replacement, distal femoral reconstruction, and proximal osteotomy, as well as the radiologist performing transluminal stent implantation, angioplasty, embolectomy, and diagnostic angiography [7].

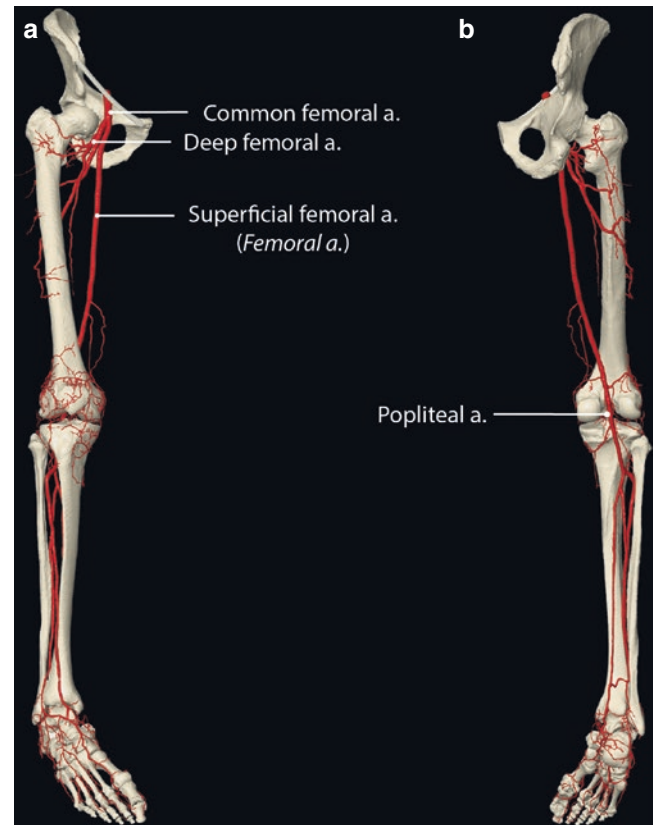


Fig. 1.42 Three-dimensional postmortem angio-CT of right lower extremity with gelatin and barium sulfate injection of the arterial system. (a). Anterior view. (b). Posterior view. The common femoral artery divides into the **superficial femoral artery** (commonly called the femoral artery as well as the official name in anatomical nomenclature), which continues as the popliteal artery, and the **deep femoral artery**, which is the main blood supply to the thigh

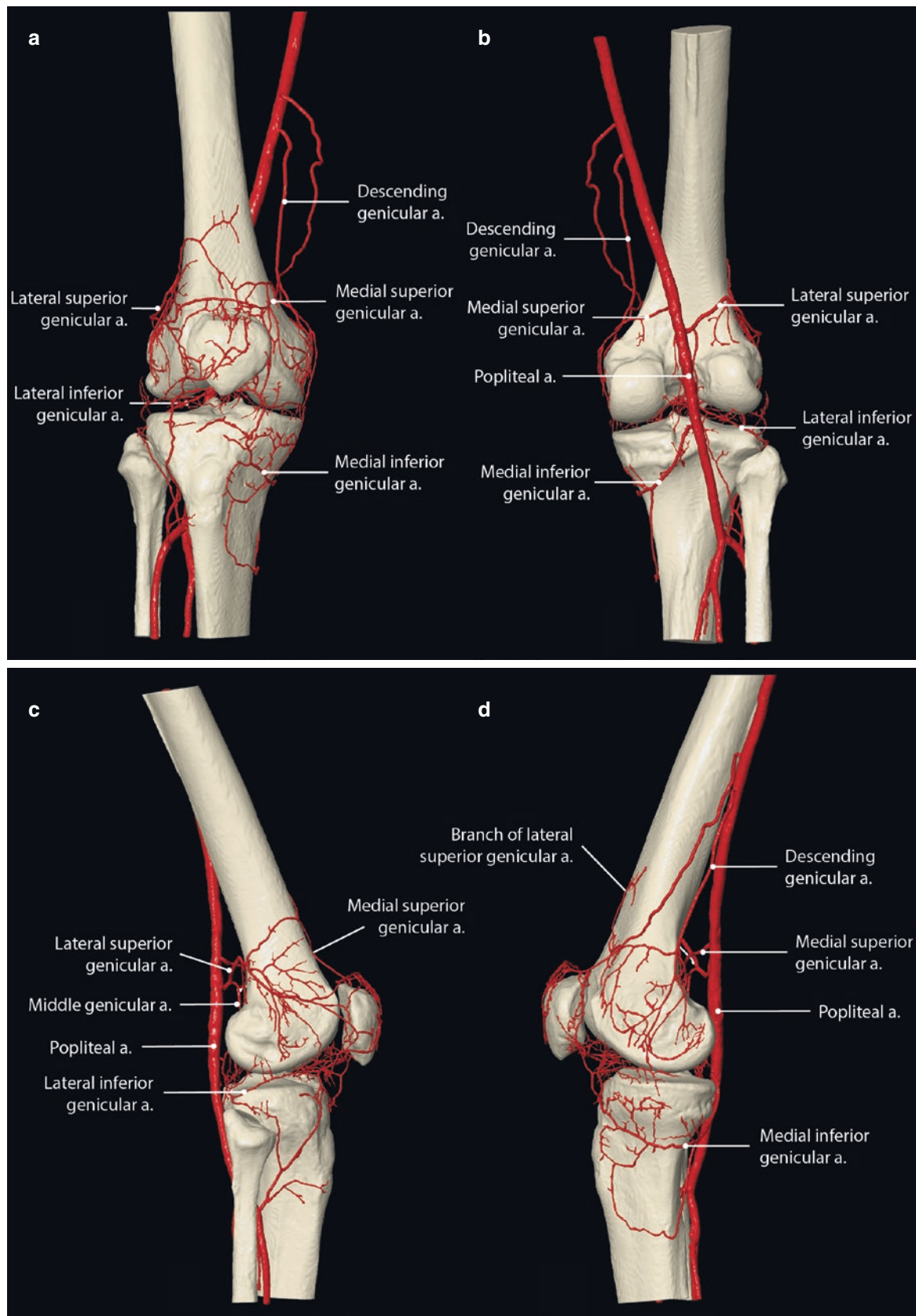


Fig. 1.43 Three-dimensional postmortem angio-CT of right knee with gelatin and barium sulfate injection of the arterial system showing genicular arteries. (a). Anterior view; (b). Posterior view; (c). Lateral view; (d). Medial view

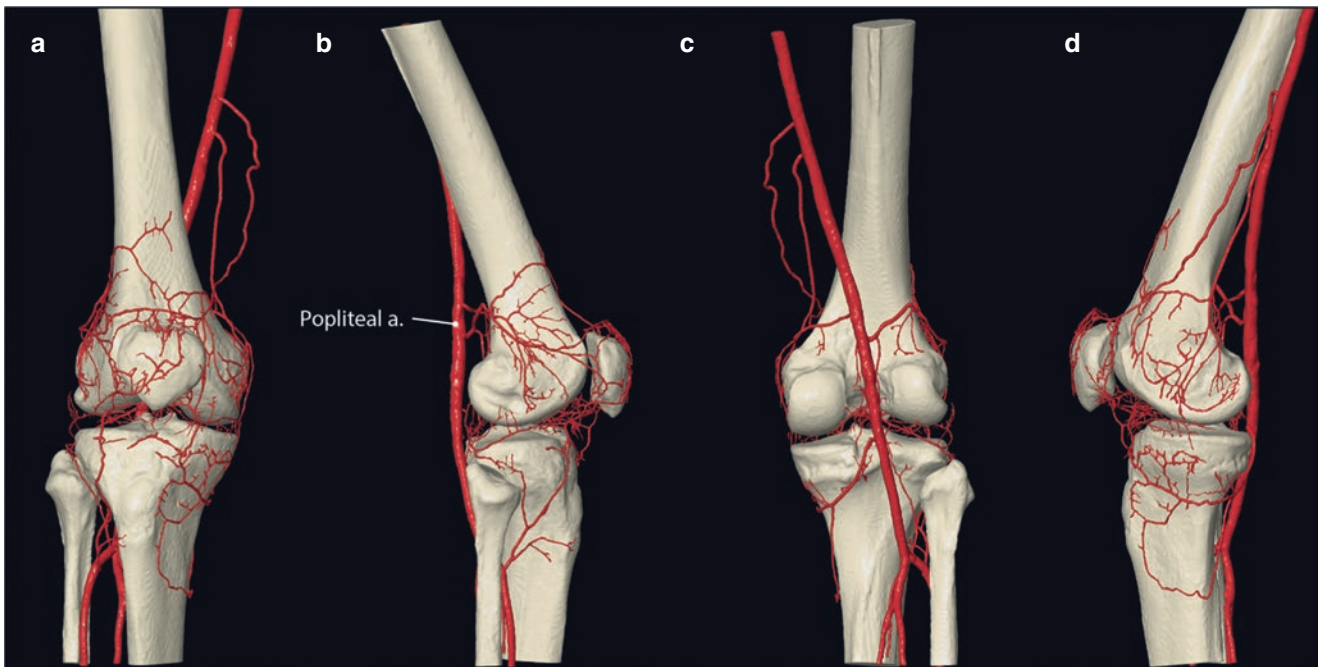


Fig. 1.44 Three-dimensional postmortem angio-CT of extended right knee with gelatin and barium sulfate injection of the arterial system (a). Anterior view; (b). Lateral view—Note how close the popliteal artery is to the posterior capsule in extension; (c). Posterior view; and (d). Medial view

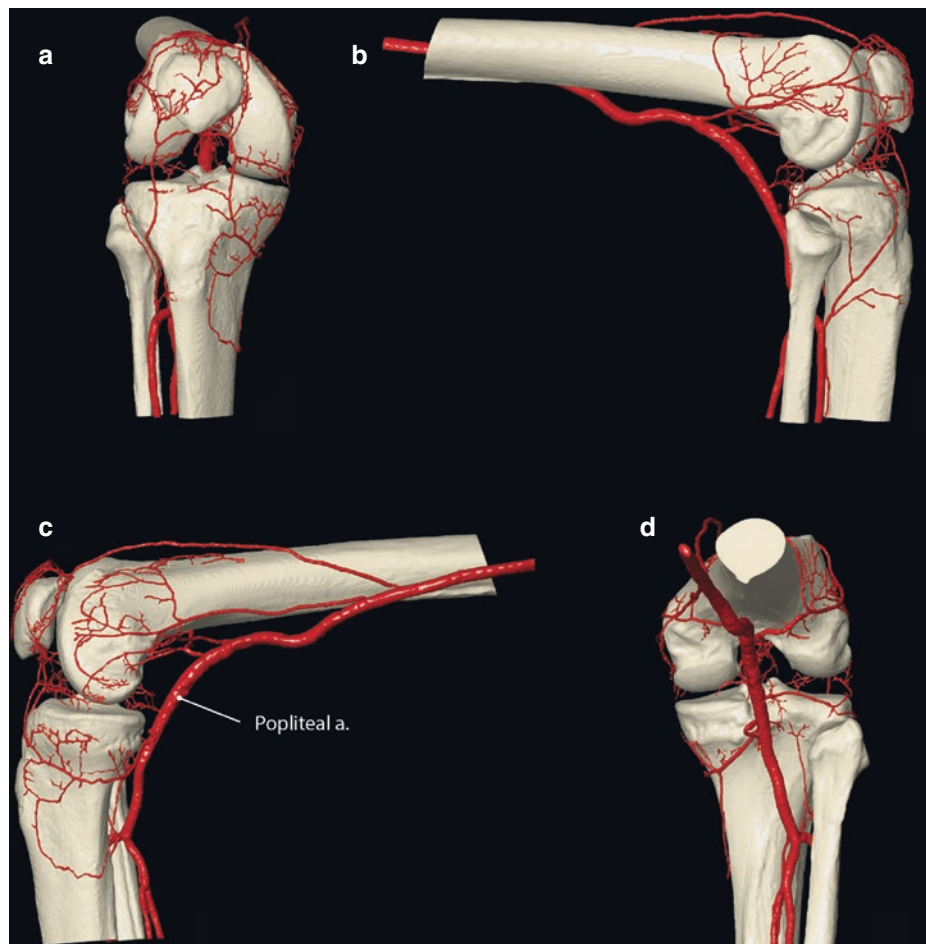


Fig. 1.45 Three-dimensional postmortem angio-CT of right knee at 90° flexion with gelatin and barium sulfate injection of arterial system (a). Anterior; (b). Lateral; (c). Medial; and (d). Posterior view

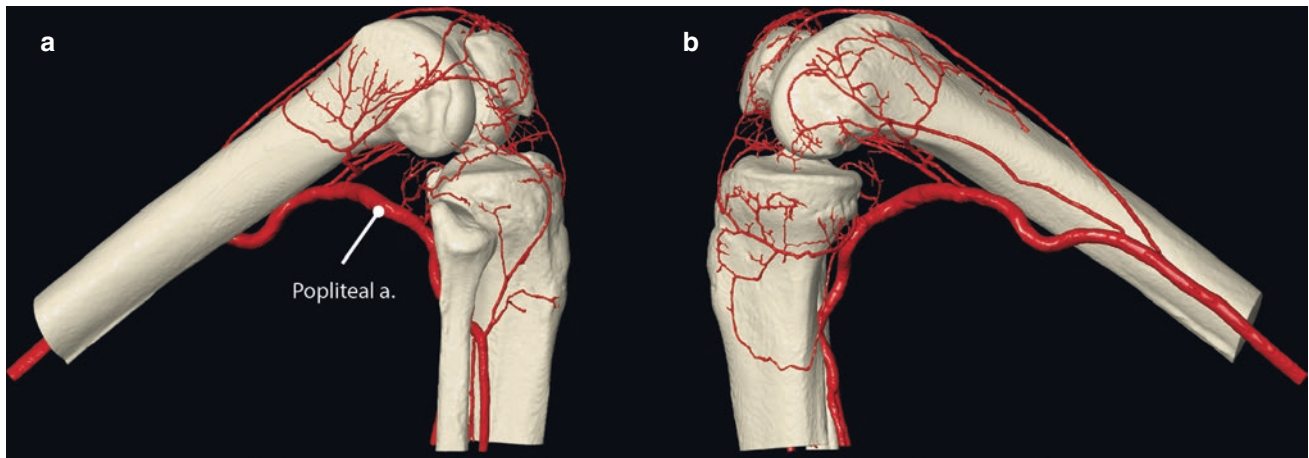
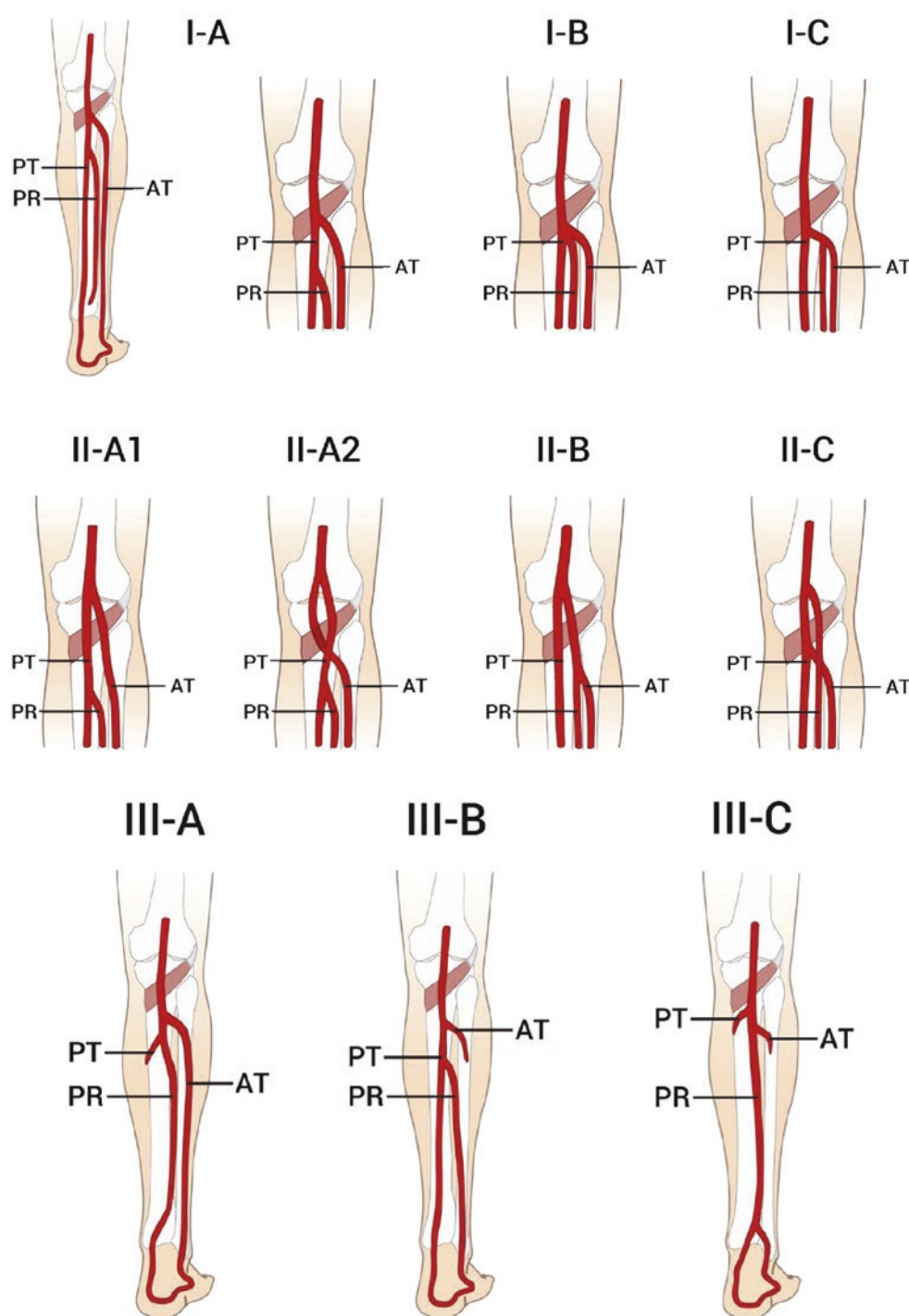


Fig. 1.46 Three-dimensional postmortem angio-CT of right knee at 120° flexion with gelatin and barium sulfate injection of arterial system (a). Lateral view. (b). Medial view. Note that the popliteal artery is far from the posterior capsule in flexion



Fig. 1.47 Three-dimensional postmortem angio-CT of right knee with gelatin and barium sulfate injection of arterial system showing dense vascularity (a). Medial view; (b). Posterior view

Fig. 1.48 Anatomic variants of the proximal tibia artery occur in about 10% of knees. They can be of concern when performing a high tibial osteotomy and other procedures. **Type I:** The anterior tibialis artery originates below the inferior border of the popliteus muscle. **Type II:** The anterior tibialis artery originates above the superior border of the popliteus muscle, and it is divided into: *Type II A:* descends deeply to the popliteus muscle. *Type II B:* superficial to the popliteus muscle. *Type II C:* results in the peroneal artery. **Type III:** The 3 end arteries originate in the inferior border of the popliteus muscle. Popliteal artery (PA), anterior tibial a. (AT), peroneal a. (PR), posterior tibial a. (PT) (From Tomaszewski et al. [6]; with permission)



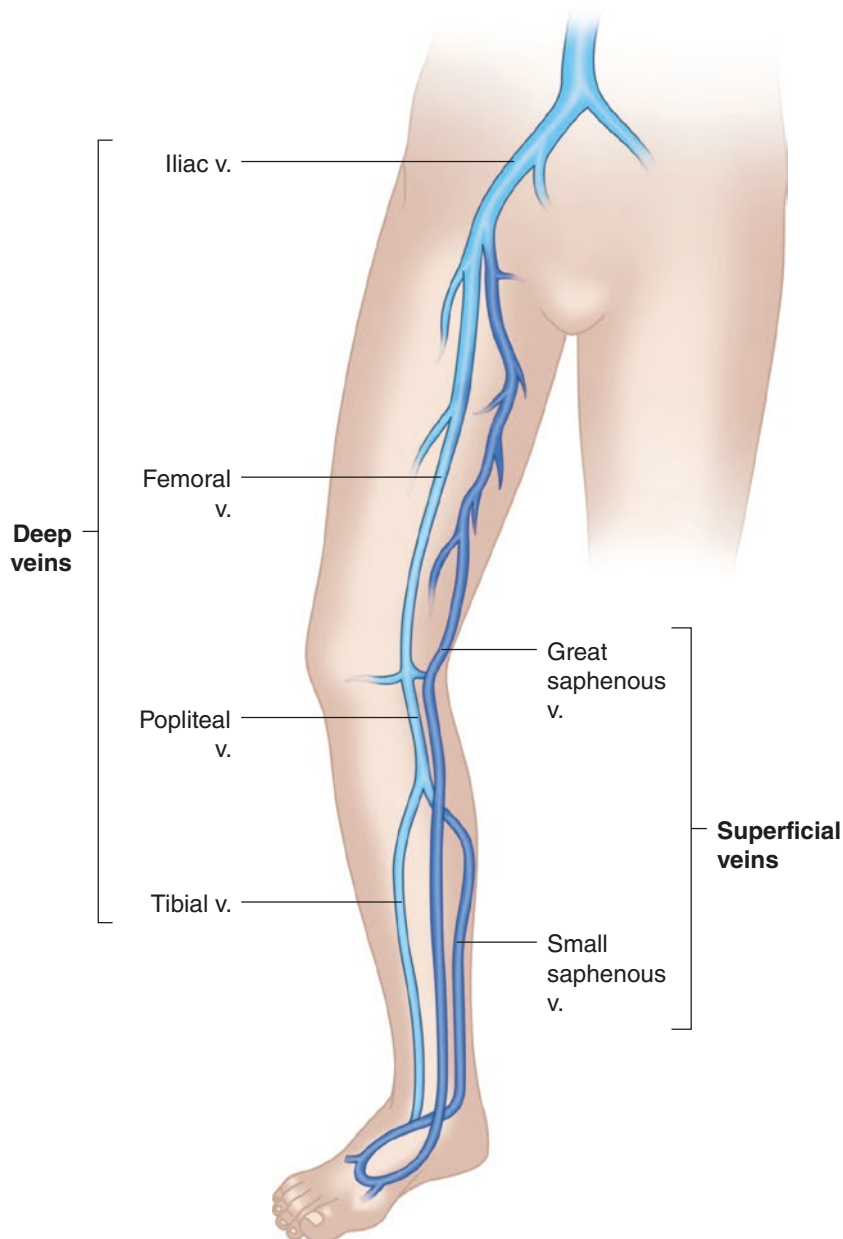
1.7 Veins

The deep veins tend to follow the arteries. They take the names of the arteries they accompany. Two veins usually accompany each artery.

The major superficial veins of the lower extremity are the **great saphenous vein** [*v. saphena magna; internal or long*

saphenous vein] and the **small saphenous vein**. [*v. saphena parva; external or short saphenous vein*]. There are connections between great and small veins. There are also connections (“perforators”) between the deep and superficial veins. Valves in the perforators prevent blood from going from the deep veins back into the superficial veins. Incompetences of these valves are associated with varicose veins (see Fig. 1.49).

Fig. 1.49 The major veins of the lower extremity. The deep and superficial veins communicate



1.8 Lymphatics

The lymphatic vessels of the lower extremity have two sets, **superficial**, which lie in the superficial fascia, and the **deep**, which accompany the deep blood vessels. Their distribution corresponds with the veins.

1.9 Nerves

Three major nerves innervate the lower extremity:

1. Obturator.
2. Femoral.
3. Sciatic.

The **obturator nerve** [*n. obturatorius*] (L2, L3, L4) innervates the adductor muscles, including the adductor magnus and gracilis muscle to the knee.

The **femoral nerve** [*n. femoralis*; *anterior crural nerve*] (L2, L3, L4) innervates the sartorius and quadriceps femoris muscles of the thigh. The femoral nerve continues distally as the **saphenous nerve** [*n. saphenous*; *long or internal saphenous nerve*]. The saphenous nerve continues to the leg to provide sensory nerves to the medial region of the leg including the area around the medial malleolus. It is the only branch of the femoral nerve that descends beyond the knee.

The **sciatic nerve** [*n. ischiadicus*; *great sciatic nerve*] courses down the posterior thigh. The sciatic nerve is actually two nerves which bifurcate in the popliteal fossa to become the

tibial nerve [n. *tibialis*; *internal popliteal nerve*] and *common peroneal nerve* [n. *peroneus communis*; *external popliteal nerve*]; *peroneal nerve*]. In the thigh, the tibial nerve innervates the long head of biceps femoris muscle. The common peroneal nerve innervates the short head of biceps muscle.

The sural nerve (*L4-S1*) supplies sensation to the postero-lateral leg to the lateral ankle. The sural nerve originates from a combination of either the sural communicating branch and the **medial sural cutaneous nerve**, or the **lateral sural cutaneous nerve**. There are other variants (*see* Fig. 1.50) [8].

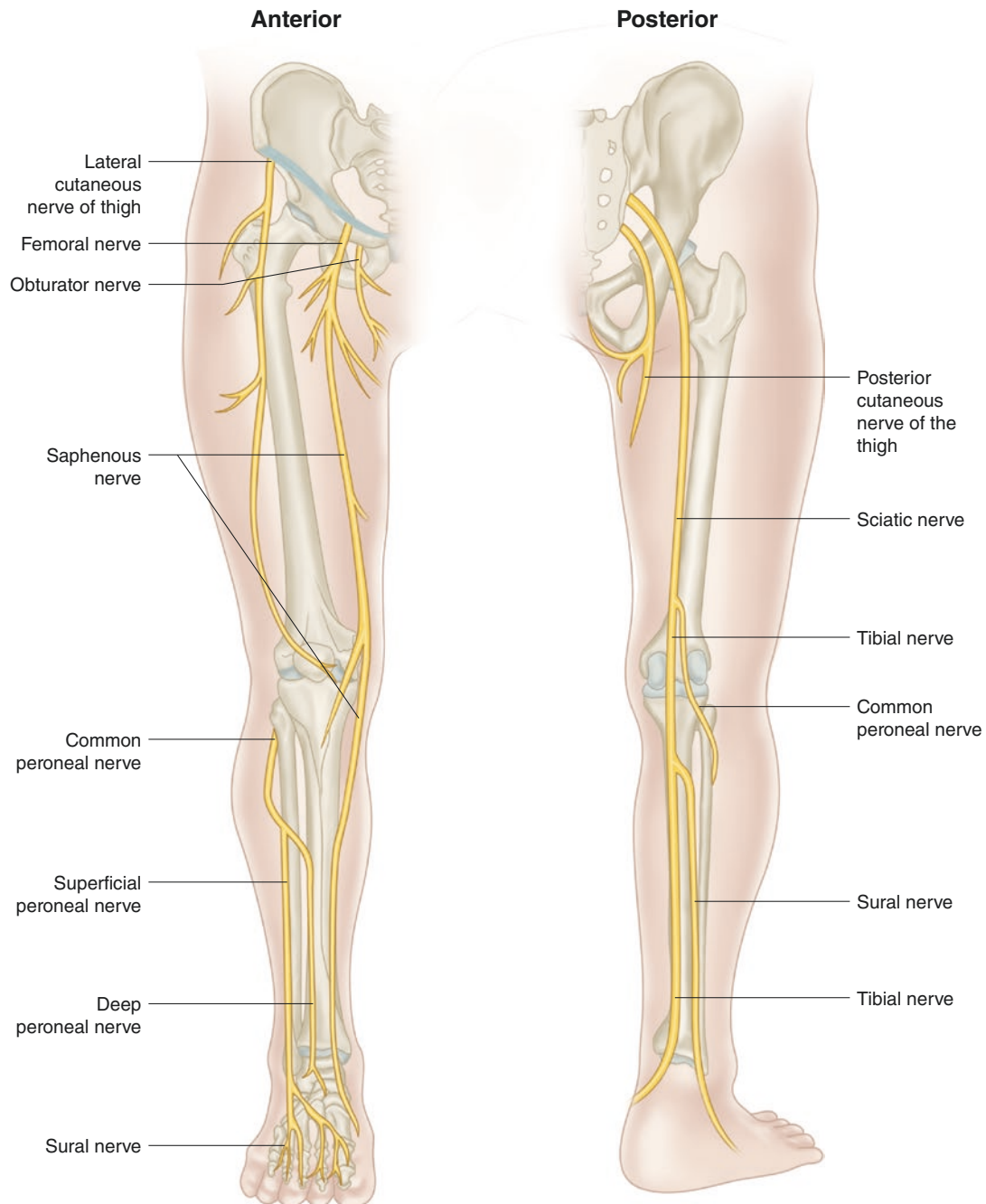


Fig. 1.50 Major nerves of lower extremity

1.10 Compartments

1.10.1 Thigh

The fascia lata gives off prolongations from its deep surface which pass between muscles separating them into groups. The **medial** and **lateral intermuscular septae** [deep transverse fascia] separate the anterior compartment from the medial and posterior compartments. The posterior compartment is separated from the medial by an indistinct **posterior intermuscular septum** (see Fig. 1.51).

The thigh thus has three compartments:

The **anterior** (extensor) compartment of the thigh contains the quadriceps and sartorius muscles. It is supplied by the femoral nerve.

The **medial** (adductor) compartment of the thigh contains the gracilis and adductor muscles. It is supplied by the obturator nerve.

The **posterior** (flexor) compartment has the hamstring muscles (biceps femoris, semitendinosus, and semimembranosus) in addition to the “hamstring” portion of the adductor magnus muscles. It is supplied by the sciatic nerve. The rest of the sciatic nerve innervates the entire leg and foot.

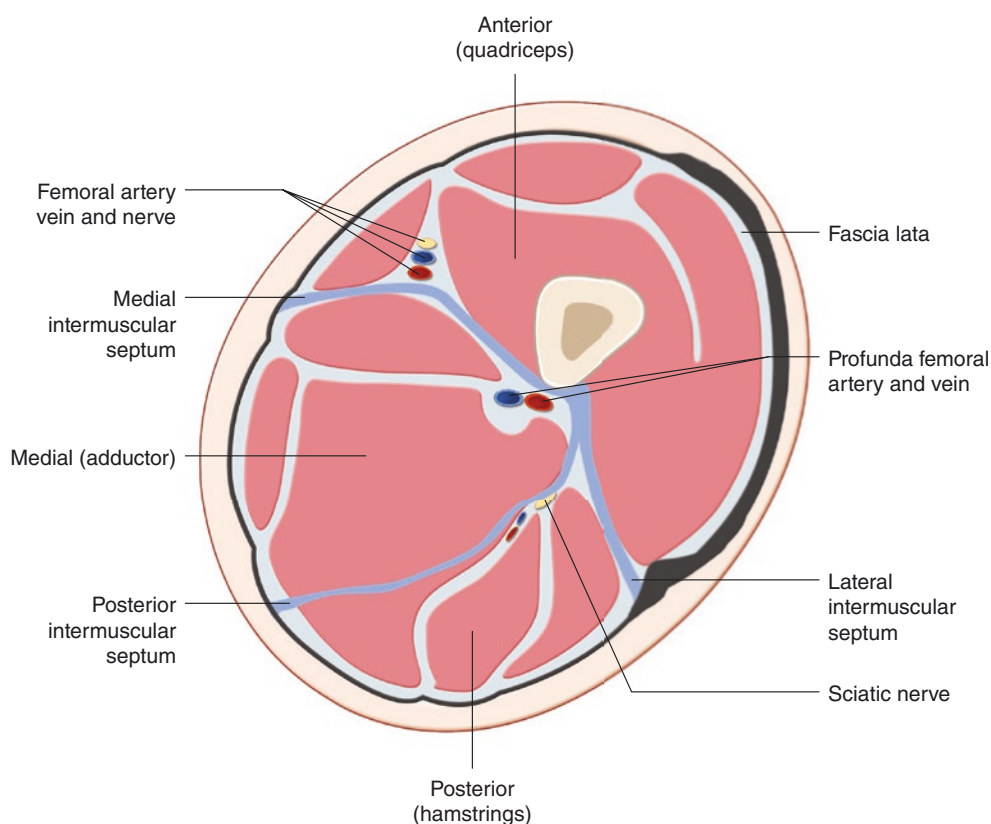


Fig. 1.51 The thigh has three compartments: The **anterior** (extensor) compartment of the thigh, which is supplied by the femoral nerve. The **medial** (adductor) compartment which is supplied by the obturator

nerve. The **posterior** (flexor) which is supplied by the sciatic nerve. Note the relationships between the intermuscular septae and the neuro-vascular structures

The sartorius muscle in the upper thigh is in the anterior compartment, but closer to the knee it becomes medial and then superficial as its tendon blends with the aponeurosis of the fascia cruris.

At the junction of the middle and distal thirds of the medial thigh, the medial septum splits to form the fascial wall of the **adductor canal** [*canalis adductorius*; *Hunter's canal*].

1.10.2 Leg

The leg has four compartments:

- The **anterior** compartment contains the tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius.
- The **lateral** compartment contains the peroneus longus and brevis.
- The **deep posterior** compartment contains the tibialis posterior, flexor hallucis longus, flexor digitorum longus, and popliteus muscles.
- The **superficial posterior** compartment has the gastrocnemius, soleus, and plantaris muscles.

Most of the neurovascular structures are in the anterior and deep posterior compartments (*see* Fig. 1.52).

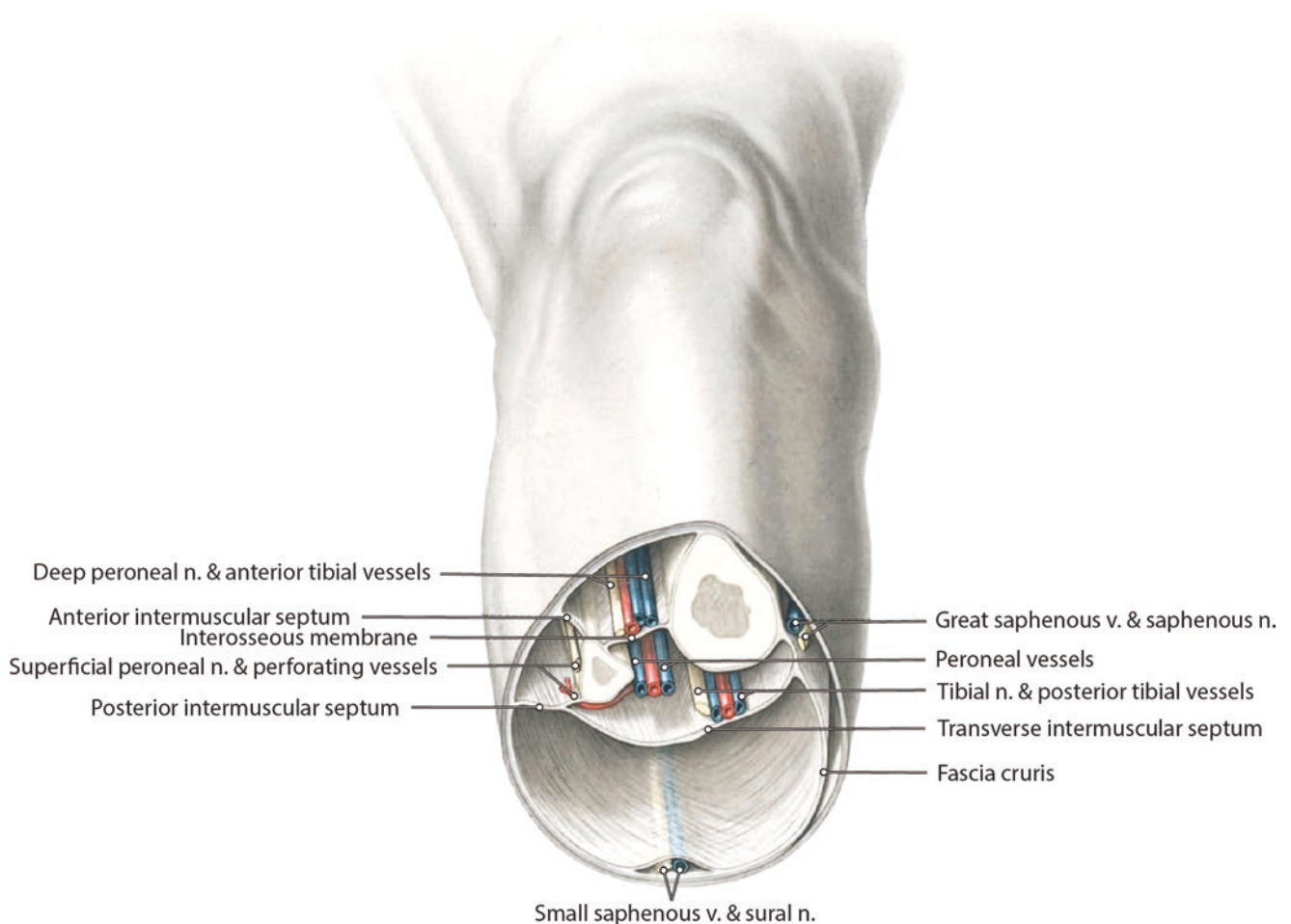


Fig. 1.52 The leg has four compartments: **anterior** (containing tibialis anterior, extensor hallucis longus, extensor digitorum longus, and peroneus tertius muscles), **lateral** (peroneus longus and brevis), **deep posterior** (tibialis posterior, flexor hallucis longus, flexor digitorum longus

and popliteus), and **superficial posterior** (gastrocnemius, soleus, and plantaris). Most of the neurovascular structures are in the anterior and deep posterior compartments (*From* von Lanz et al. [9]; with permission)

1.11 Cross-sections

Cross-sections of the lower extremity are shown in Figs. 1.53, 1.54, and 1.55.

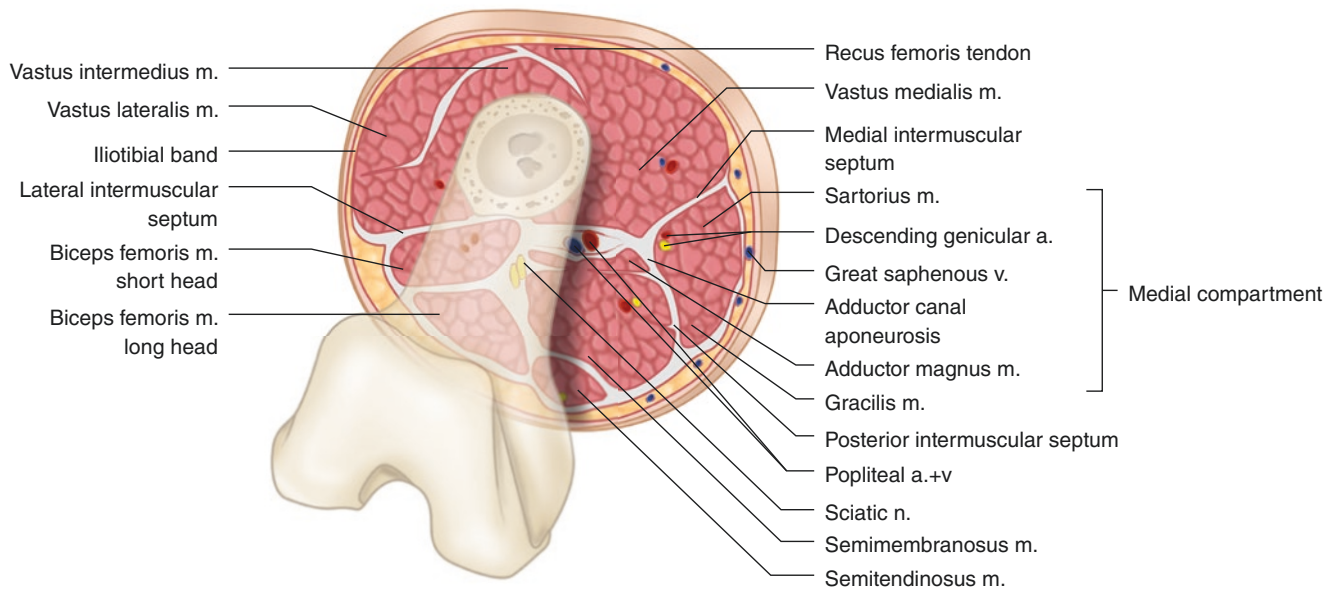
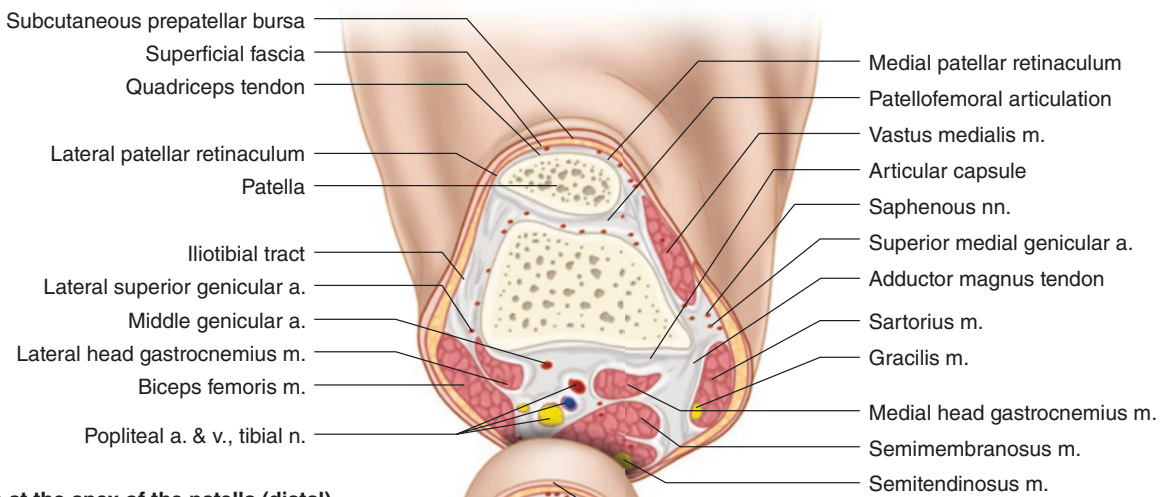
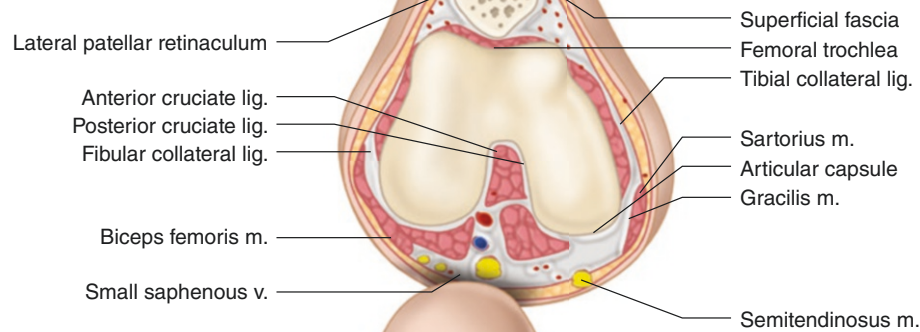
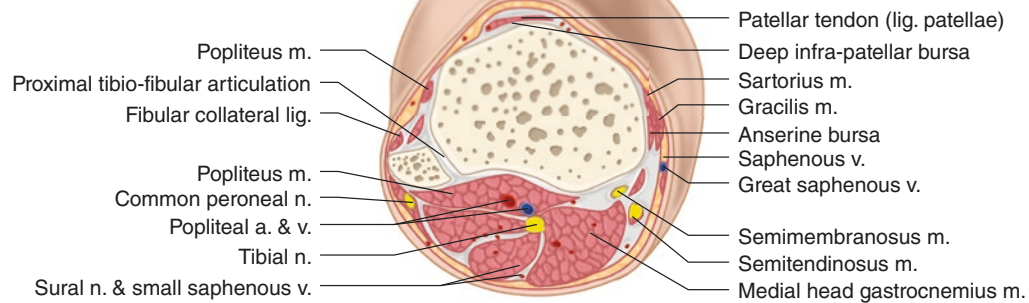


Fig. 1.53 Cross-section of lower thigh

a Cross section at the base of the patella (proximal)**b Cross section at the apex of the patella (distal)****c Cross section at level of tibial condyle****Fig. 1.54** Cross-sections at the knee

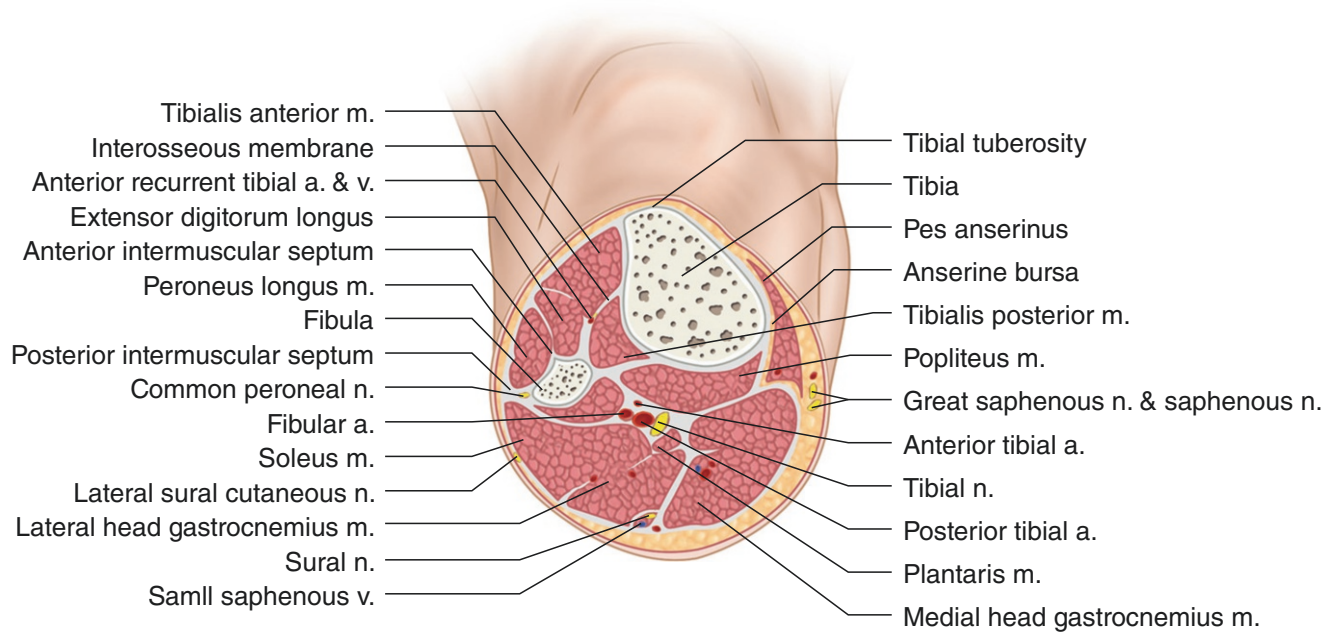


Fig. 1.55 Cross-section of upper leg

1.12 Growth Plates (Physes)

There are three **epiphyseal** growth plates (physes) in the knee: distal femur, proximal tibia, and proximal fibula. There is one **apophyseal** growth plate: for the tibial tuberosity apophysis. The proximal tibial is the only major bone in which the epiphyseal and apophyseal growth plates are continuous (*see* Figs. 1.56 and 1.57).

The **patella** is ossified from a single center, which usually appears in the second or third year, but may be delayed until the sixth year. The patella occasionally is developed by two adjacent centers. Ossification is usually complete at puberty.

For the surgeon, it is important to know the locations of the growth plates relative to anatomical structures (*see* Figs. 1.58 and 1.59).

The **distal femoral** epiphyseal plate (physis) contributes 70% of the longitudinal growth of the femur. Thirty percent of longitudinal growth of the femur occurs at the proximal femoral epiphyseal plate [10]. The tibial collateral ligament attaches to the femur on the metaphysis, not the epiphysis.

The **proximal tibia** has a primary ossification center, an **epiphyseal physis**, where 60% of the longitudinal growth of the tibia occurs [10]. Forty percent of tibial growth occurs distally. There is a secondary ossification center at the proxi-

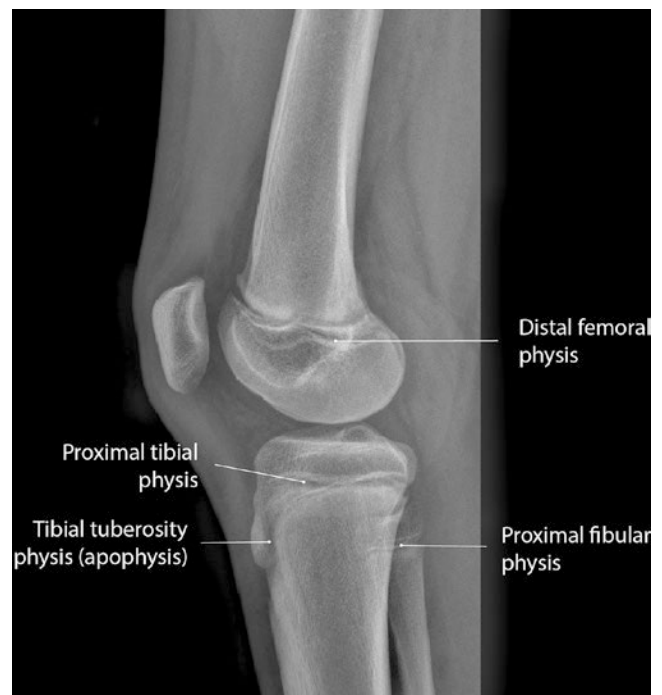


Fig. 1.56 There are three **epiphyseal** growth plates (physes) in the knee: distal femur, proximal tibia, and proximal fibula. There is one **apophyseal** physis: tibial tuberosity. Note that the proximal tibial physis is continuous with the apophyseal physis

Fig. 1.57 3D CT scan showing three epiphyseal and one apophyseal physis (growth plate) of knee. (a). Lateral view. (b). Posterior view

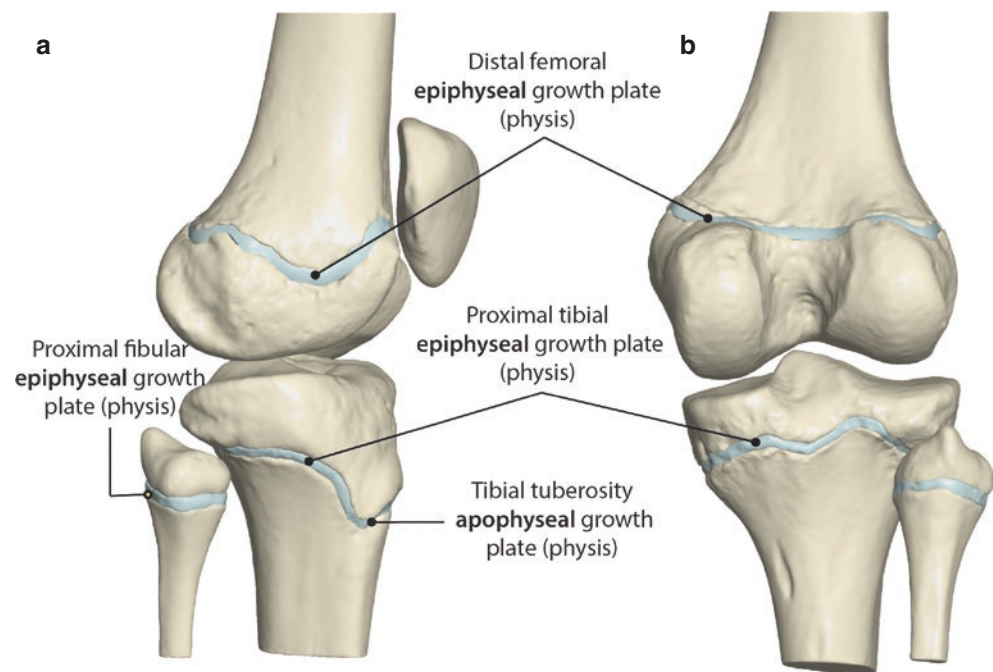


Fig. 1.58 Sagittal MRI of an 11-year-old boy's knee. Note relationships of growth plates to ligament attachments

mal tibia which is an **apophyseal physis**. No longitudinal bone growth occurs here. The patellar tendon inserts onto the tibial tuberosity apophysis. As the bone grows in length (through the epiphyseal physis), the apophyseal physis grows along the side of the bone to maintain the proper distance from the joint of the tendon insertion. As growth nears completion, the two growth centers join and become continuous. There is considerable variation in the ages at which growth plate closure occurs; it is about 2 years earlier in girls than in boys. The proximal tibial growth plate begins to close at about age 12 and is complete between the ages 18–20 in males and 16–20 in females.

Important Point

Tibial tubercle avulsion fractures are common in adolescents near the end of skeletal growth. The most common fracture pattern (Ogden Type III) [11–13] is one in which the fracture propagates between the primary ossification center (proximal tibial physis) and the secondary ossification center (tibial tubercle apophysis). It is an avulsion fracture of the insertion of patellar tendon. Since this is a Salter III fracture [12] growth arrest can occur anteriorly (see Fig. 1.60). Growth continues in the posterior part of the tibial physis, so the posterior tibia becomes longer than the front. The result is a **genu recurvatum** deformity.

Fig. 1.59 Drawing of the knee to show attachments of ligaments in relation to growth plates (*From von Lanz et al. [9]; with permission*)

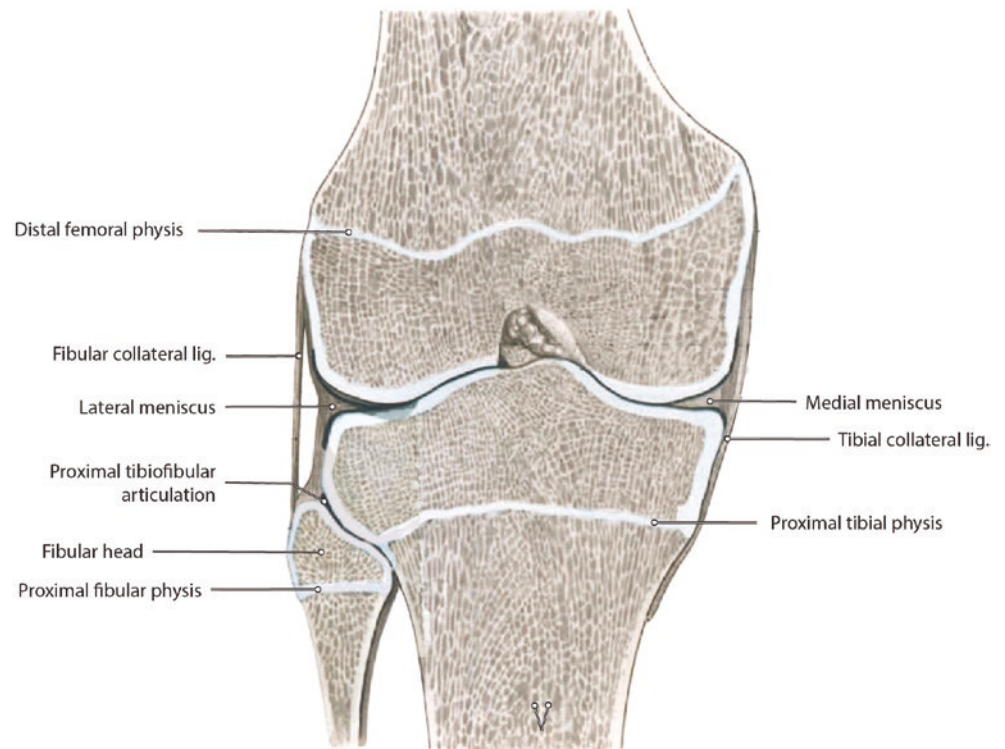


Fig. 1.60 Lateral X-ray of a knee with an Ogden type III avulsion fracture of the tibial tuberosity apophysis (arrow). This is a Salter type III fracture. This can result in premature closure of the anterior part of the proximal tibial epiphyseal plate and a resultant genu recurvatum deformity



1.13 Biomechanics

The knee is often described as hinge, but it is more complicated than a hinge joint. It is a modified ginglymus, or a **modified hinge joint**. In addition to flexion and extension, it has a **rolling-sliding movement** as well as a rotatory component to its motion. The axis about which motion takes place is not fixed but shifts forward during extension and backwards during flexion (*see* Fig. 1.61).

If the shaft of the femur is held vertically, the medial condyle projects more distally than the lateral. However, in a normal upright posture, this is not true. This is because the mechanical axis and anatomic axis of the femur do not coincide. The **anatomic axis** passes through the center of the knee joint and along the femoral shaft, inclining laterally. The **mechanical axis**, on the other hand, passes from the center of the knee joint through the center of the hip joint and is more vertical. The angle between the mechanical axis and anatomical axis is approximately 6° (*see* Fig. 1.62).

In the coronal or frontal plane, the angulation of the lower extremities can be described as **genu varum** (or genu varus)

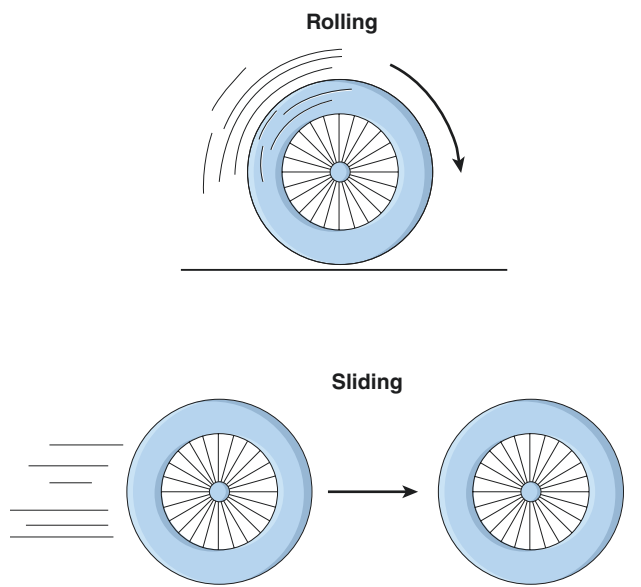


Fig. 1.61 The knee joint is not a hinge, but a **rolling-sliding** joint

when the lower leg is angled inward (“bowlegged”). The opposite is **genu valgum** (commonly called genu valgus), in which the lower leg is angled away from the midline of the body (“knock-kneed”). In the sagittal view, excessive hyperextension of the knee is called **genu recurvatum** (“back knee”) (*see* Fig. 1.63).

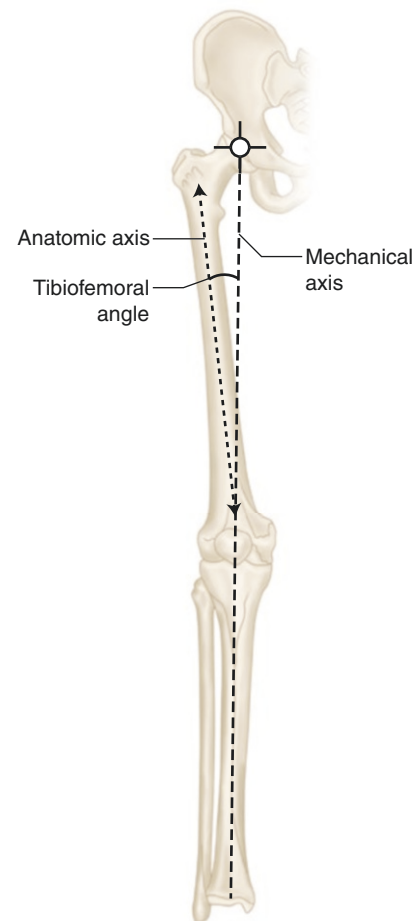


Fig. 1.62 The **anatomic axis** of the lower extremity passes through the center of the knee joint and along the femoral shaft, inclining laterally. The **mechanical axis** passes from the center of the knee joint through the center of the hip joint and is more vertical. The angle between the mechanical axis and anatomical axis is approximately 6°

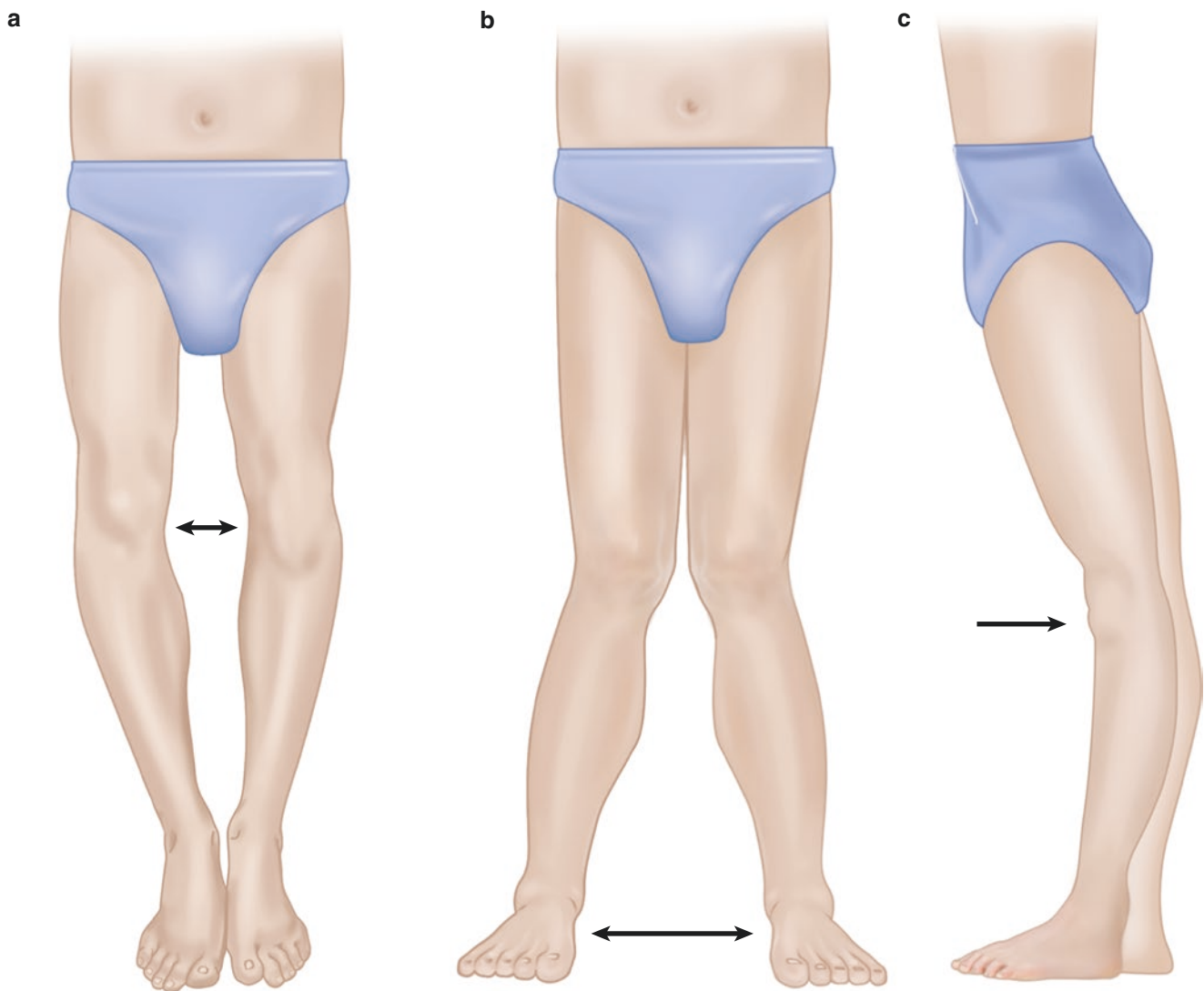


Fig. 1.63 In the coronal plane, the angulation of the lower extremities can be described as: (a). **Genu varum** (or genu varus) when the lower leg is angled inward (“bowlegged”). (b). The opposite is **genu valgum** (com-

monly called genu valgus) when the lower leg is angled away from the midline of the body (“knock-kneed”). (c). In the sagittal view, excessive hyperextension of the knee is called **genu recurvatum** (“back knee”)

1.14 Knee Joint Movement

The *rotations* are as follows:

- Internal-external
- Flexion-extension
- Adduction-abduction

The *translations* are as follows:

- Anterior-posterior
- Medial-lateral
- Compression-distraction

The knee has six degrees of freedom: three rotations and three translations (*see* Fig. 1.64).

Noyes has pointed out that manual stress examinations of the knee are designed to test just one or two limits at a time [14]. Therefore, combinations of these motions (coupled motions) are important to diagnose knee ligament injuries.

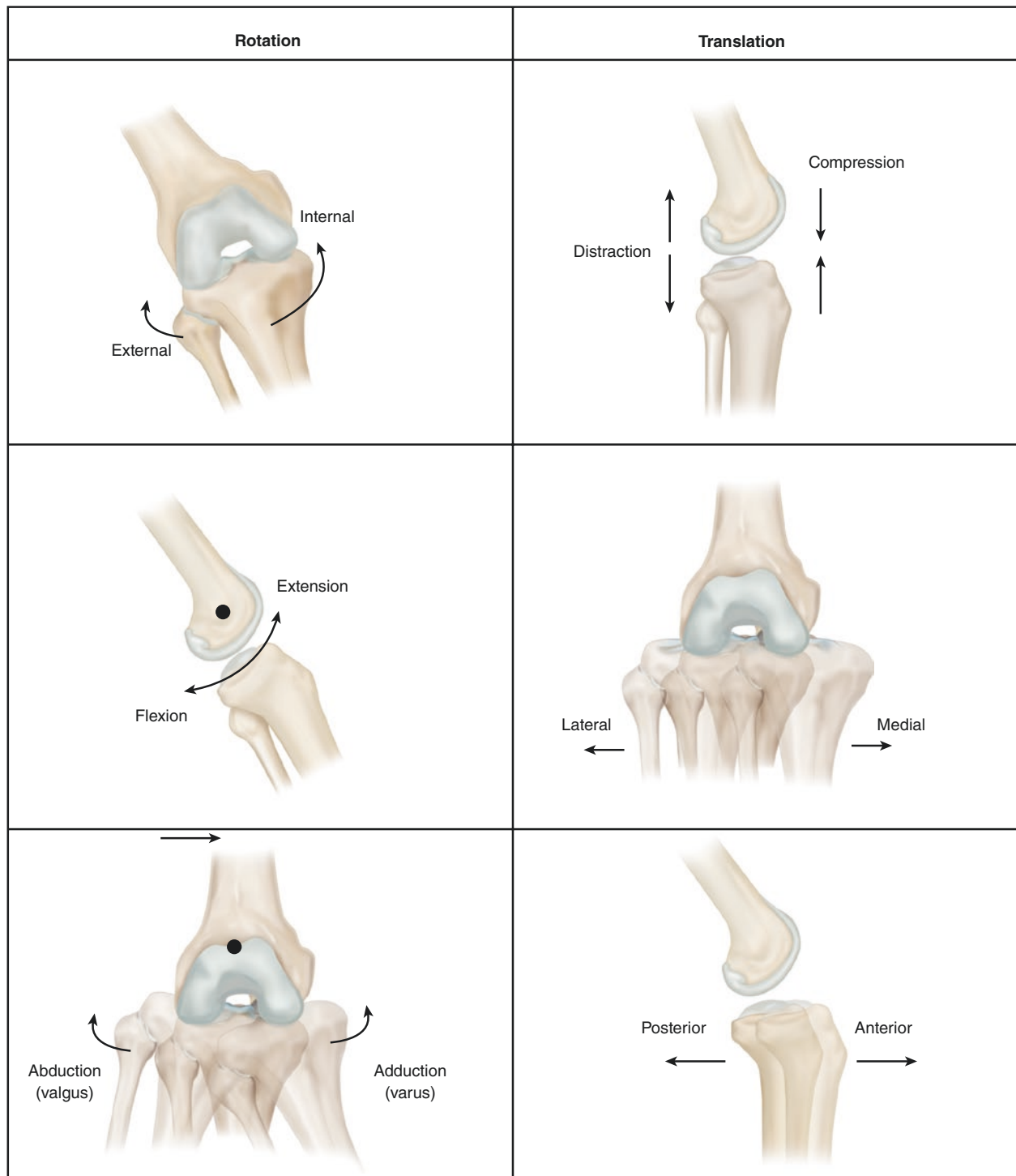


Fig. 1.64 The knee has six degrees of freedom: three rotations and three translations

1.15 Screw-Home Mechanism

The **screw-home** mechanism is important in stabilizing the knee. It is a slight external rotation of the tibia as the knee goes into the last 10° of extension. The result is tightening of

both cruciate ligaments, which locks and stabilizes the knee in the upright, standing position. The relative shapes of the medial and lateral femoral condyles and the corresponding tibial plateaus govern the screw-home mechanism [15, 16] (see Fig. 1.65).

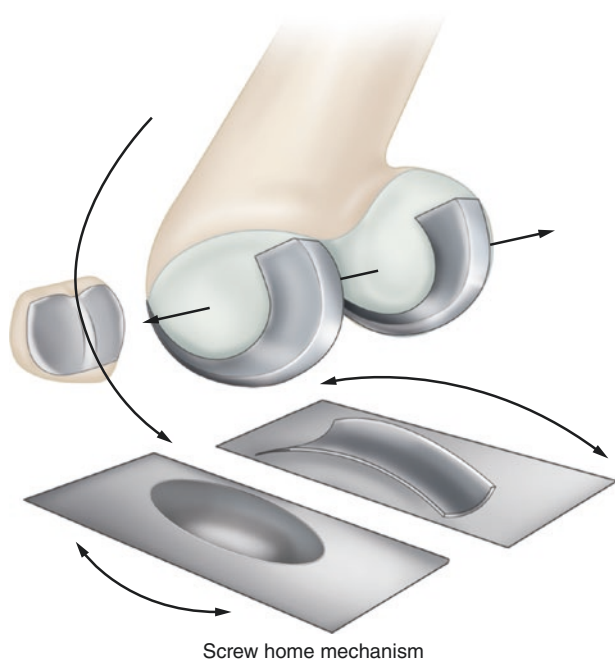


Fig. 1.65 The lateral tibiofemoral joint is round. The medial tibiofemoral joint is elongated

As the knee extends, the tibia glides anteriorly on the femur. When the knee comes to the last 10° of extension, the articular surface in the lateral compartment is used up (because the lateral compartment is round and short). However, there is still articular surface left medially (because the medial femoral condyle and corresponding medial tibial condyle are long). Thus, the medial side of the tibia continues to move, resulting in a slight external rotation of the tibia (see Fig. 1.66).

Because of the external rotation of the tibia, the patella sits slightly lateral in the extended knee. However, there is little force on the patella in this position. As the knee flexes, the patella centers itself within the trochlear groove.

Terminology

The movement of the distal part in relation to the proximal determines the designation, regardless of which segment is fixed.

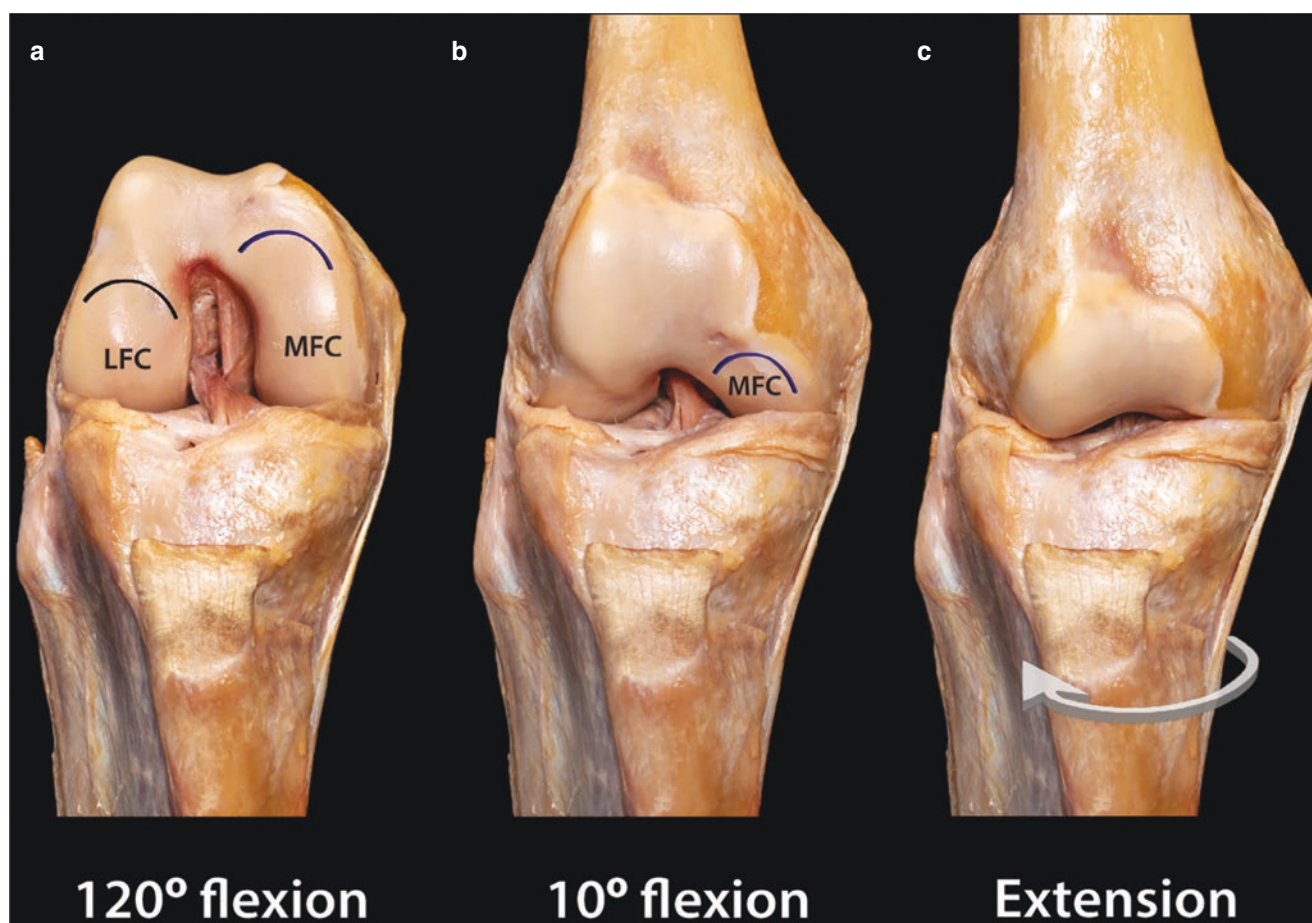


Fig. 1.66 Screw-home mechanism explained. (a). At 120° flexion, the medial femoral condyle can be seen to be longer than the lateral. (b). When the knee is at 10° flexion, the articular surface in the lateral femoral condyle has been used up (because the lateral compartment is round and short). However, there is still articular surface left on the medial

femoral condyle (because the medial femoral condyle and corresponding medial tibial condyle are long). (c). With further extension the medial femoral condyle keeps sliding on the medial tibial plateau. The result is a slight external rotation of the tibia as the knee locks in extension

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Imaging of the Knee

2

Beata Ciszowska-Łysoń and Aleksandra Zielińska

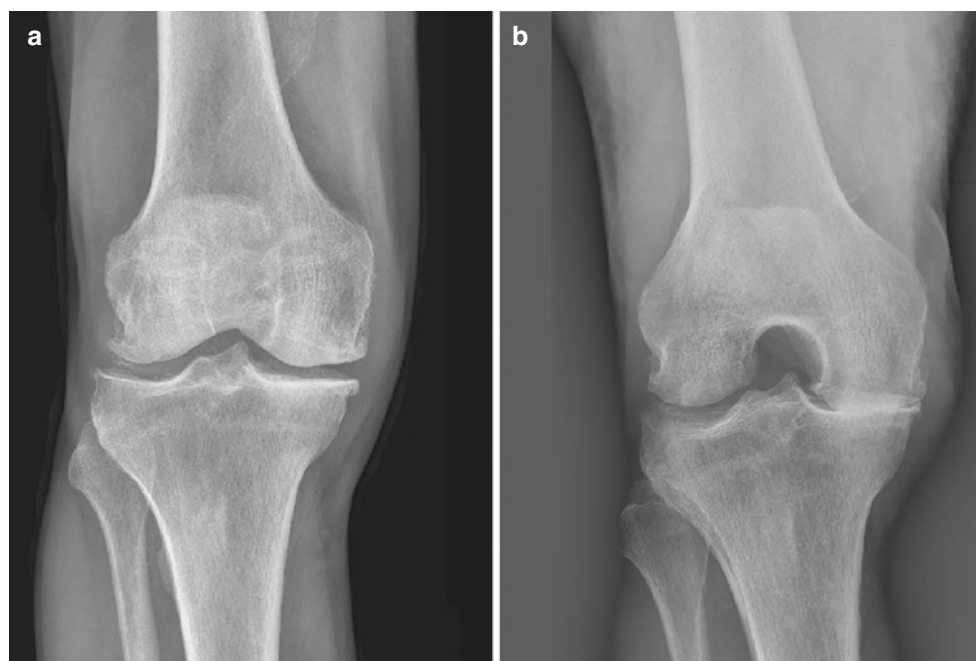
2.1 X-Ray (Radiography)

The **anteroposterior (AP)** view is the most basic projection for assessing the distal femur, proximal tibia, and fibula (see Fig. 2.1a). If the radiograph is obtained during weight-bearing, it can show joint space narrowing due to cartilage loss. The flexed **posteroanterior (PA)** standing view, with the X-ray beam directed parallel to the tibial plateau, is more sensitive than the AP view to detect cartilage loss over the posterior weight-bearing femoral condyles [1] (see Fig. 2.1b). The

flexed PA view is similar in appearance to the **tunnel view**, which is usually done supine. The tunnel view shows the intercondylar notch well and is valuable for diagnosing intercondylar osteophytes and osteochondritis dissecans.

The standard **lateral view** is taken with the knee slightly flexed, but the angle of flexion can be difficult to control [2]. **In extension** (see Fig. 2.2a), the **lateral view** is more reproducible than in flexion, but patients can have difficulty fully extending the knee. On a good lateral view, the femoral condylar contours should overlap (see Fig. 2.2b).

Fig. 2.1 Comparison X-rays of the same knee. The standing anteroposterior (AP) view in extension (a) is not as sensitive as standing posteroanterior (PA) view at 45° flexion with the X-ray beam directed parallel to the tibial plateau (b) to detect cartilage loss in the medial compartment



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Definitions

Blumensaat line (intercondylar line) is a line that can be drawn on a lateral X-ray of the knee [3]. It corresponds to the roof of the intercondylar notch. At 30° knee flexion, the Blumensaat line should intersect the inferior pole of the patella. It can be used to define the femoral attachment point of the medial patellar femoral ligament [4, 5]. It is a guide to the femoral attachment points of the anterior and posterior cruciate ligaments (*see* Fig. 2.3).

The **internal oblique view** is done with the patient sitting and the X-ray beam directed toward the tibial tuberosity. This view helps to visualize the patellofemoral joint and the

anterior tibial tuberosity in patients with suspected Osgood-Schlatter disease (*see* Fig. 2.4).

Sunrise and **skyline** views are imprecise terms for an axial radiograph taken with the X-ray beam tangential to the patellofemoral compartment and parallel to the long axis of the lower leg. The **Merchant view** is an axial projection of the patella with the knee flexed 45° (*see* Fig. 2.5a). The **tangential view** of the patella with the knee flexed 30° reproduces the knee angle that is clinically significant, but it is more difficult to obtain compared to the Merchant view (*see* Fig. 2.5b).

Leg length AP images are full-length standing radiographs of the pelvis and lower extremities. They are used to evaluate the articular alignment and length discrepancies of the lower extremities. If the pelvis is included, it also provides information about spinal curvature and pelvic obliquity (*see* Fig. 2.6).



Fig. 2.2 Comparison lateral X-rays of the same knee. **(a) Extension.** Easy to align to obtain a true lateral view, but not always possible to extend knee after trauma. **(b) 30° flexion.** Hard to align the knee for

true lateral, but better to show height of patella. The image is taken correctly when the outlines of the femoral condyles overlap

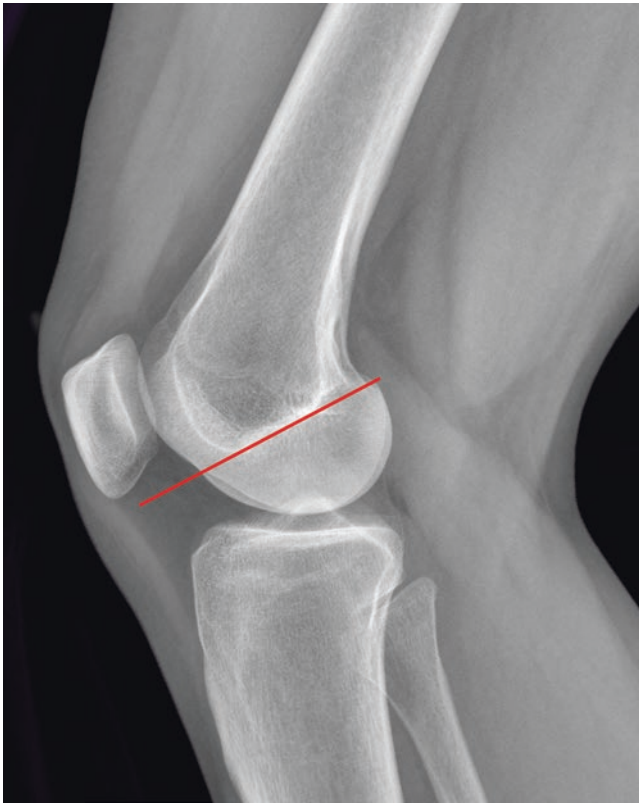


Fig. 2.3 Blumensaat line (red) is a line that can be drawn on a lateral X-ray of the knee. It corresponds to the roof of the intercondylar notch



Fig. 2.4 Internal oblique X-ray view of knee. Useful to evaluate tibial tuberosity, such as in Osgood-Schlatter disease. The femoral condyles are misrepresented in this view

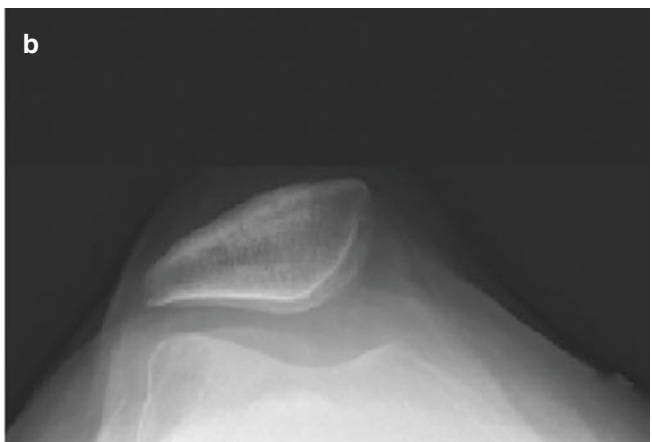
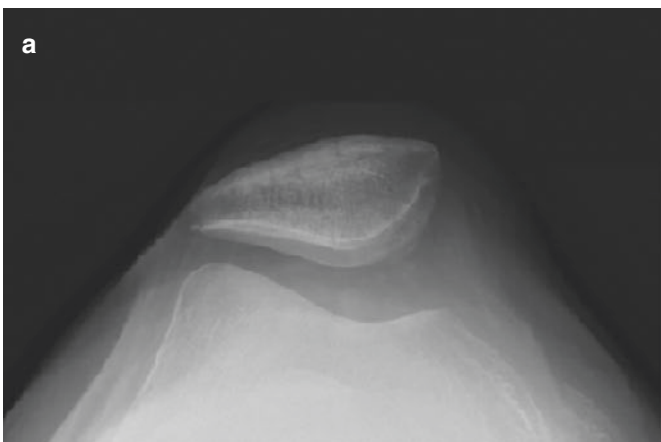


Fig. 2.5 (a) The **Merchant view** is an axial projection of the patella with the knee flexed 45°. (b) The **tangential view** of the patella with the knee flexed 30° reproduces the knee angle that is clinically significant, but it is more difficult to obtain than the Merchant view



Fig. 2.6 The anteroposterior (AP) projection **full-length standing radiograph** is used to evaluate the limb alignment and length. If the pelvis is included, it also provides information about spinal curvature and pelvic obliquity

2.2 Computed Tomography (CT)

Computed tomography (CT) uses ionizing radiation to produce both two- and three-dimensional images. It best depicts cortical bone but also shows trabecular bone and some soft tissues. The CT examination is usually performed in a supine patient without contrast material.

Direct injection of iodinated contrast material (**CT arthrogram**) outlines the synovial capsule and intraarticular structures, fills chondral defects, and flows into meniscal tears (see Fig. 2.7).

Dedicated 3D-printed surgical guide systems can help plan surgery (see Figs. 2.8 and 2.9).

CT three-dimensional (3D) **volume rendering** is a valuable tool for analyzing surface morphology (see Fig. 2.10). It can be used to create a 3D model for surgical planning, allowing the surgeon to simulate osteotomy and osteoplasty interventions.

Spatial reconstruction of the knee joint can focus on visualization of the bones (see Fig. 2.11) or soft tissues (see Fig. 2.12). Spatial reconstruction can be used to isolate a particular structure (see Fig. 2.13).

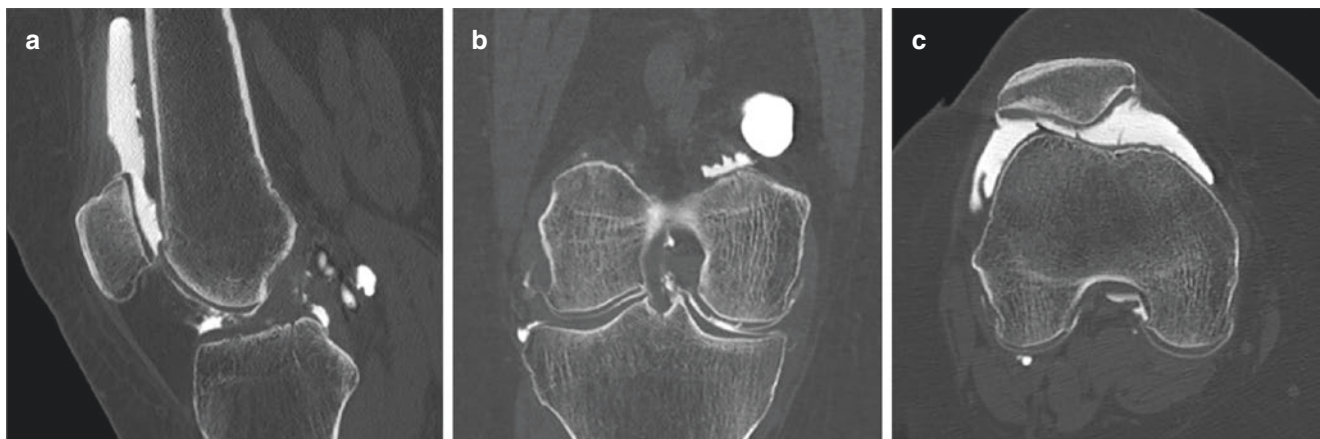


Fig. 2.7 Computed tomography (CT) **arthrogram**. A multiplanar (MPR) reconstruction from CT scans of the knee joint following direct contrast administration into the knee joint. Very good representation of

the structural makeup of the bone, outlining the cartilage and menisci damage. The evaluation of soft tissues structure is not possible. (a) Sagittal view. (b) Coronal view. (c) Axial view

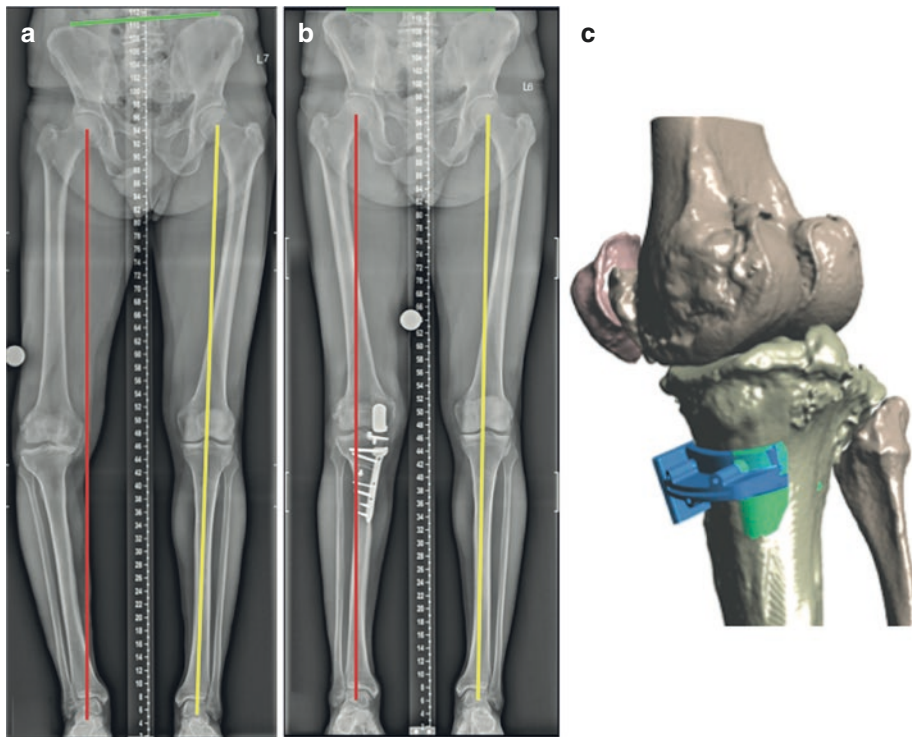


Fig. 2.8 3D models can be created from CT scans. (a) Limb alignment X-ray before high tibial osteotomy (HTO). (b) Alignment 6 months postop HTO. (c) Dedicated **3D-printed surgical guide** system that was used to plan HTO

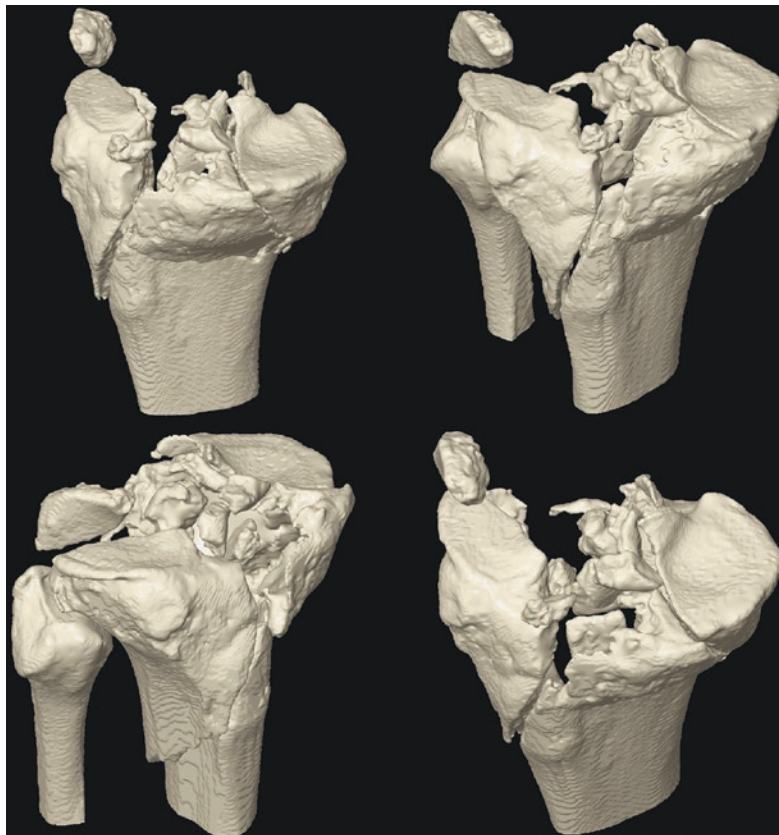


Fig. 2.9 Digital model of a comminuted tibial fracture that was created from a CT scan to simulate the fracture and plan internal fixation

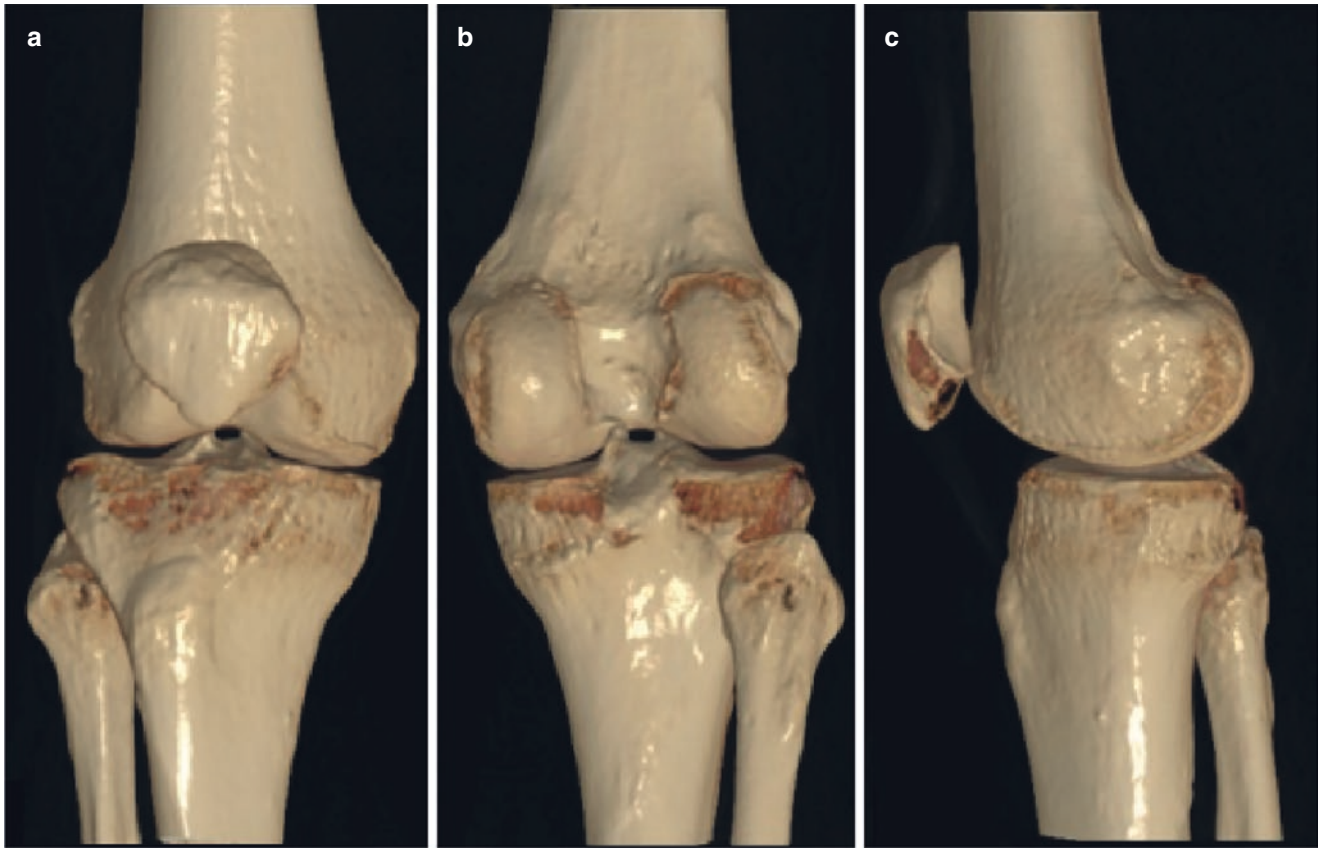


Fig. 2.10 CT 3D volume rendering of the knee joint. (a) Anterior. (b) Posterior. (c) Medial



Fig. 2.11 Spatial reconstruction of the knee joint focused on bones. Perspective looking down on the patellofemoral joint



Fig. 2.12 Spatial reconstruction of the knee joint focused on soft tissues visualization. Perspective looking down on the patellofemoral joint. 1. Patellar tendon. 2. Quadriceps tendon. 3. Medial head of the quadriceps muscle. 4. Medial collateral ligament. 5. Fibular collateral ligament. 6. Medial meniscus. 7. Lateral meniscus. 8. Vastus lateralis muscle

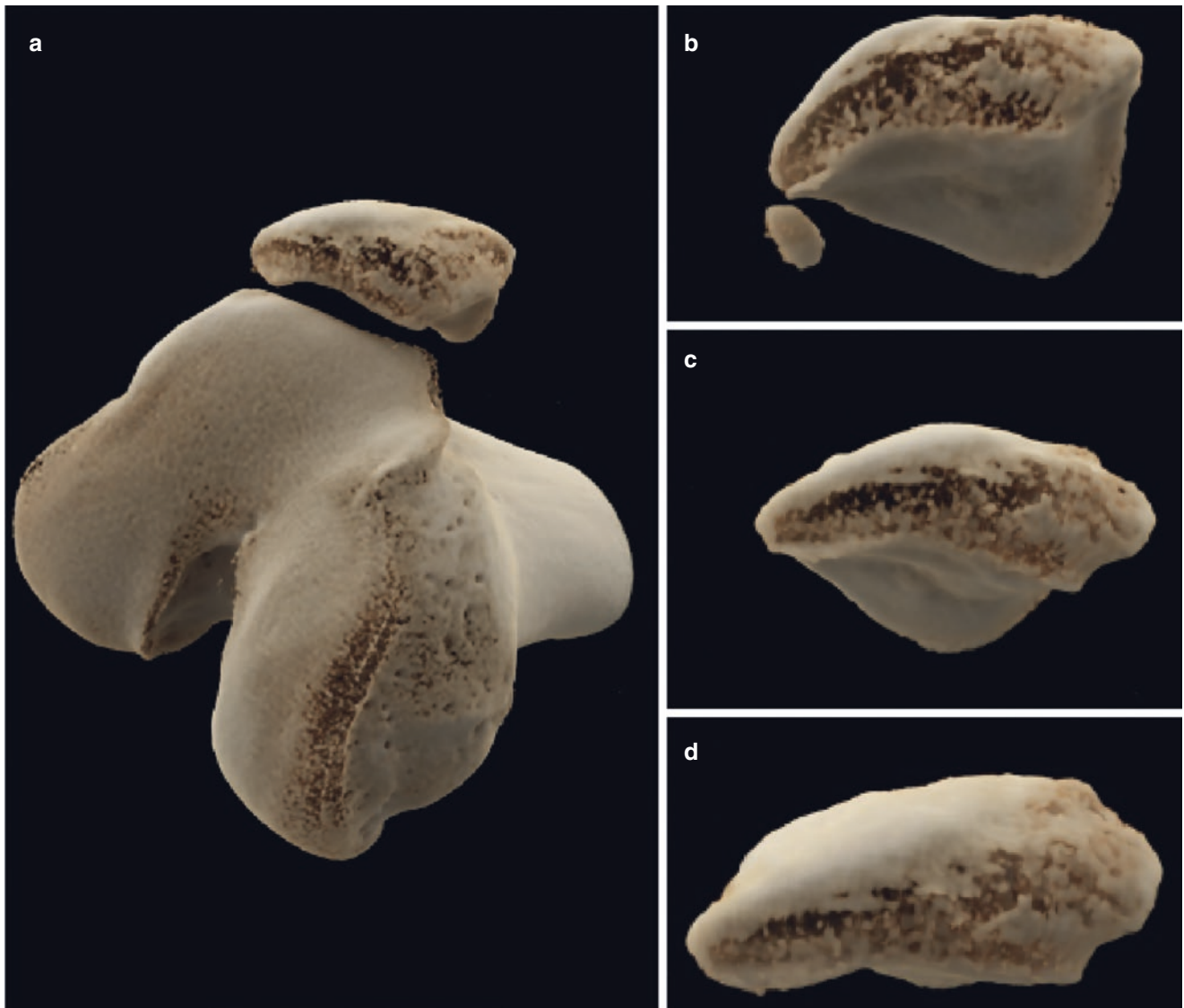


Fig. 2.13 Spatial reconstruction can be used to assess a particular structure. The extracted structure can be moved freely and assessed from different angles, as well as sliced at any level to evaluate its inter-

nal structure. (a) Spatial rendering of the patellofemoral joint seen from below after the removal of tibia for better visualization. (b–d) Patella extracted from the scan viewed from different angles

2.3 Magnetic Resonance Imaging (MRI)

Magnetic Resonance Imaging (MRI) has the advantage of using magnetic field rather than ionizing radiation to produce detailed images of bone marrow and soft tissues [6].

Interesting Developments

Recently developed reformatting methods allow MRI images to be converted into CT scan-like images. This methodology will allow for 3D modelling similar to CT [7, 8].

MRI tracks hydrogen nuclei (*protons*). Hydrogen is widely present within the body. It comprises water and is present in hydrogen-containing compounds, such as fat. Different chemical compounds and hydrogen-based tissues have different particle lengths. They produce different signals and, therefore, different MRI images. Therefore, a weakness of MRI is visualization of cortical bone due to paucity of hydrogen/protons.

When the body is placed in a strong **magnetic field**, such as an MRI scanner, the axes of the protons line up. The uniform alignment creates a magnetic vector that is oriented along the axis of the MRI scanner.

MRI scanners come in different field strengths, such as 1 Tesla (T), 5 T, 3 T, and even in 7 T. At high field strengths, increased signal enables increased spatial resolution and anatomical detail [9]. A **coil** dedicated to a given examination region is placed over the knee. Coils allow to focus the electromagnetic waves.

Examples of anatomical structures of the knee as shown in MRI are shown in Figs. 2.14 (coronal), 2.15 (sagittal), and 2.16 (axial) views.

2.3.1 Contrast-Enhanced MRI

To enhance MRI images of the knee, it is possible to administer a contrast agent into the knee directly or indirectly.

Indications for Contrast-Enhanced MRI

- *With intravenous contrast*—focal lesions, inflammation, avascular necrosis/ischemic changes
- *With intraarticular contrast*—internal knee joint assessment, often used in cases of previously traumatized joint, helpful in re-injury/secondary meniscal lesions detection, and post-operative healing assessment (as an alternative to a second-look arthroscopy) [10].

2.3.2 Indirect MR Arthrogram

Intravenous administration of contrast improves visualization of tissues that have abnormal structure. This is useful to differentiate between inflammatory lesions and tumors and to evaluate the structure of cartilage (most often used in clinical trials) [11]. Contrast that is injected intravenously eventually absorbs into the synovial fluid. Exercise increases the signal intensity in the joint and improves the contrast for soft tissues. However, the image quality is poor compared to the direct arthrography, so it is not commonly ordered. Intravenous administration of contrast improves visualization of tissues that have abnormal structure. This is useful to differentiate between inflammatory lesions and tumors and to evaluate the structure of cartilage (most often used in clinical trials) [11]. Contrast that is injected intravenously eventually absorbs into the synovial fluid. Exercise increases the signal intensity in the joint and improves the contrast for soft tissues. However, the image quality is poor compared to the direct arthrography, so it is not commonly ordered (*see* Fig. 2.17).

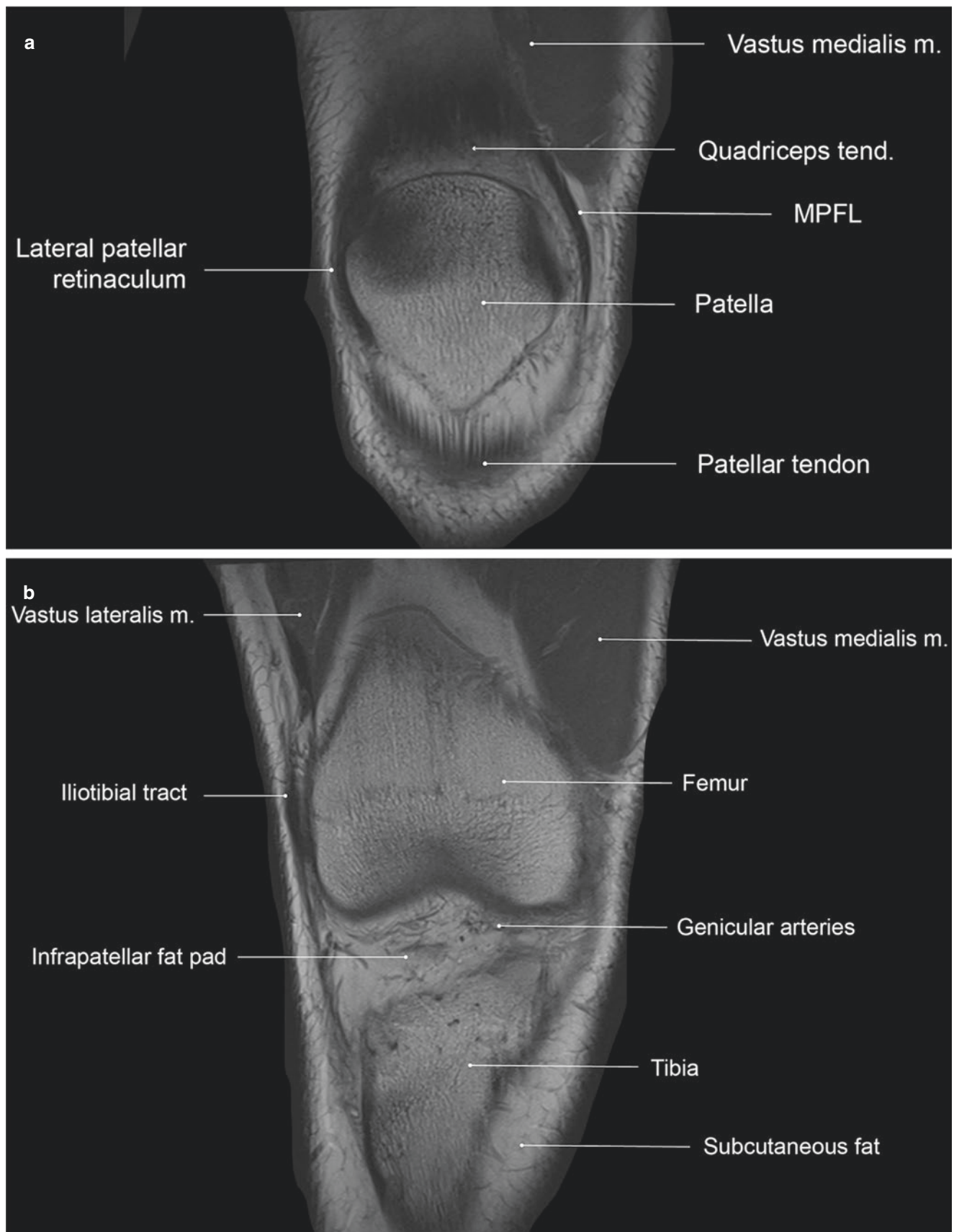


Fig. 2.14 (a–g) Coronal view knee MRI images

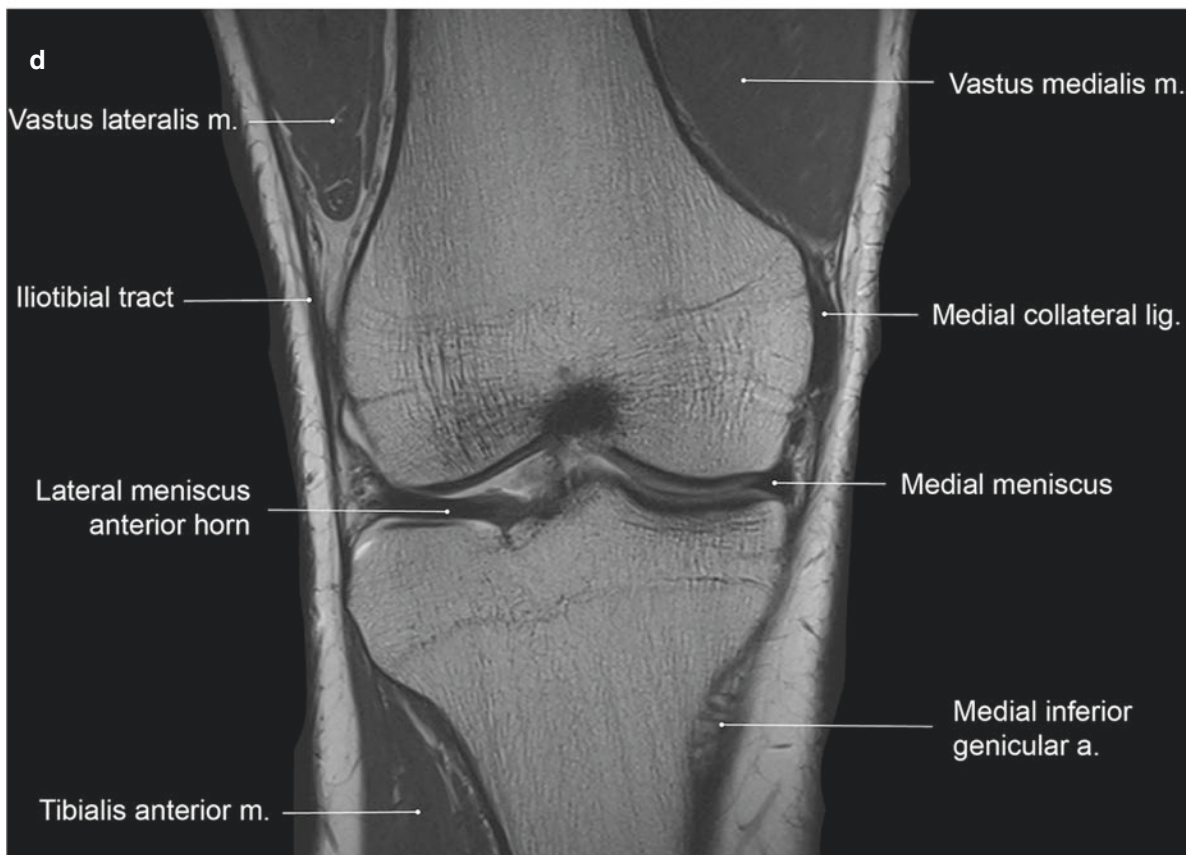
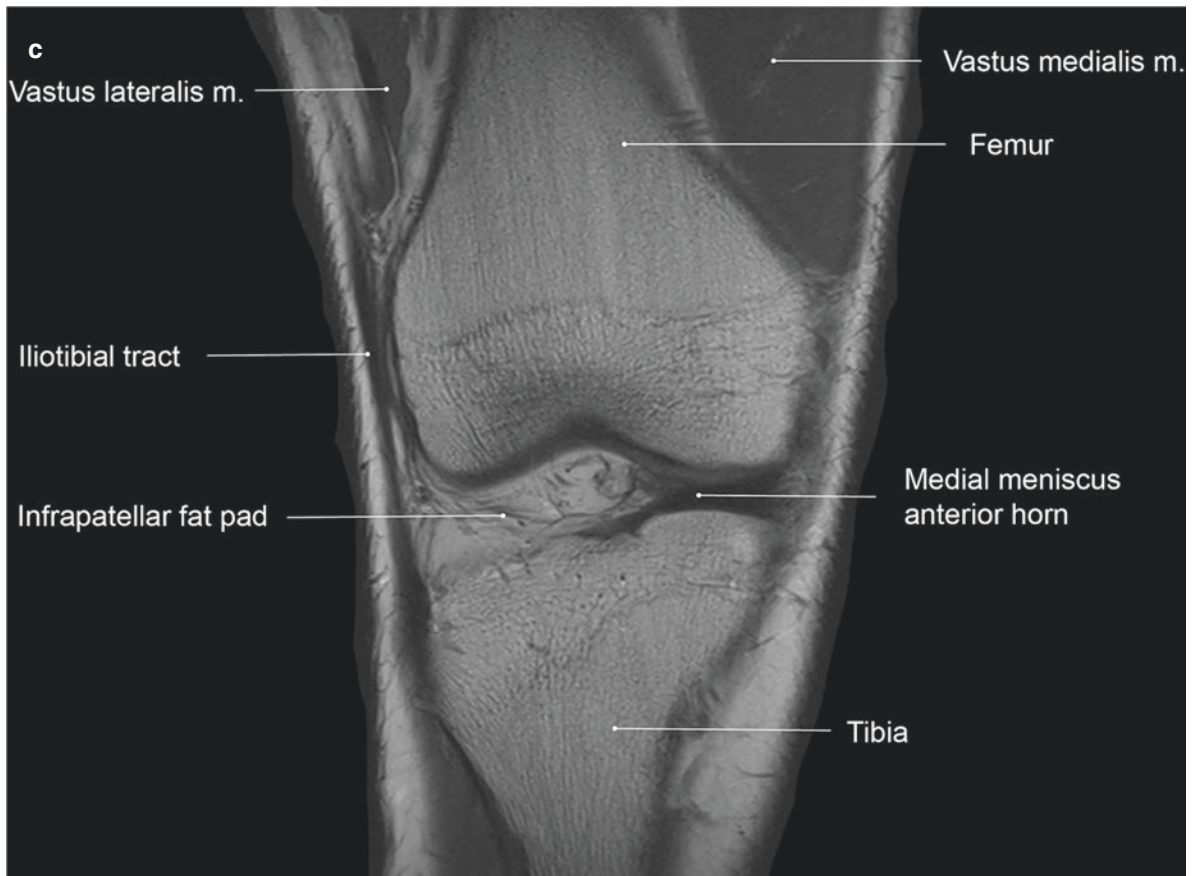


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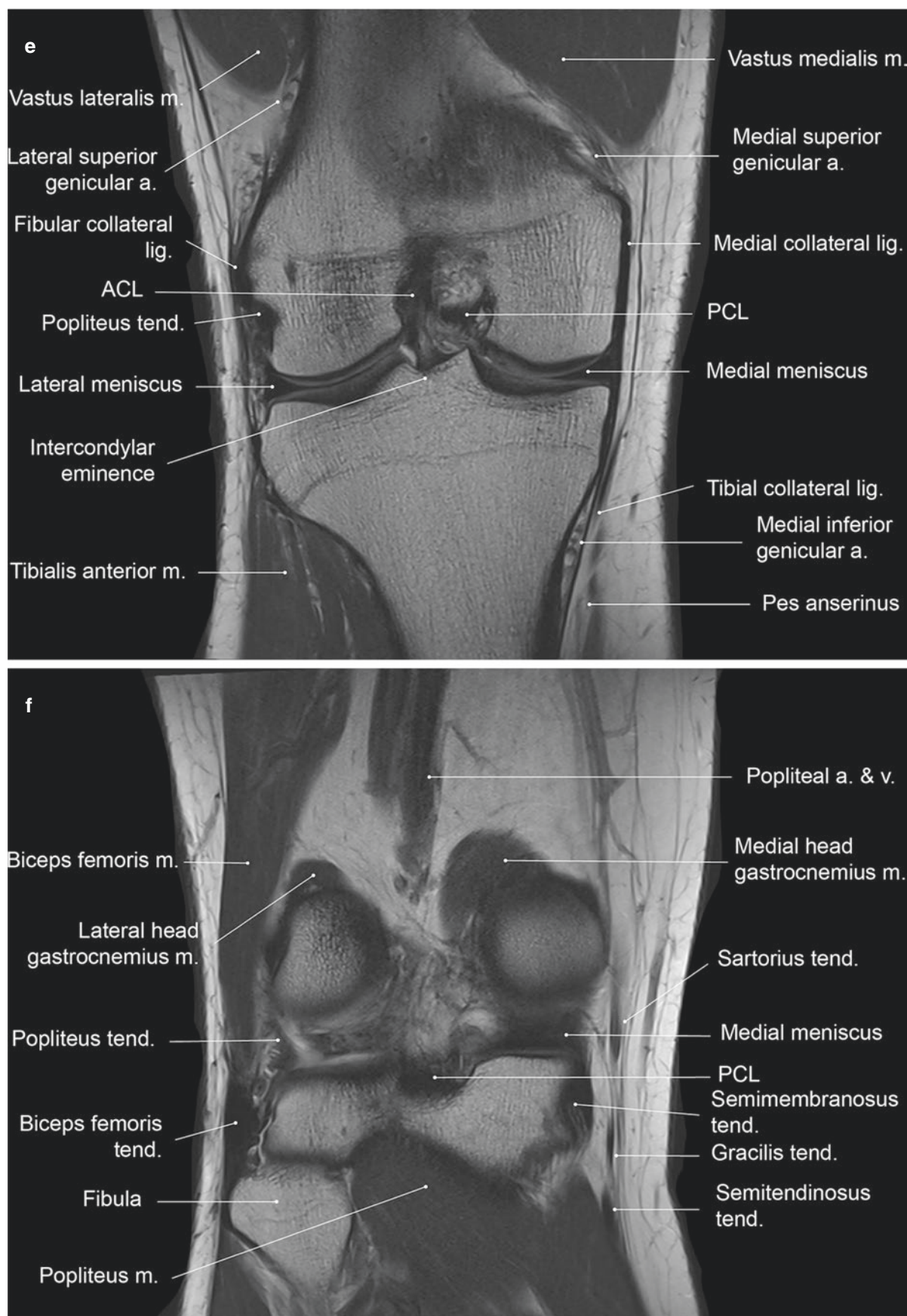


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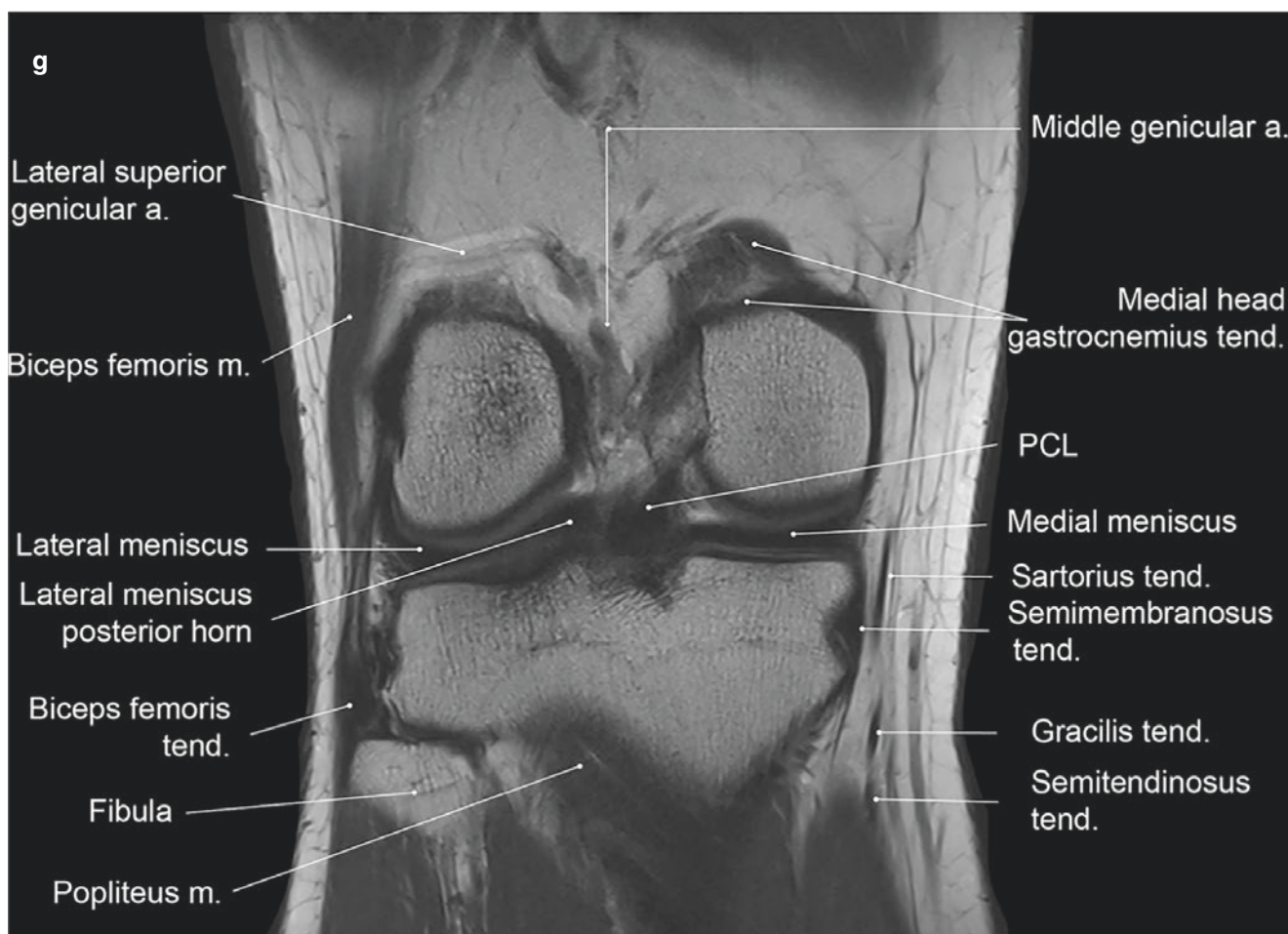


Fig. 2.14 (continued)

2.3.3 MR Arthrogram

Intraarticular injection of the MRI contrast agent (diluted gadolinium contrast) gives better visualization of cartilage lesions and other tissues. The contrast solution increases the signal

intensity (brightness) of intraarticular fluid (T1, T1 fat sat, PD), which can fill damaged articular cartilage or menisci providing better detection and/or more detailed assessment of the extent of damage (*see* Fig. 2.18). With improvements in conventional MRI, the current role of MR arthrography is extremely limited.

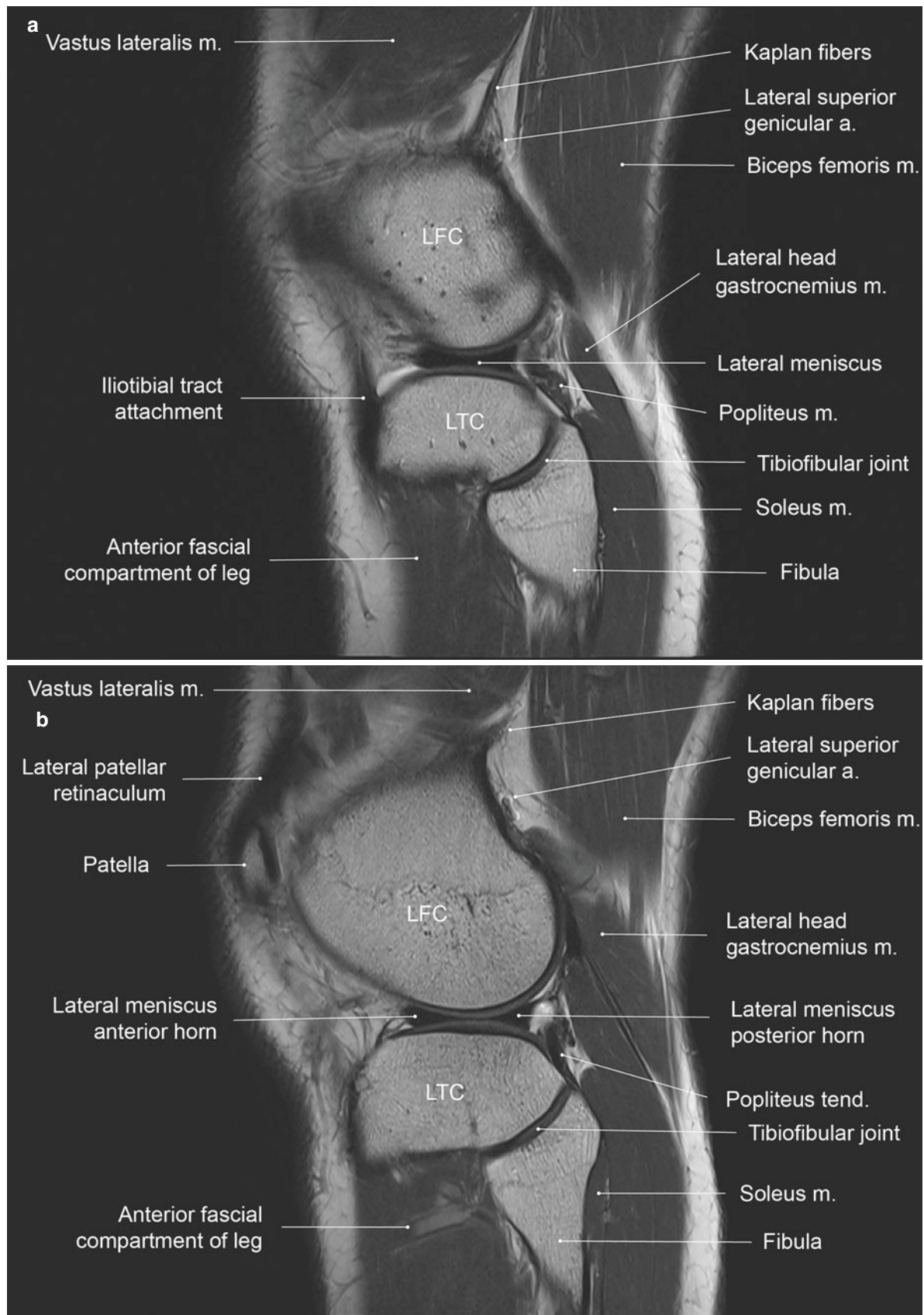


Fig. 2.15 (a–h) Sagittal view knee MRI images

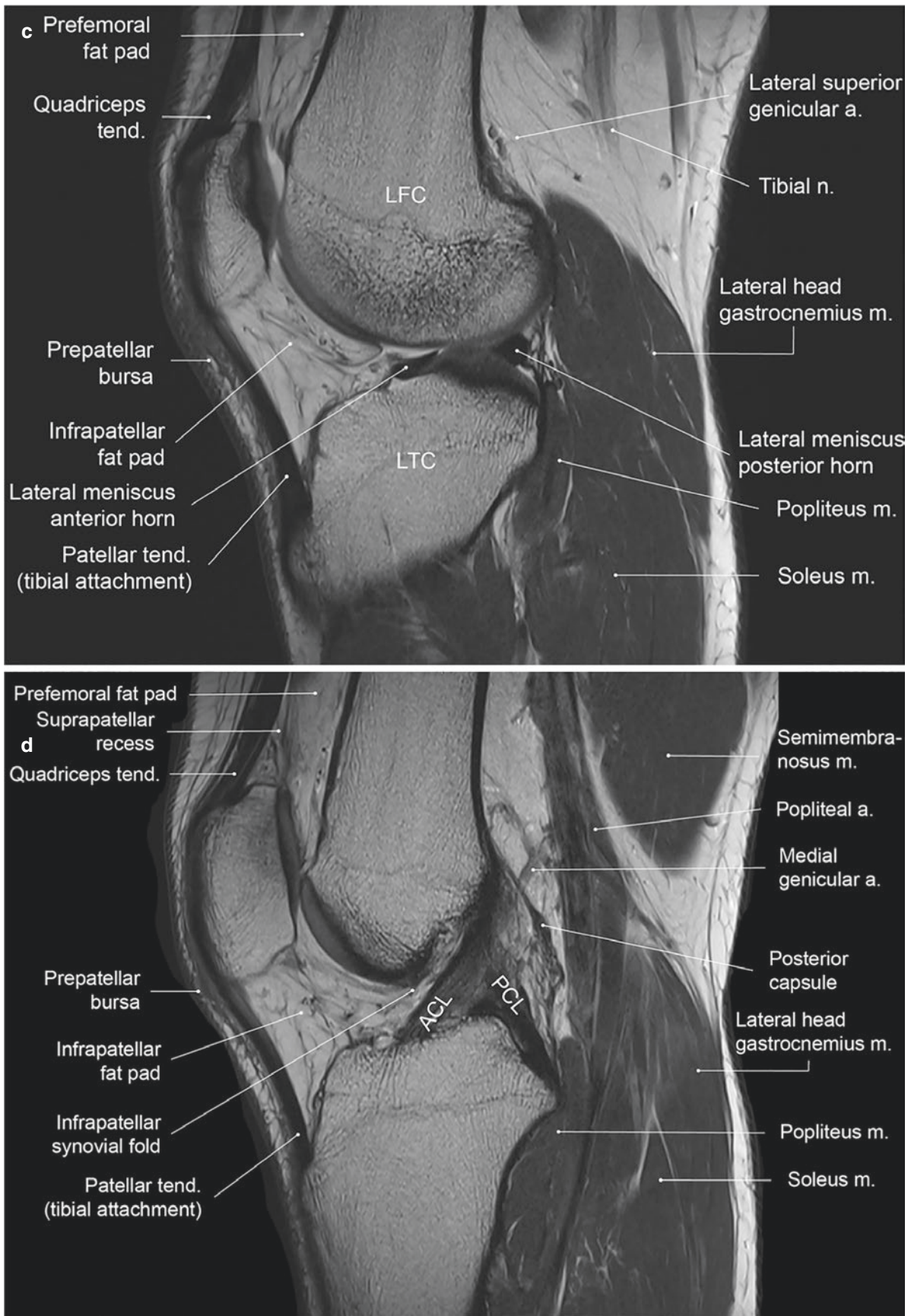


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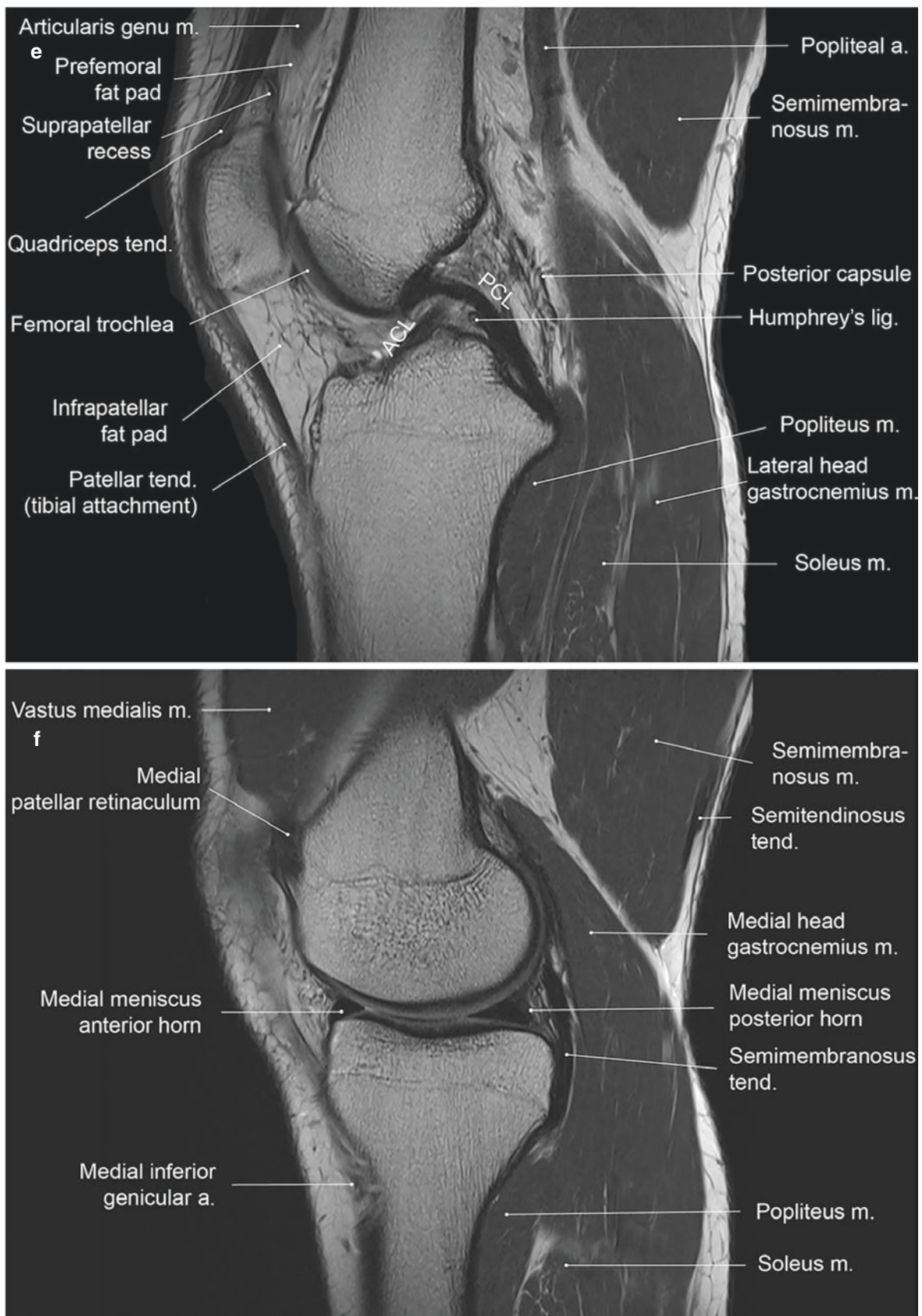


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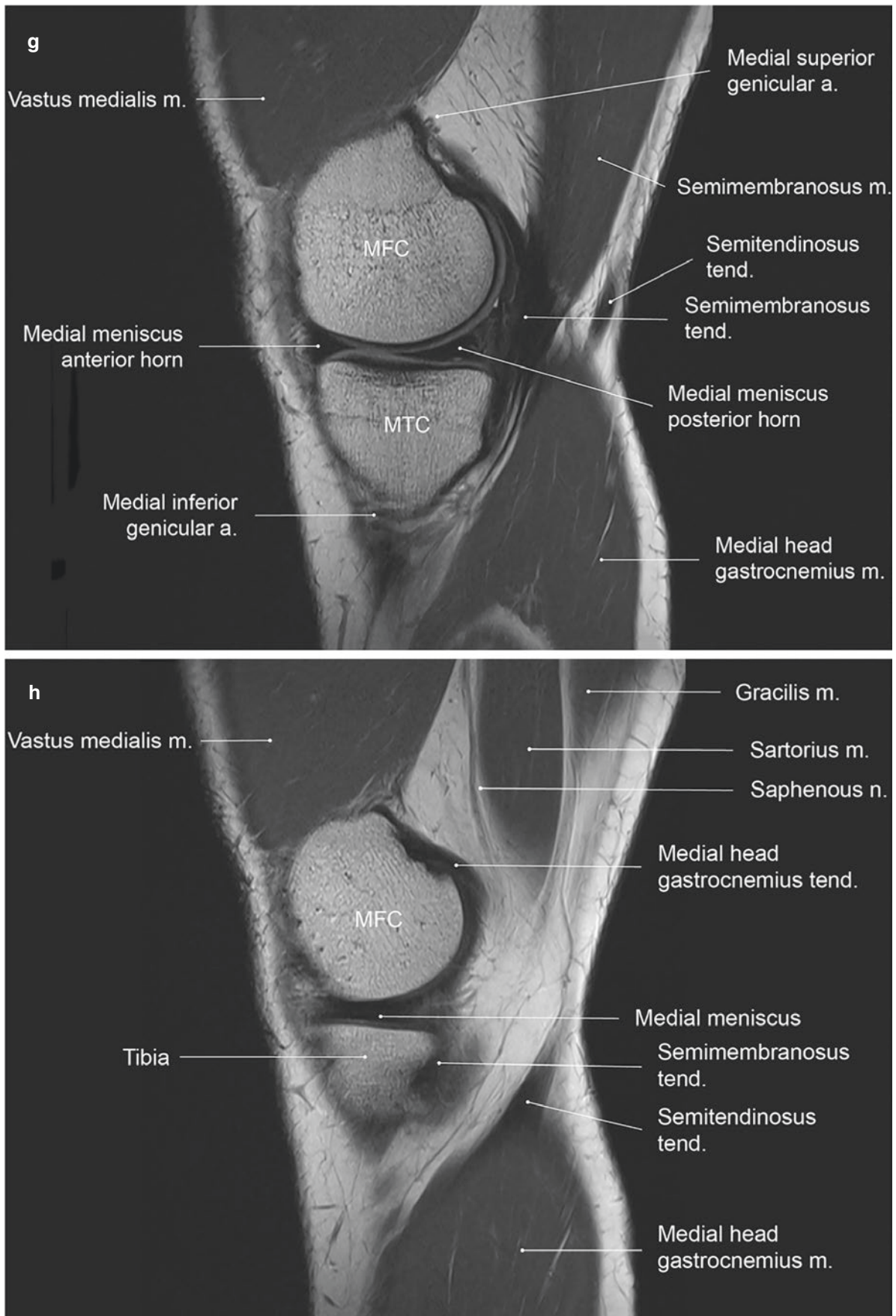


Fig. 2.15 (continued)

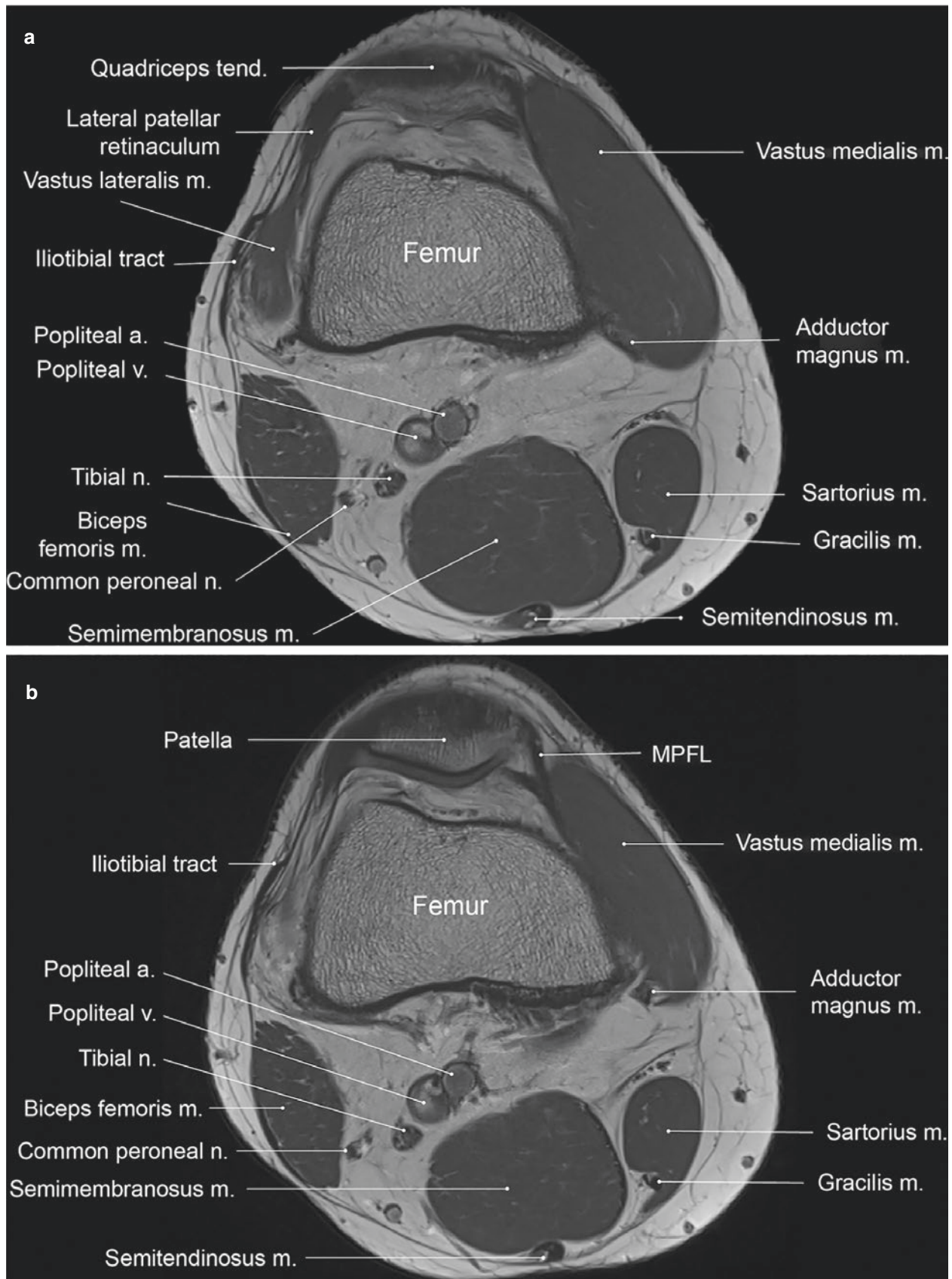


Fig. 2.16 (a–g) Axial view knee MRI images

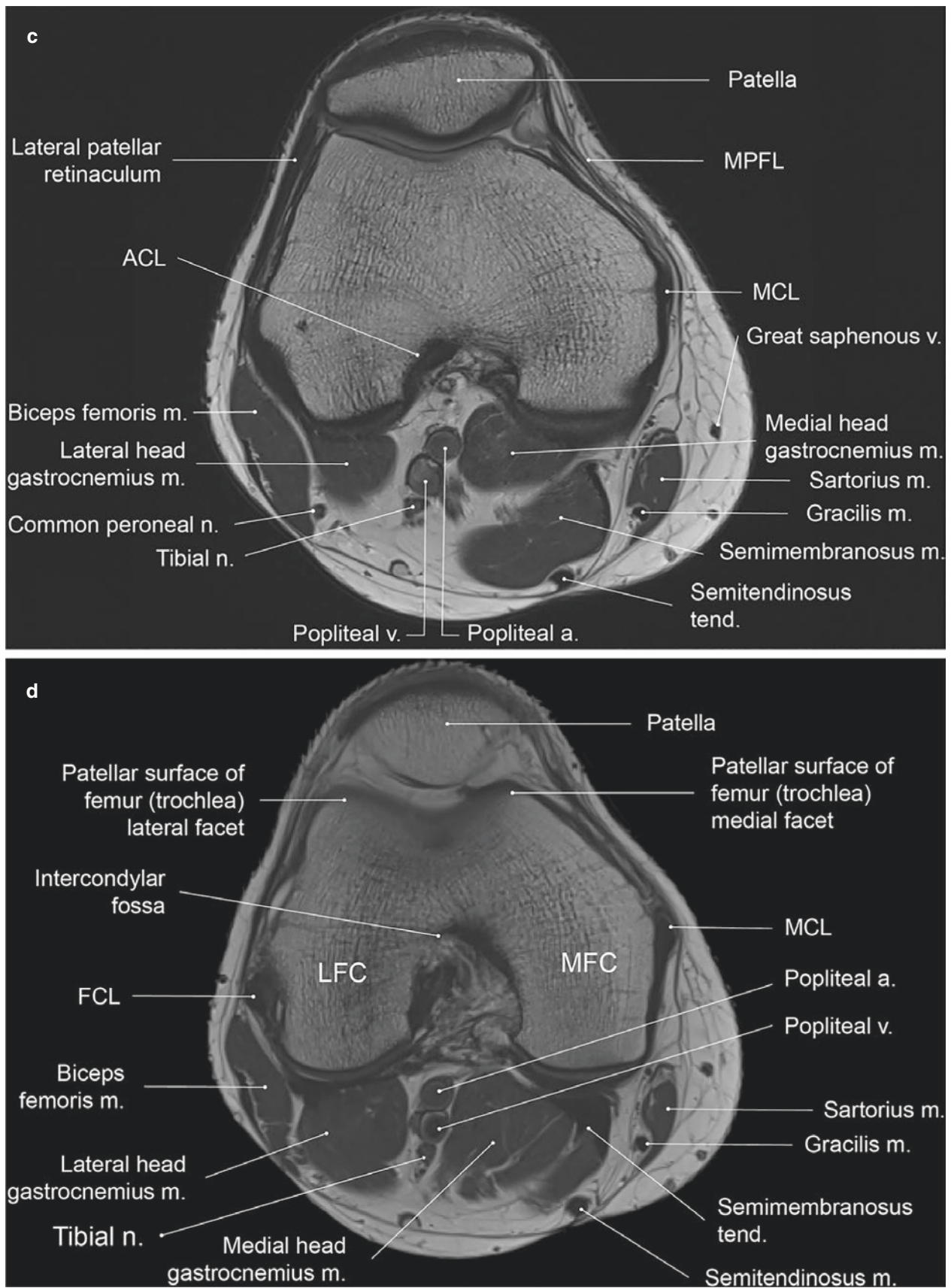


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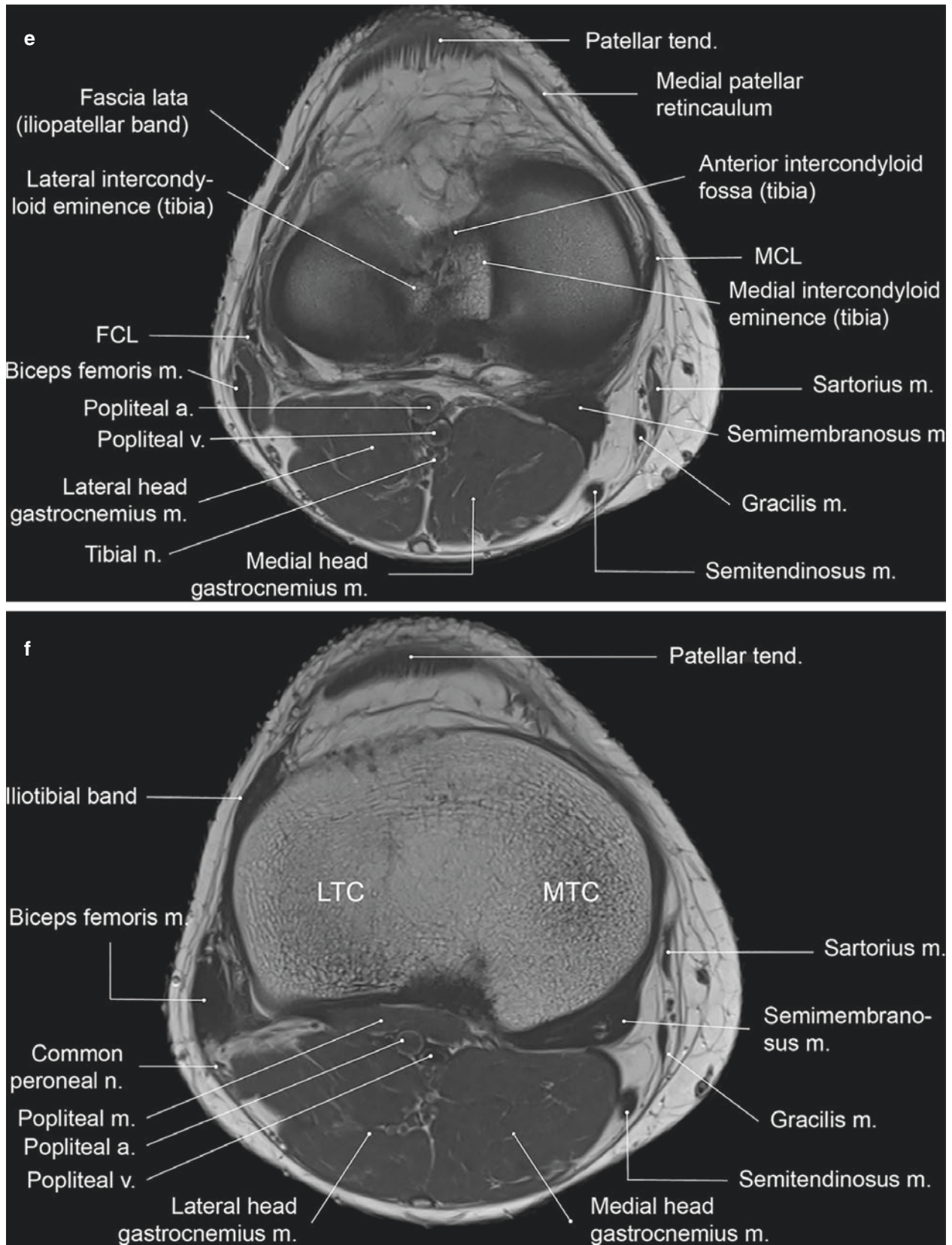


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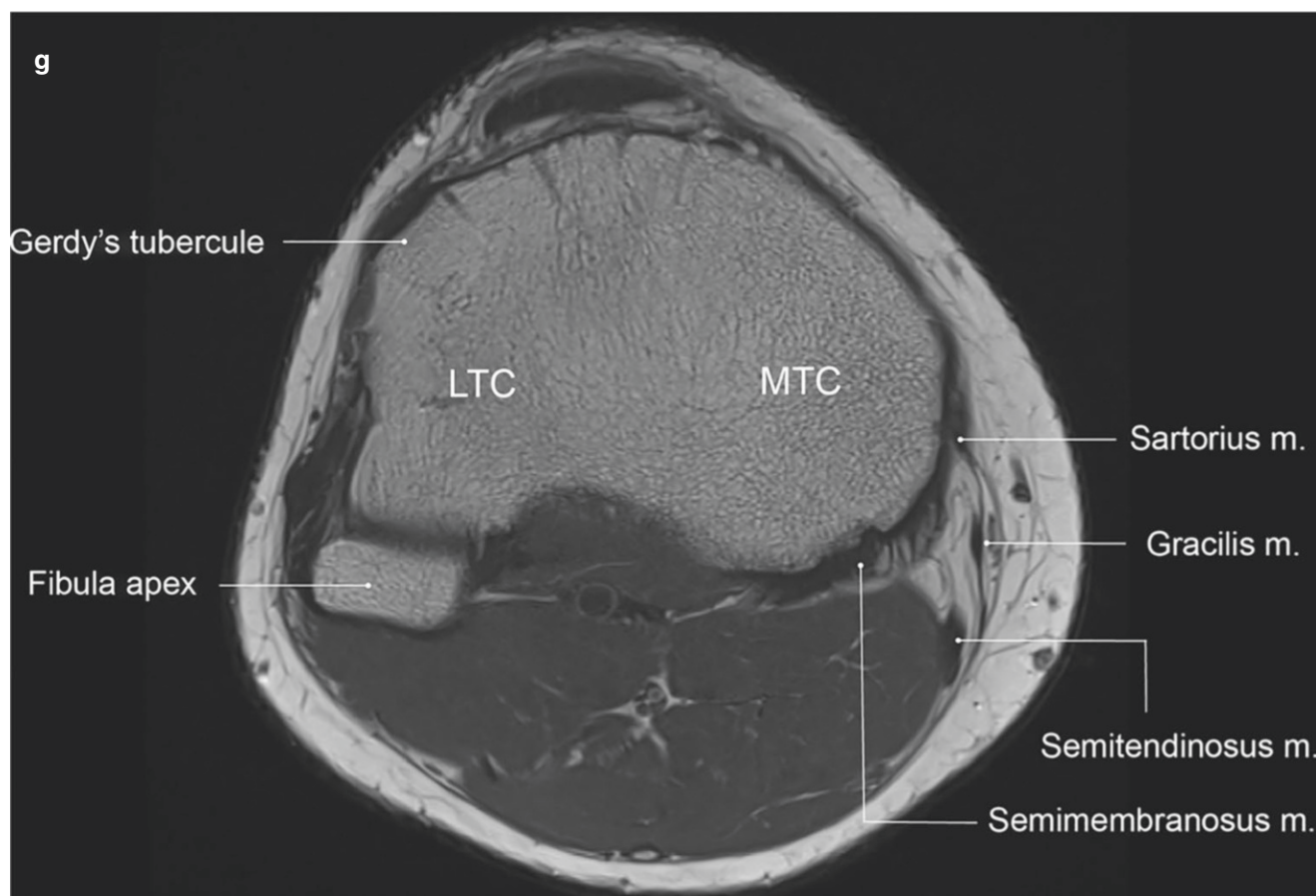


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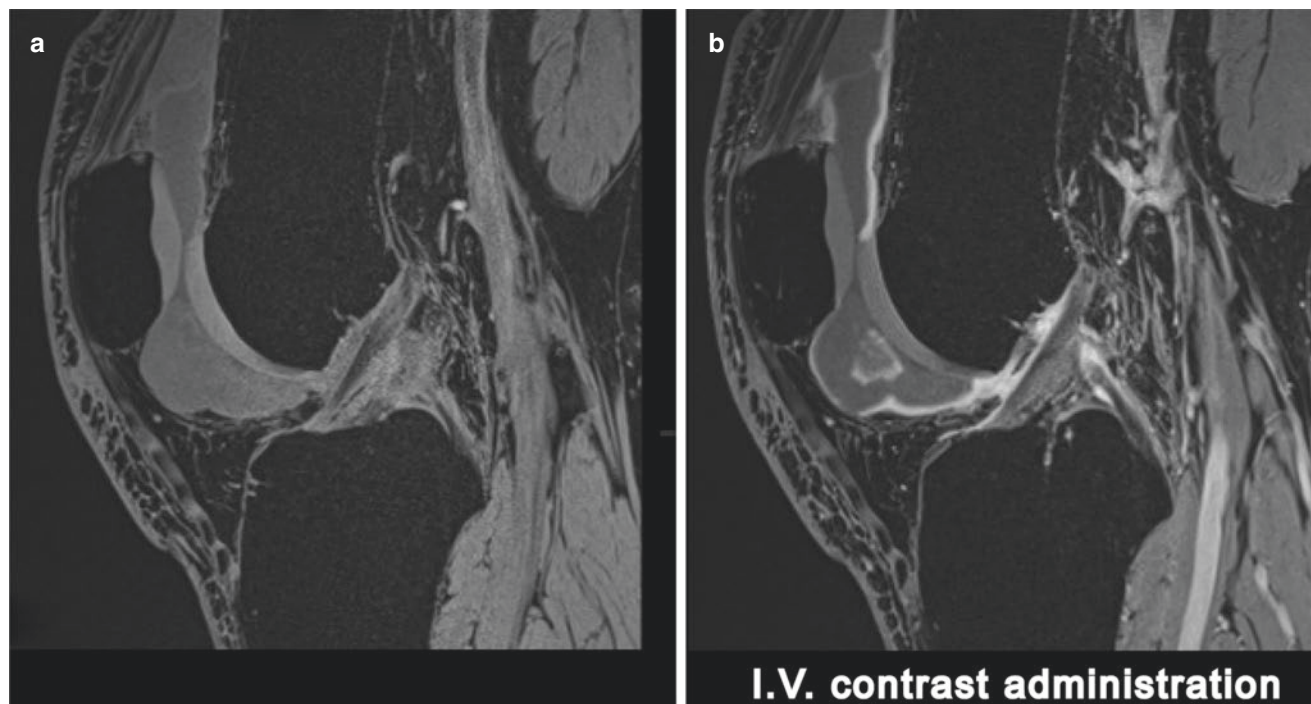
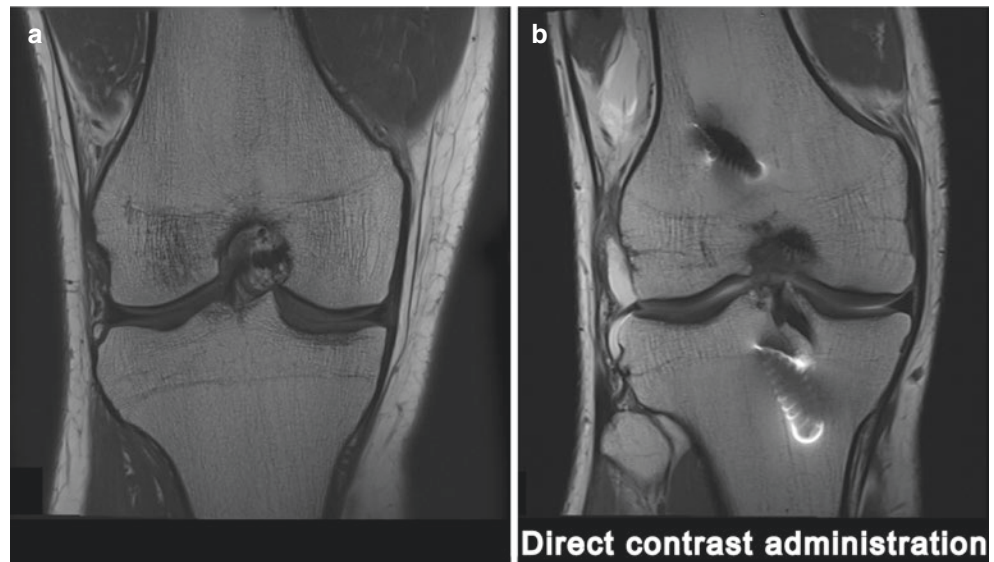


Fig. 2.17 Indirect MR arthrogram with intravenous contrast administration. (a) **T1-weighted** image (fat is black) before contrast administration, tissues within the joint are visible, with a fairly homogeneous color ranging from gray to black. (b) Image **following intravenous**

administration of a contrast agent, distinct strengthening of the inflamed synovium becomes white and non-uniform enhancement within the focal lesion in the infrapatellar fat pad is visible in case of this patient (changes characteristic on the course of chondromatosis)

Fig. 2.18 Direct knee arthrography (MR arthrogram). (a) T1-weighted coronal images. (b) Same slice following direct intraarticular contrast administration. Contrast administration results in the change of the synovial fluid's color to white, offering a better contrast between the fluid and tissues



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Suggested Readings

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3.1 Capsule

The articular capsule of the knee (*capsula articularis*; *capsular ligament*) is complex. It blends with the ligaments and retinacula, so it is difficult to define as a separate structure. The capsule envelopes the knee joint and is attached to the bones close to the articular surfaces.

Anterior knee capsule: The patella replaces the capsule in the anterior knee. Anteromedially and anterolaterally, the capsule fuses with the patellar retinacula which attach to the medial and lateral edges of the patella, respectively (see Fig. 3.1). The capsule anteromedially and anterolaterally is thin to allow knee flexion (see Fig. 3.2).

Medial knee capsule: The capsule anteromedially is strengthened and partly blended with the medial patellar retinaculum to help stabilize the patella (refer to Chap. 4). The **middle third** of the **medial capsule** is thick and strong to provide sideways stability to the knee. The middle third is also called the “**deep medial collateral ligament**” [1]. The posterior third is again thick to limit hyperextension of the knee. It blends with the posterior fibers of the tibial collateral ligament and deep fascia (see Fig. 3.3, refer to Chap. 6).

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In a vertical direction, the articular capsule of the knee has **menisco-femoral** and **menisco-tibial** portions. The menisco-tibial part of the capsule is also called the coronary ligament (see Fig. 3.4).

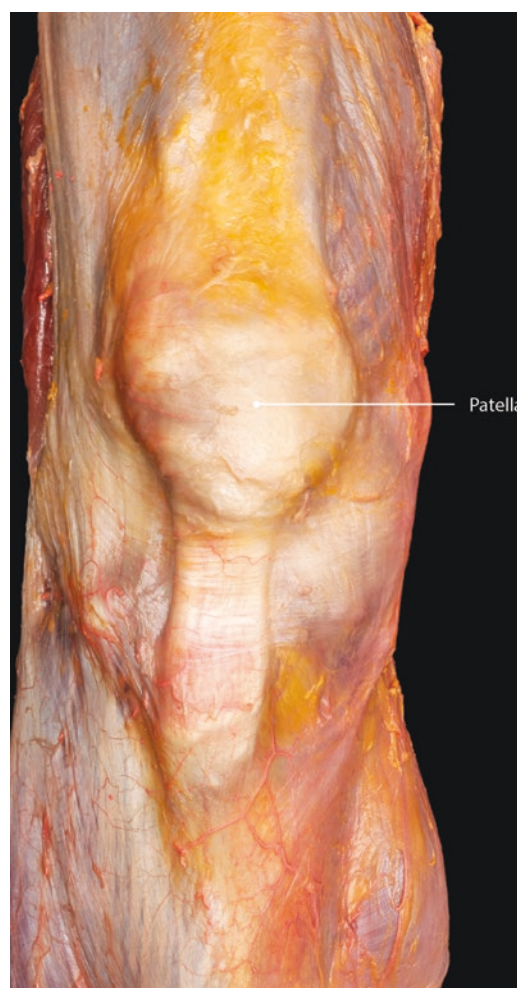


Fig. 3.1 Right knee. The medial and lateral patellar retinacula fuse with the capsule anteriorly to attach to the edges of the patella

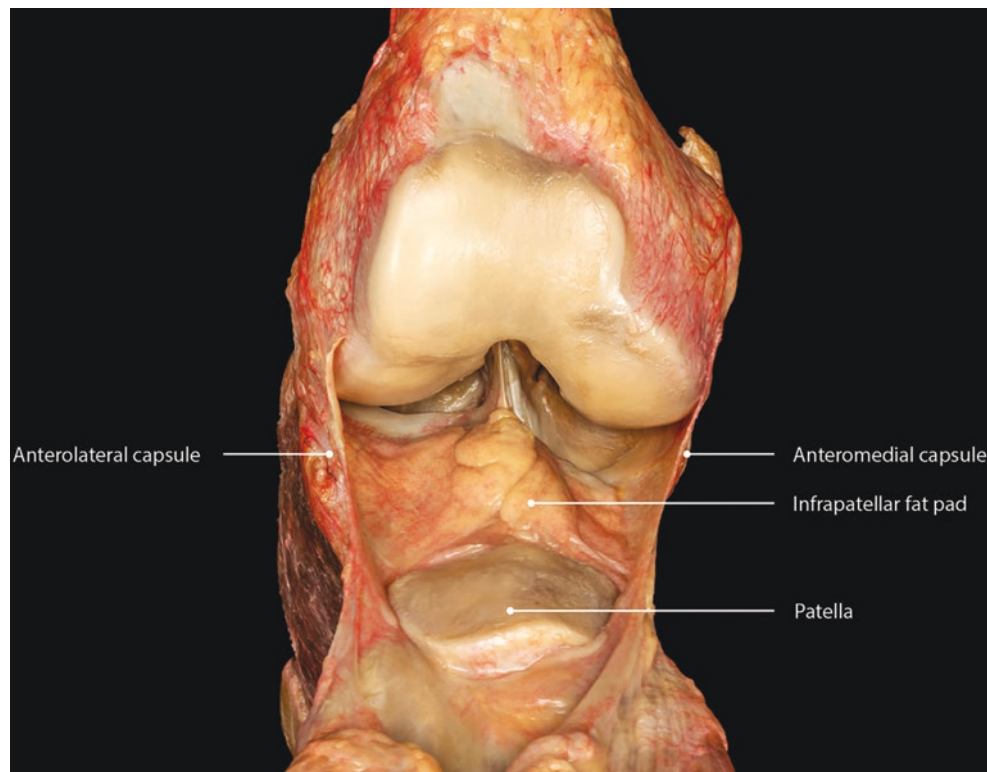


Fig. 3.2 Right knee, anterior aspect, with patella flipped down. The anteromedial and anterolateral capsules are thin to allow knee flexion

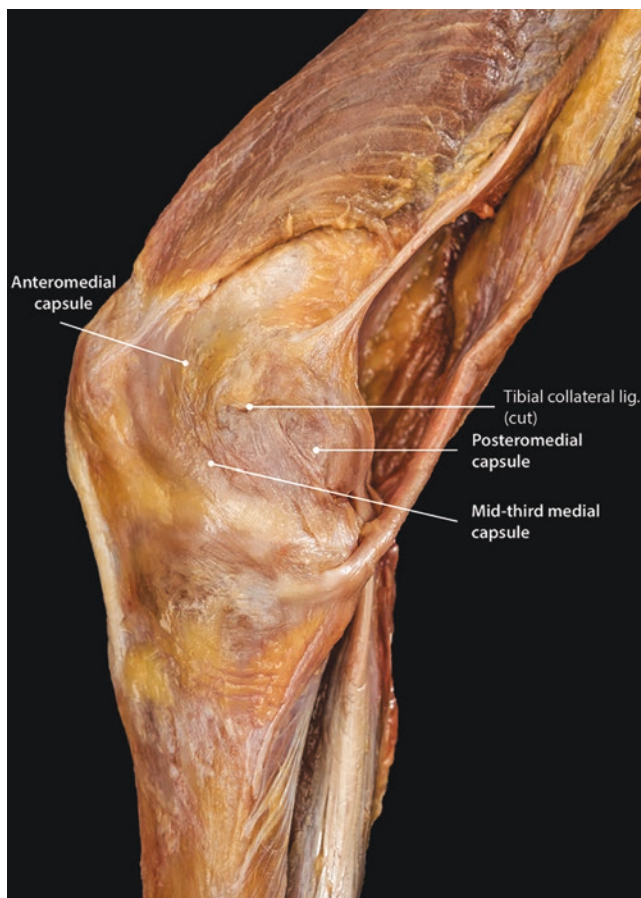


Fig. 3.3 Right knee, medial articular capsule

The term **medial collateral ligament** refers to a functional, not anatomic, unit. It is composed of a superficial part (**tibial collateral ligament**) and a deep part (**mid-third medial capsule**).

Lateral knee capsule: The anterior and middle thirds of the lateral capsule are thin. The posterior third is thick (*see Fig. 3.5*). The popliteus tendon pierces the capsule at the junction of the middle and posterior thirds of the lateral meniscus. The lateral capsule is separated from the fibular collateral ligament (FCL). The FCL is located posterior to the midline (*refer to Chap. 7*).

Posterior knee capsule: The posterior capsule is thick and strong to resist hyperextension. There are two named portions of the posterior capsule: the **oblique popliteal ligament** (a continuation of the insertion of the semimembranosus tendon) and the **arcuate ligament** (which forms an arch over the popliteus tendon as it enters the joint) (*refer to Chap. 8*) (*see Fig. 3.6*). The posterior capsule encloses the two femoral condyles (*see Figs. 3.7 and 3.8*).

The posteromedial capsule commonly has an opening of varying size that connects the knee joint to the gastrocnemius-semimembranosus bursa. The capsular opening can act as a one-way flap valve. Synovial fluid from the knee can then be pushed into the bursa and build up under pressure causing a popliteal (Baker's) cyst (*see Fig. 3.9*).

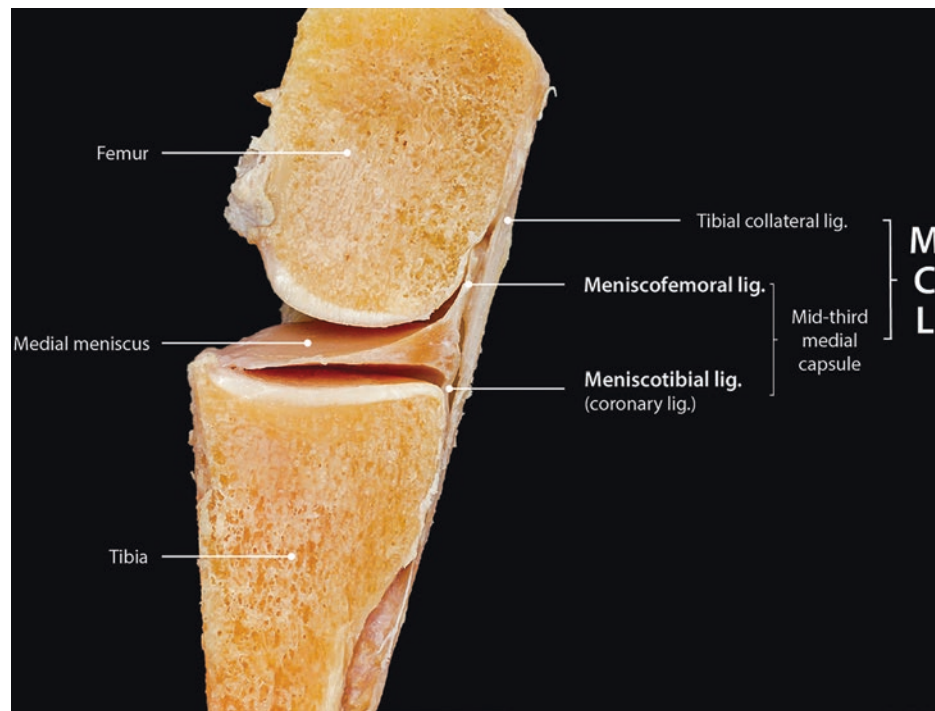


Fig. 3.4 The articular capsule has **meniscofemoral** and **menisco-tibial** portions. The menisco-tibial part of the capsule is also called the coronary ligament. The **medial collateral ligament (MCL)** is a func-

tional unit that has a superficial part (**tibial collateral ligament**) and a deep part (**mid-third medial capsule**)

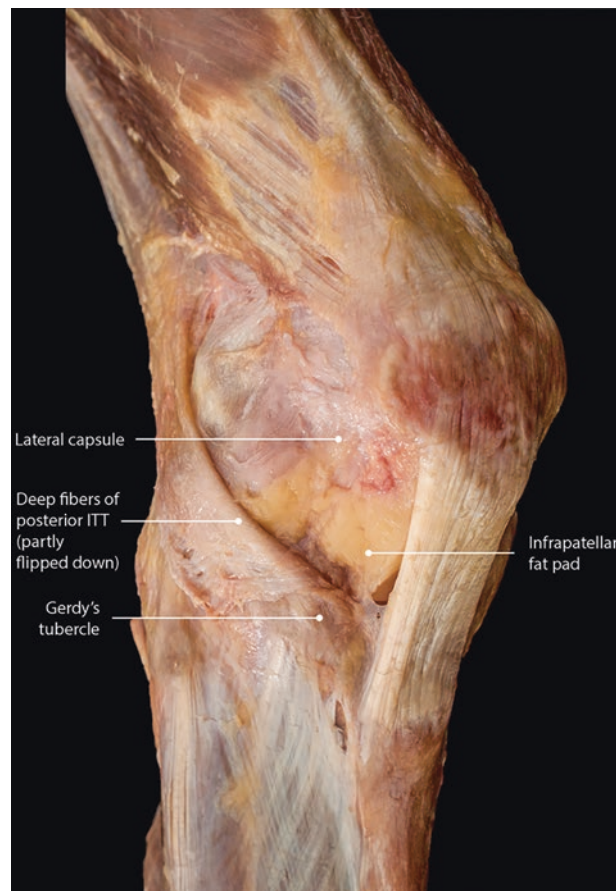


Fig. 3.5 Right knee, lateral articular capsule

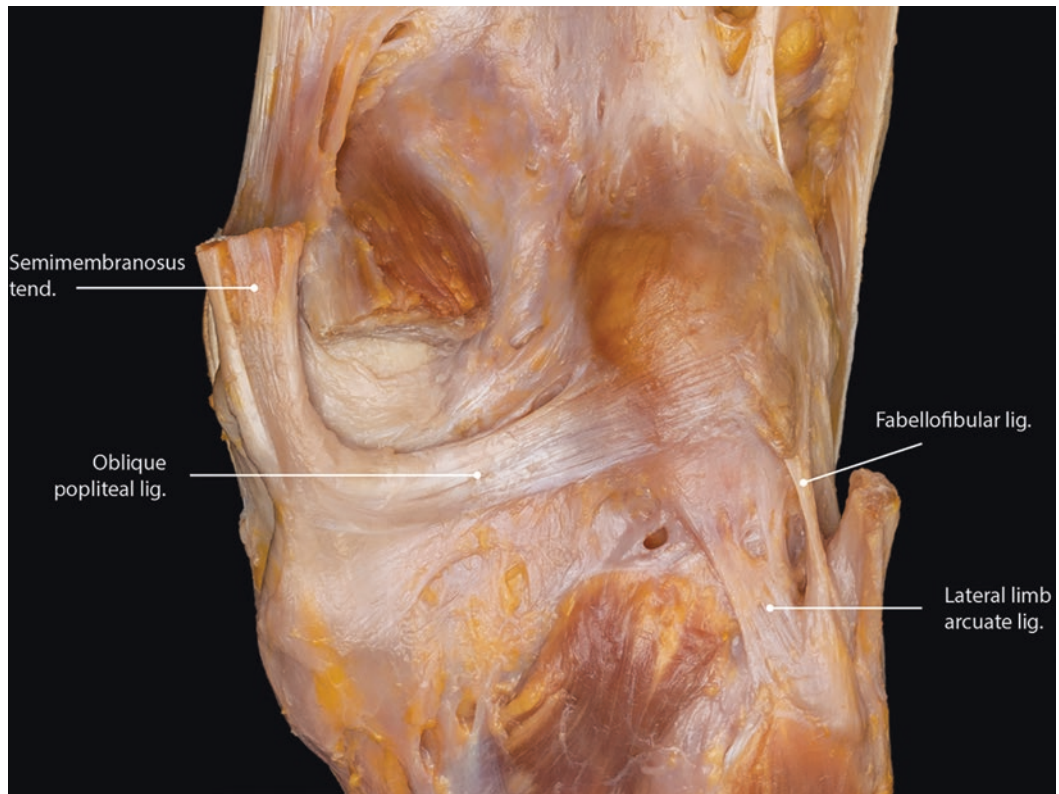


Fig. 3.6 Right knee, posterior aspect, showing posterior capsule. The oblique popliteal ligament is an expansion of the semimembranosus tendon insertion. This knee has a fabellofibular ligament. The lateral head of gastrocnemius has been removed

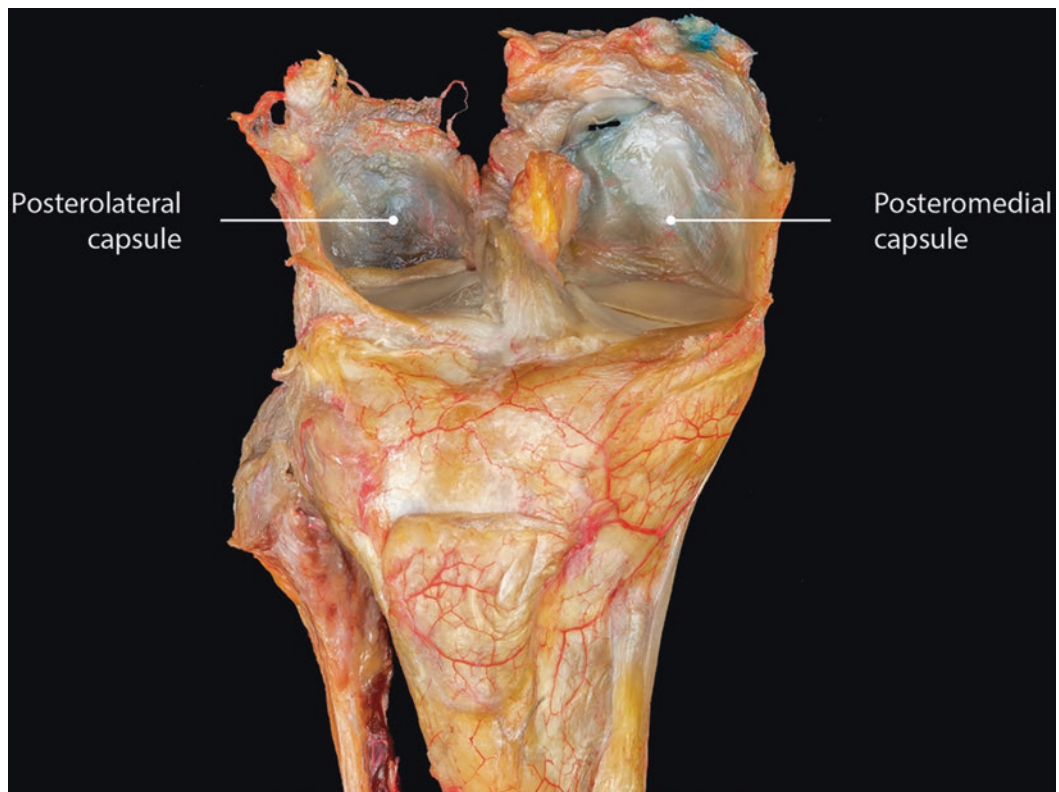


Fig. 3.7 Right proximal tibia and fibula, anterior aspect, with posterior capsule still attached

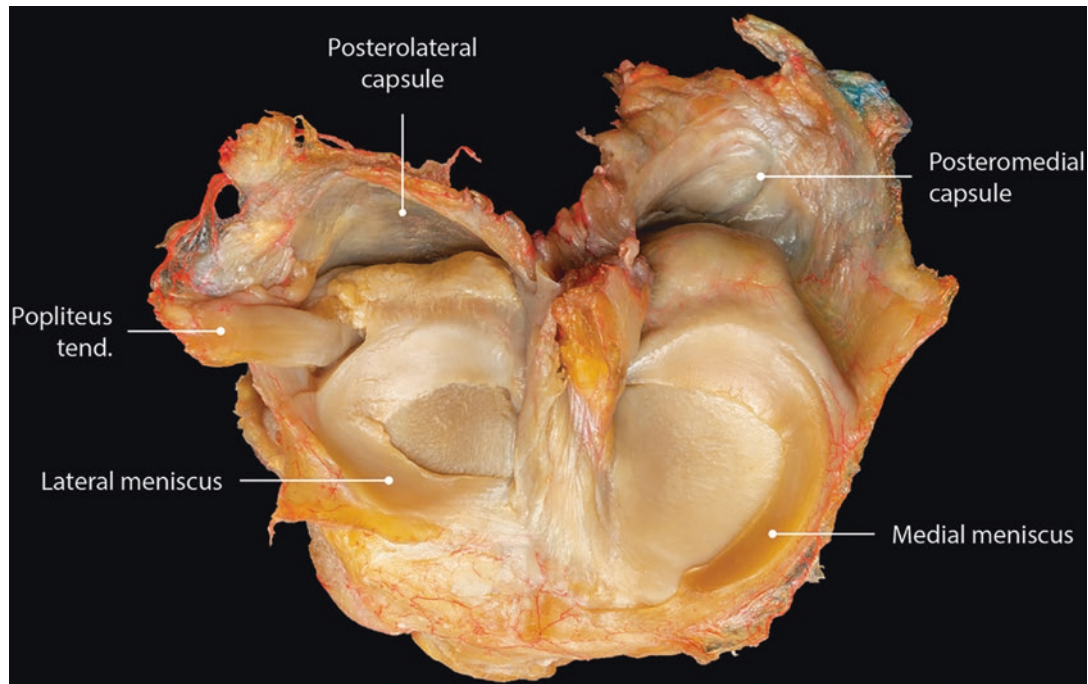


Fig. 3.8 Right tibia, superior aspect, showing posterior articular capsules

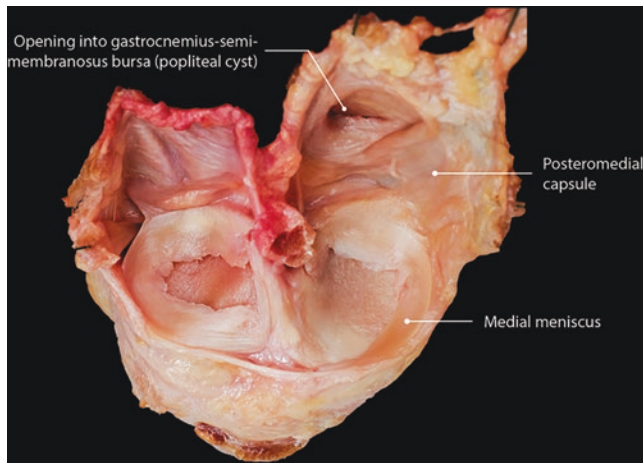


Fig. 3.9 Right knee, top of tibia showing opening in posteromedial capsule that can result in a popliteal (Baker's) cyst

3.2 Synovium

A thin layer of synovium lines the inside of the capsule. It continues superiorly just proximal to the trochlea under the quadriceps tendon to line the **suprapatellar pouch** (also known as the suprapatellar bursa or suprapatellar recess) (see Fig. 3.10). The synovial linings in the medial and lateral gutters allow knee motion. Posteriorly, the synovium extends forward enveloping both cruciate ligaments.

The knee has several thin fibroelastic connective tissue folds that are lined with synovium that are called **synovial plicas**. Plicas vary in size and cause symptoms infrequently.

The term **suprapatellar plica** (see Fig. 3.11) may not be the correct name for the structure that is located at the border between the suprapatellar bursa and the knee joint proper. The fetal knee capsule ends superiorly at the upper edge of the patella. A septum completely separates the knee joint from the suprapatellar bursa at the end of the fourth fetal month. A perforation of varying size occurs at the end of the fifth fetal month [2, 3].

Four types of suprapatellar septum have been described by Zidorn [2]: *Type I* is a complete septum without communication between the knee joint and suprapatellar bursa; *Type II* is a perforated septum with one or multiple openings, usually laterally (called porta) allowing passage of fluid; *Type III* is a small arcuate plica, usually medial; and *Type IV* is complete absence of the plica.

Important Point

A loose body can be trapped in the suprapatellar bursa if the suprapatellar plica is imperforate or has a small opening.

Fig. 3.10 The synovium continues superiorly under the quadriceps tendon to line the suprapatellar recess to create the suprapatellar pouch or bursa. (The quadriceps and patellar tendons have been omitted in the illustration) (From von Lanz et al. [31]; with permission)

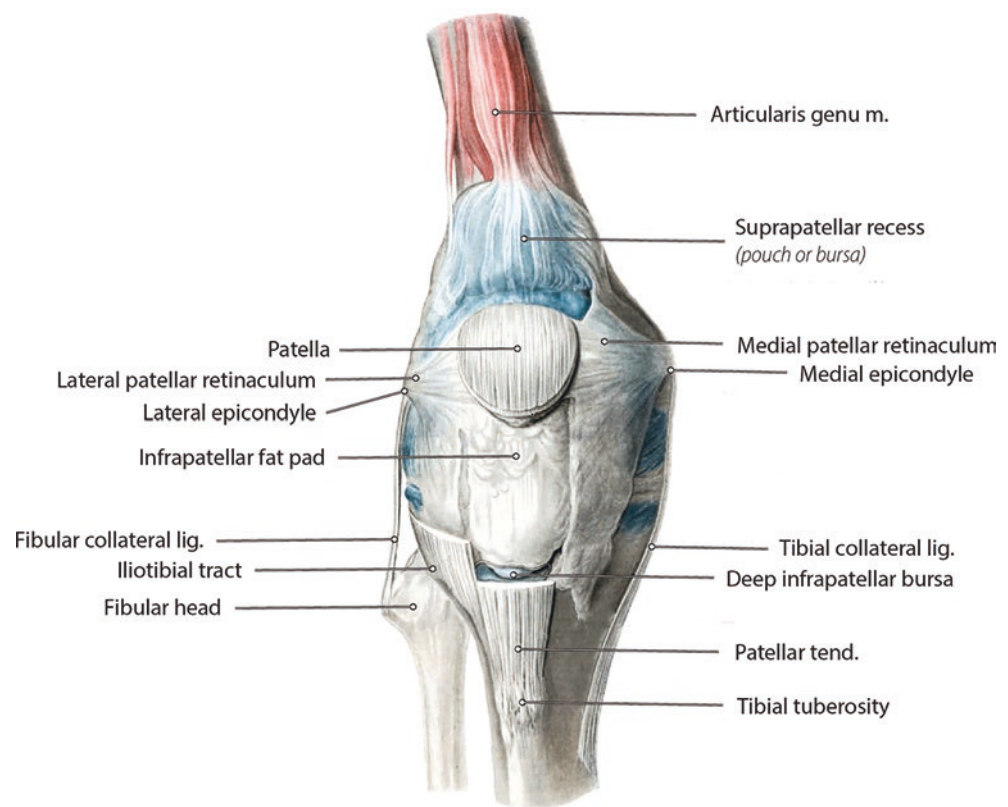


Fig. 3.11 Arthroscopic view of suprapatellar plica

The **medial synovial plica** (plica synovialis or medial synovial shelf) is a small synovial fold medial to the patella (see Figs. 3.12 and 3.13).

The **infrapatellar plica** (also called **ligamentum mucosum**) is a remnant of the embryonic division of the medial from the lateral knee joint. It can be a thin band that is partially attached to the anterior cruciate ligament. The ligamentum mucosum can be split, fenestrated or absent. It can be a complete septum in which case it is called a **septum mucosum** (see Fig. 3.14).

Arthroscopy Tip

The ligamentum mucosum, especially as a complete septum, can make it difficult to pass the arthroscope from the anterolateral to anteromedial knee.

Viewing from an anterolateral portal, the septum can be avoided by following the lateral edge of the intercondylar notch upward to the top of the notch and then downwards into the medial compartment (see Fig. 3.15). The septum can be cut or resected arthroscopically, a step which is usually necessary when performing anterior cruciate ligament reconstruction.

There is a rare **lateral plica** is a thin fold that can be located 1–2 cm lateral to the patella.

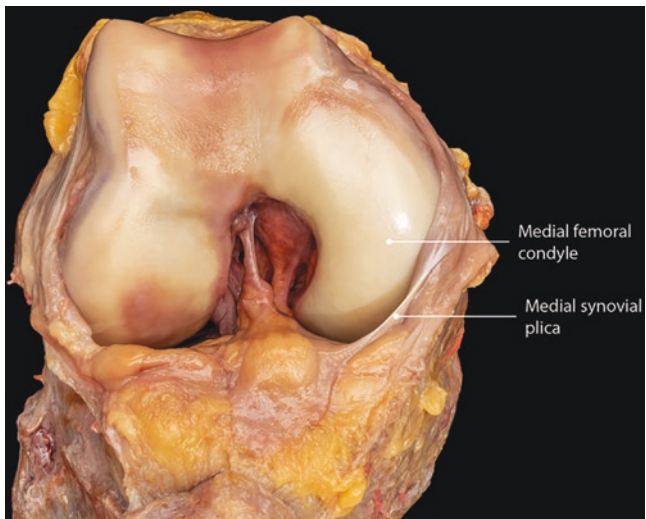


Fig. 3.12 The medial synovial plica is a small fold of synovium adjacent to the medial femoral condyle

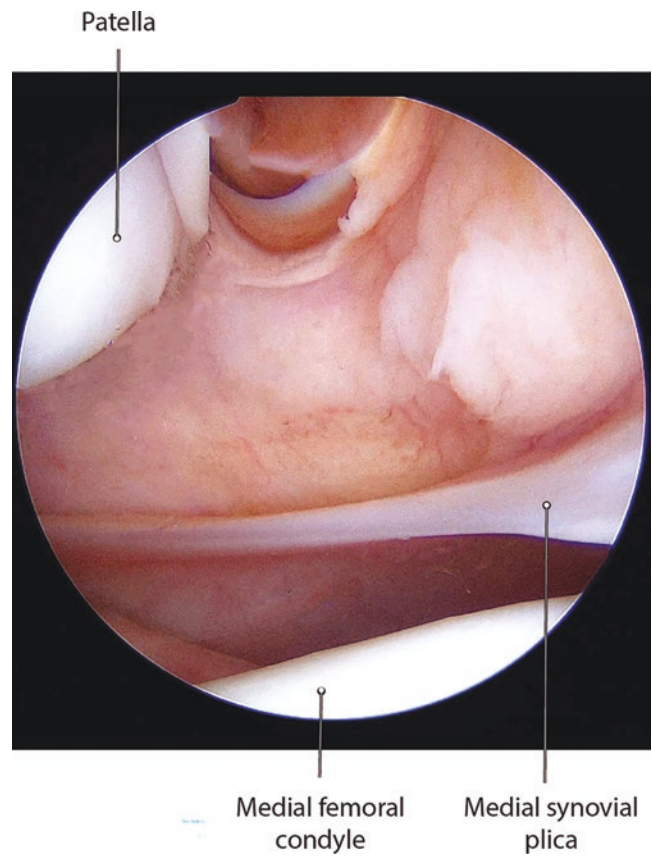


Fig. 3.13 Right knee, arthroscopic view of medial synovial plica

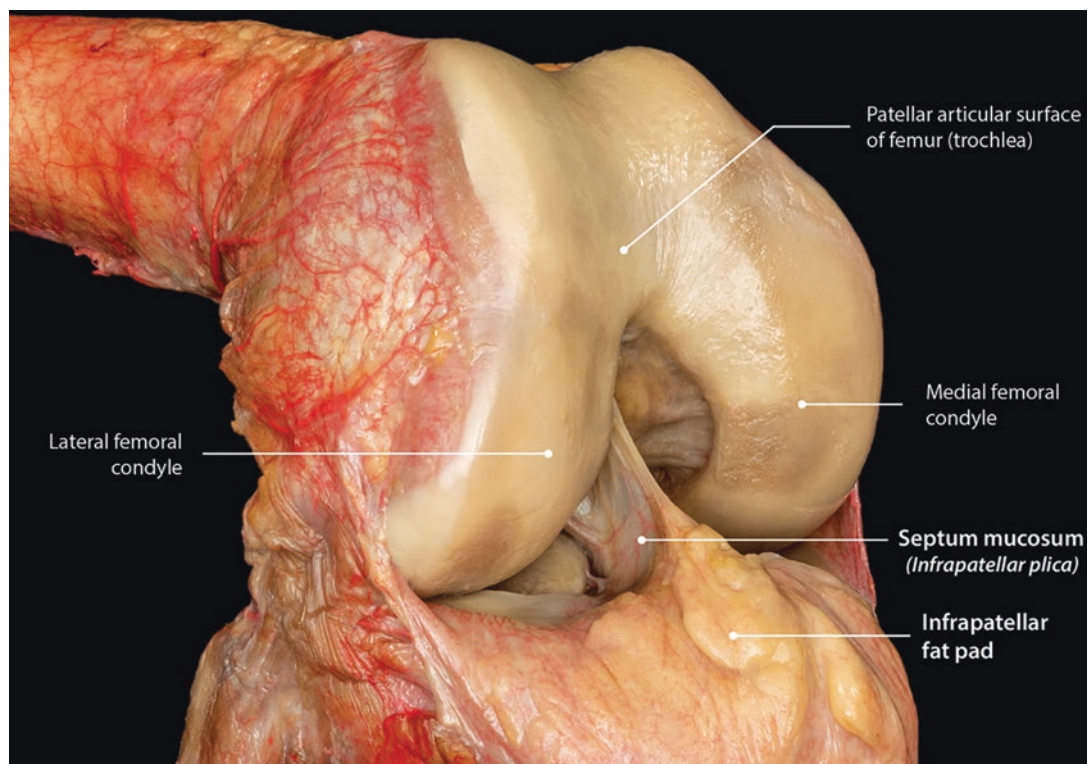


Fig. 3.14 Right knee, anterior aspect, showing infrapatellar fat pad and septum mucosum (infrapatellar plica)

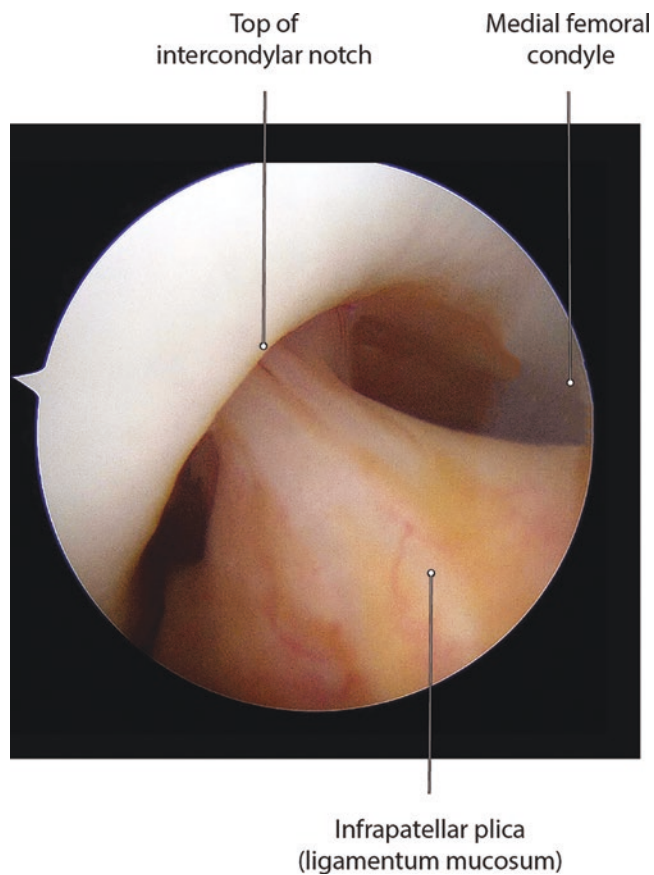


Fig. 3.15 Right knee, arthroscopic view from the lateral side of an infrapatellar plica (ligamentum mucosum)

3.3 Bursa

There are several **synovial bursae** around the knee (*see* Fig. 3.16). The medial collateral ligament bursa lies between the tibial collateral and the mid-third medial capsule. The pes anserinus bursa lies between the hamstring tendons and the tibial collateral ligament (*see* Fig. 6.18). The subcutaneous prepatellar bursa is located anteriorly over the patella. There is a superficial as well as deep infrapatellar bursa (*see* Fig. 3.17). The semimembranosus-gastrocnemius bursa can communicate with the joint cavity (*see* Figs. 3.18 and 8.30). When a synovial cyst communicates with a joint, their synovial membranes are continuous.

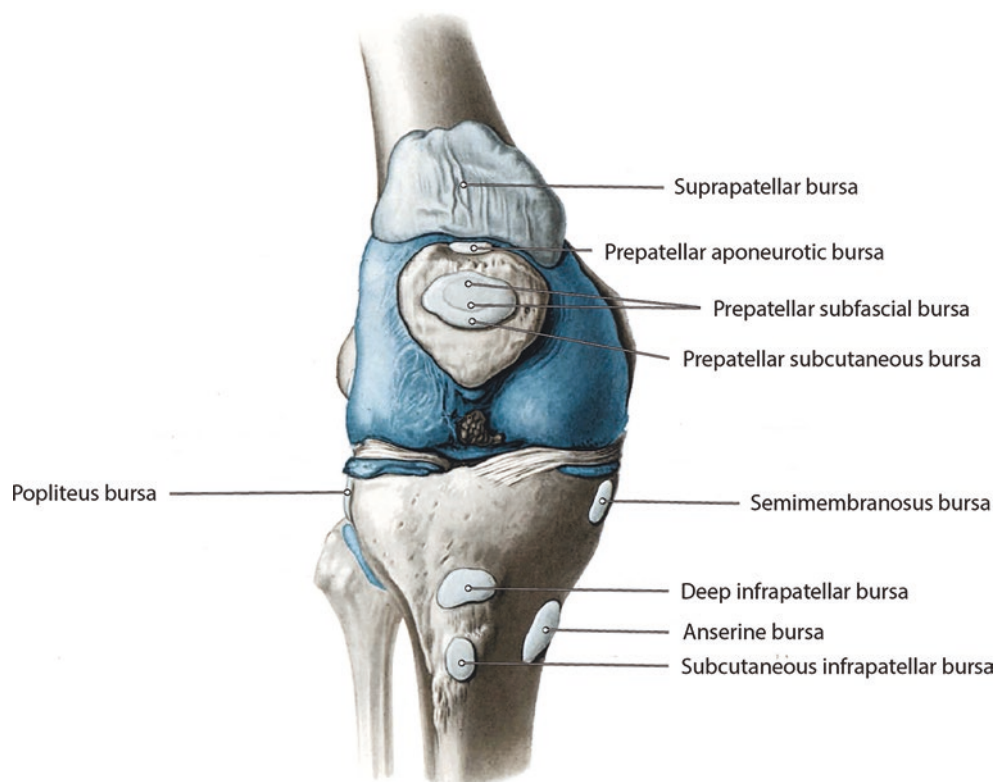


Fig. 3.16 There are several **synovial bursae** around the knee (*From* von Lanz et al. [31]; *with permission*)

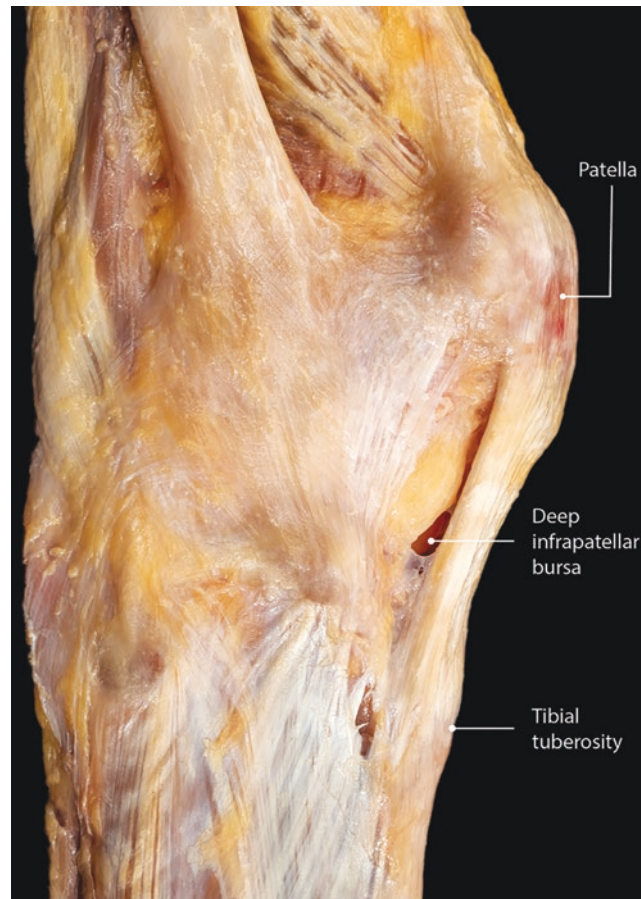


Fig. 3.17 Lateral aspect of the right knee showing the **deep infrapatellar bursa** lying between the under surface of the patellar tendon and the tibial tuberosity

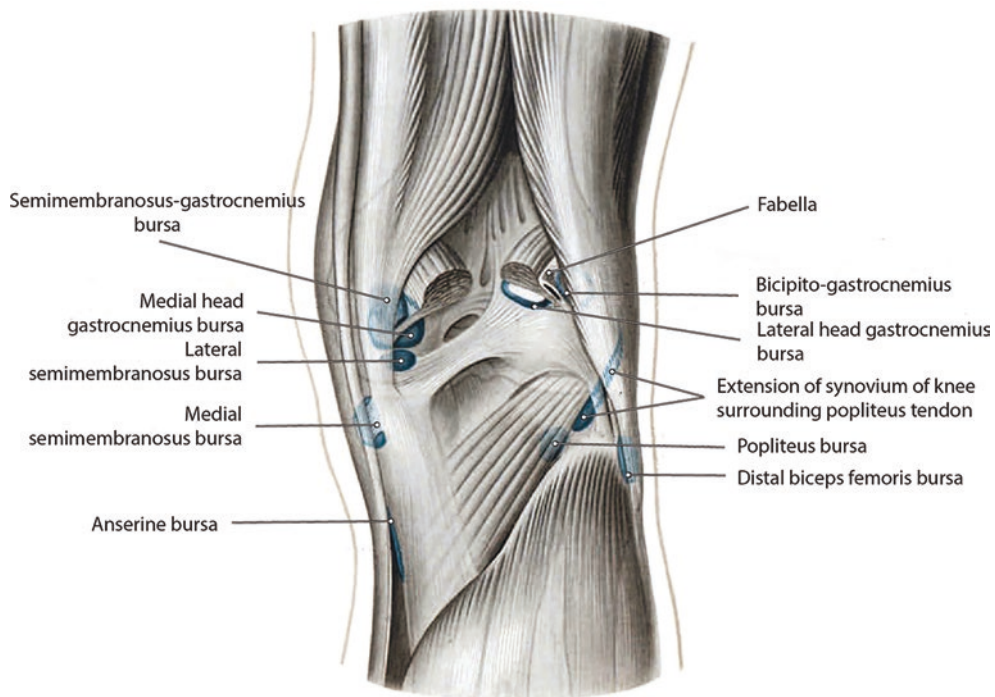


Fig. 3.18 Bursae of the posterior knee. The gastrocnemius-semimembranosus bursa can communicate with the joint cavity. If the connection is in the form of a flap valve, it can result in a popliteal (Baker's) cyst (*From von Lanz et al. [31]; with permission*)

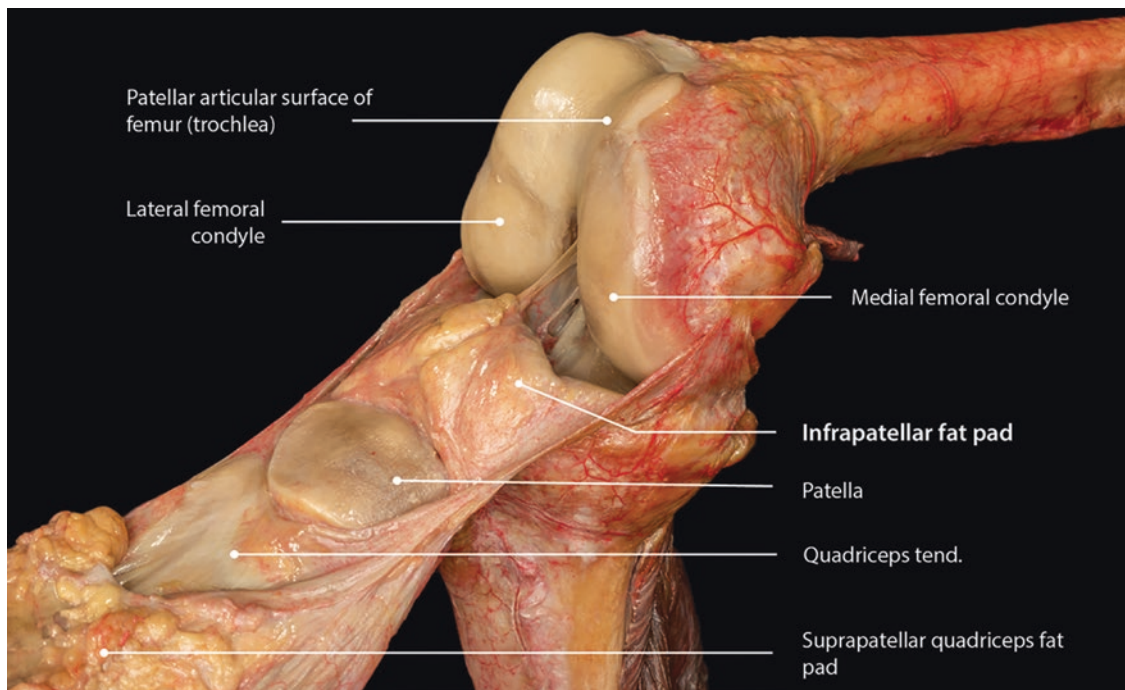


Fig. 3.19 Right knee, with extensor mechanism flipped down. Note that the fat pad attaches to the inferior pole of the patella

3.4 Fat Pad

The space in the anterior intercondylar area of the knee is filled with an infrapatellar fat pad (also called Hoffa's fat pad) (*corpus adiposum infrapatellare*). It attaches proximally to the apex (distal pole) of the patella (see Figs. 1.9 and 3.19). There is also a pre-femoral fat pad (see Fig. 2.15c).

3.5 Ligaments

Terminology

Muscles and tendons have “**origins**” (proximal) and “**insertions**” (distal).

Ligaments have “**attachments.**”

3.5.1 Medial Collateral Ligament (Refer to Chap. 6)

The medial collateral ligament is a functional unit composed of a superficial part (**tibial collateral ligament**) and a deep part (**mid-third medial capsule**) (see Figs. 3.4 and 3.20).

The tibial collateral ligament (superficial medial collateral ligament) (*ligamentum collaterale tibiale*; *internal lateral ligament*) attaches in a semicircle on the prominence of the medial epicondyle that is continuous with the attachment of the posteromedial capsule. The mid-third medial capsule (deep portion of the medial collateral ligament) attaches to a shallow depression just distal to the epicondyle (see Fig. 3.21).

The TCL attaches to the tibia about 8–10 cm distal to the joint line. It moves posteriorly with knee flexion (see Fig. 3.22).

3.5.2 Fibular Collateral Ligament (Refer to Chap. 7)

The **fibular collateral ligament (FCL)** (**lateral collateral ligament**) (*ligamentum collaterale fibulare*; *external lateral or long external lateral ligament*) attaches to the lateral femoral epicondyle immediately proximal to the groove for the tendon of the popliteus tendon. Distally it attaches to the lateral side of the head of the fibula. In flexion, the FCL is lax. In extension, it is taught and resists hyperextension (see Fig. 3.23).

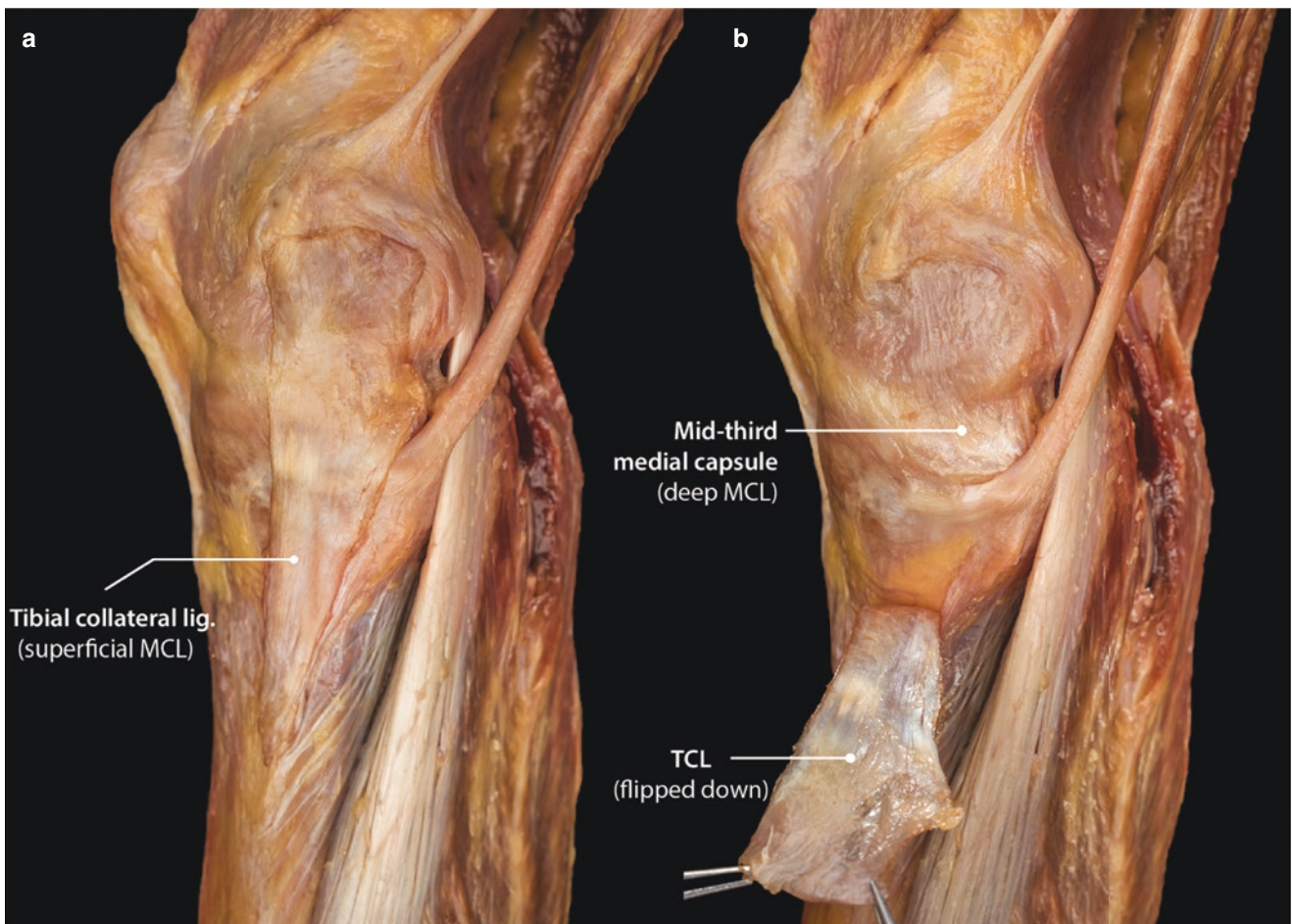


Fig. 3.20 Medial aspect right knee. The medial collateral ligament has two parts: (a) the tibial collateral ligament (superficial part) and (b) the mid-third medial capsule (deep part)

Fig. 3.21 Right distal femur, medial aspect, showing the attachments of the tibial collateral ligament (TCL) (superficial medial collateral ligament) and the mid-third medial capsule (deep medial collateral ligament)



Fig. 3.22 Right knee, medial aspect. The tibial collateral ligament (TCL) attaches to the tibia about 8–10 cm distal to the joint line. The TCL moves posteriorly as the knee goes from extension (a) to flexion (b)

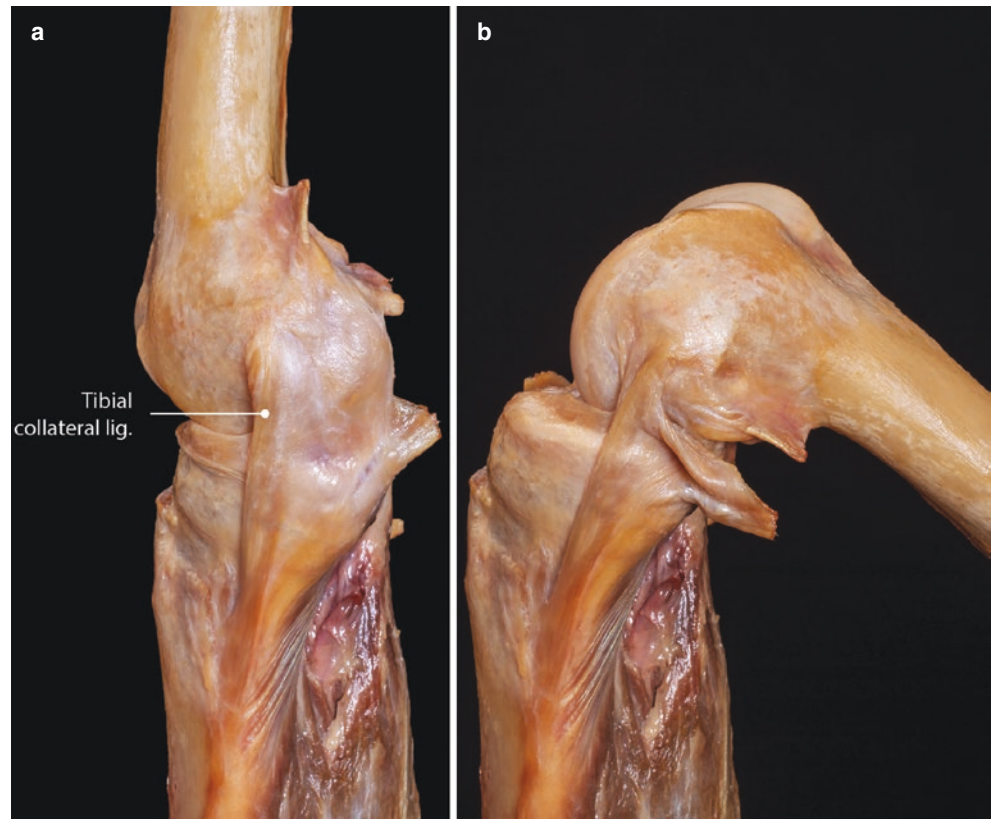
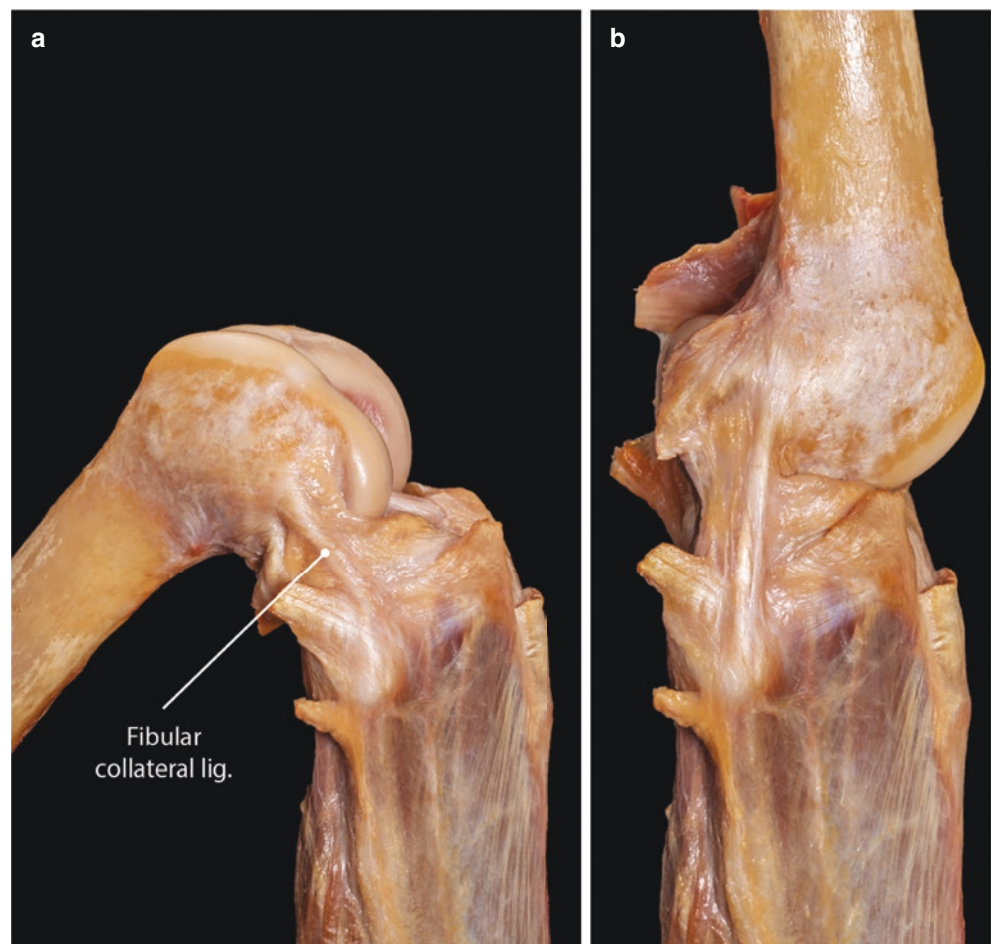


Fig. 3.23 The fibular collateral ligament (FCL) attaches to the lateral femoral epicondyle and to the fibular head. In flexion (a), the FCL is lax. In extension (b), it is taut and resists hyperextension



3.5.3 Anterior and Posterior Cruciate Ligaments

The **cruciate ligaments** function to provide both antero-posterior and rotary stability. With internal rotation of the tibia, the cruciate ligaments twist on each other and tighten. With external rotation, the cruciate ligaments unwind (*see* Fig. 3.24). With continued external rotation, anterior cruciate is wrapped around medial side of lateral femoral condyle and limits further external rotation.

Important Point

When the knee joint is loaded, such as in the stance phase, the tibia is fixed and the femur rotates. In orthopedic terminology, the movement of the distal part in relation to the proximal determines the designation, regardless of which segment is fixed.

Due to oblique insertions on the femoral condyles, a torsional effect is placed on the cruciate ligaments with flexion and extension. This arrangement causes some fibers of the cruciate ligaments to remain taut at all angles of knee flexion.

The **anterior cruciate ligament (ACL)** (*ligamentum cruciatum anterius; external crucial ligament*) attaches to the lateral femoral condyle in the posterior aspect of the intercondylar notch (*see* Fig. 3.25). The ACL passes through the intercondylar notch to attach to the top of the tibia. The anterior cruciate ligament has the appearance of a ribbon [4–7] (*see* Fig. 3.26).

The ACL has also been described as having two major bundles—an anteromedial and a posterolateral bundle. When the knee is extended, the posterolateral bundle is tight and the anteromedial bundle is moderately lax. As the knee is flexed, the anteromedial bundle tightens and the posterolateral bundle relaxes [8].

The ACL attaches to the anterior intercondylar area of the tibia posterior to the anterior horn of the lateral meniscus and

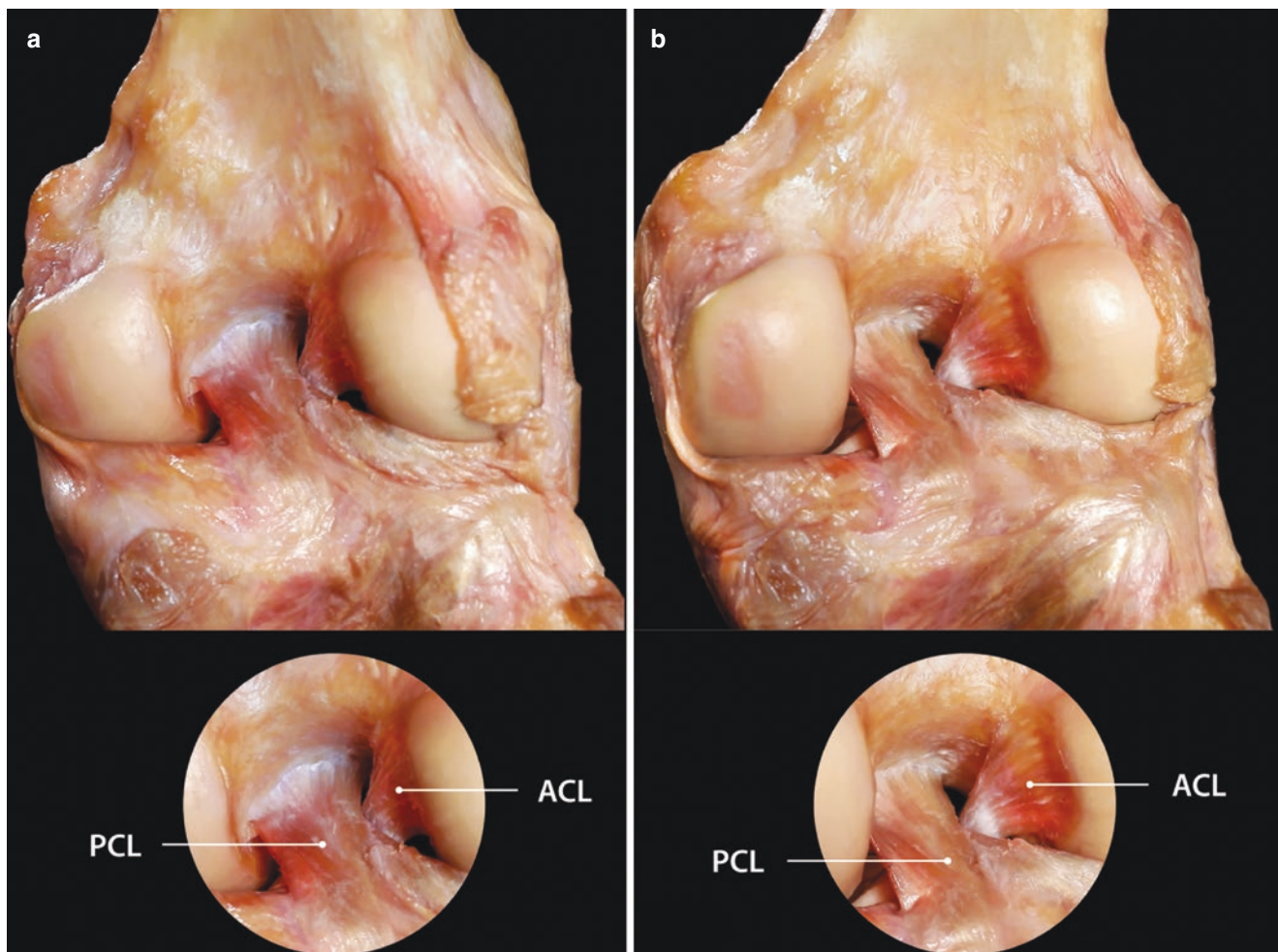


Fig. 3.24 Right knee, posterior aspect. (a) With internal rotation of the tibia, the cruciate ligaments twist on each other and tighten. (b) With external rotation, the cruciate ligaments unwind

medial to the anterior horn of the medial meniscus (see Fig. 3.27).

The ACL attachment sites as seen on MRI images are shown in Figs. 3.28, 3.29, 3.30, and 3.31. A cross section of the ACL is shown in Fig. 3.32.

The **posterior cruciate ligament (PCL)** (*ligamentum cruciatum posterius; internal crucial ligament*) attaches to the medial surface of the medial femoral condyle at the anterior aspect of the intercondylar notch (see Figs. 3.33, 3.34,

3.35, and 3.36). The PCL attaches to the posterior intercondylar surface of the tibia slightly distal to the joint line (see Fig. 3.37).

The PCL, like ACL, has been described as a flat structure [9].

The attachment sites of the PCL as seen on MRI images is shown in Fig. 3.38. A cross section of the PCL is shown in Fig. 3.39. This knee has both anterior and posterior meniscofemoral ligaments.

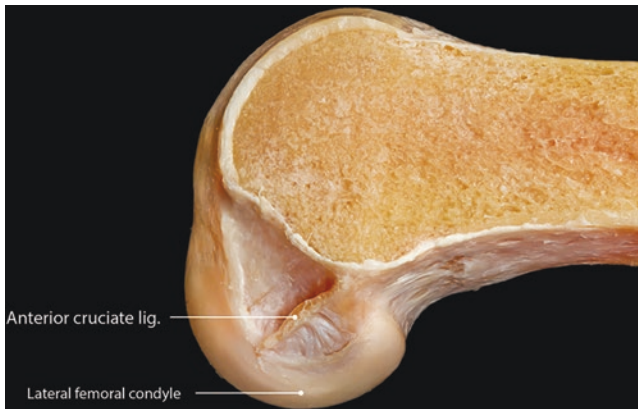


Fig. 3.25 Right knee. Cut section of lateral femoral condyle showing anterior cruciate ligament (ACL) attachment site to the intercondylar notch posteriorly. Follow the posterior cortex of the femur distally—it will lead you to the attachment of the ACL

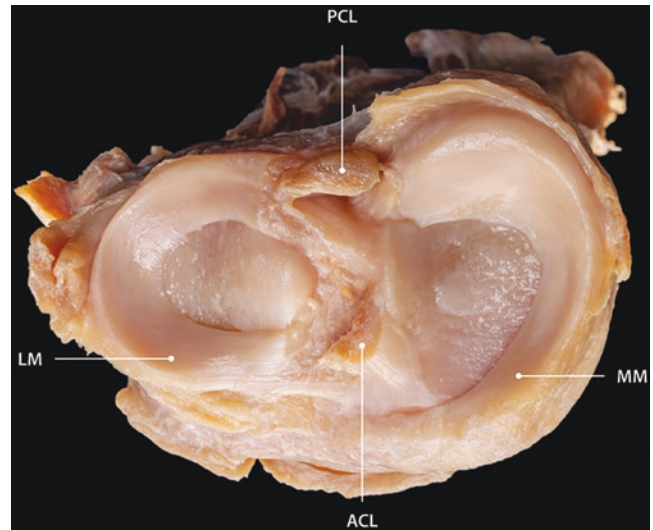


Fig. 3.27 Right tibia, superior aspect, showing attachment site of anterior cruciate ligament (ACL) to the top of the tibia. The posterior cruciate ligament (PCL) attaches to the posterior tibia just below the top surface. MM—medial meniscus, LM—lateral meniscus

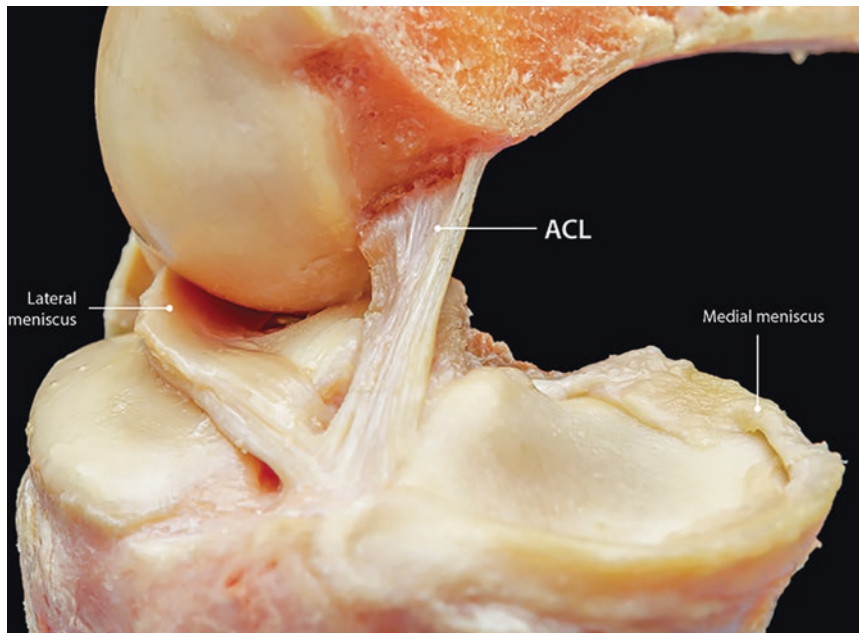


Fig. 3.26 Right knee viewed from anteromedial aspect. The medial femoral condyle has been removed. The anterior cruciate ligament (ACL) attaches proximally to the lateral femoral condyle (LFC). It

attaches distally to the top of the tibia in the anterior intercondylar area. Note the ACL has the appearance of a ribbon. Lateral femoral condyle (LFC)



Fig. 3.28 Anterior cruciate ligament shown on sagittal MRI sections

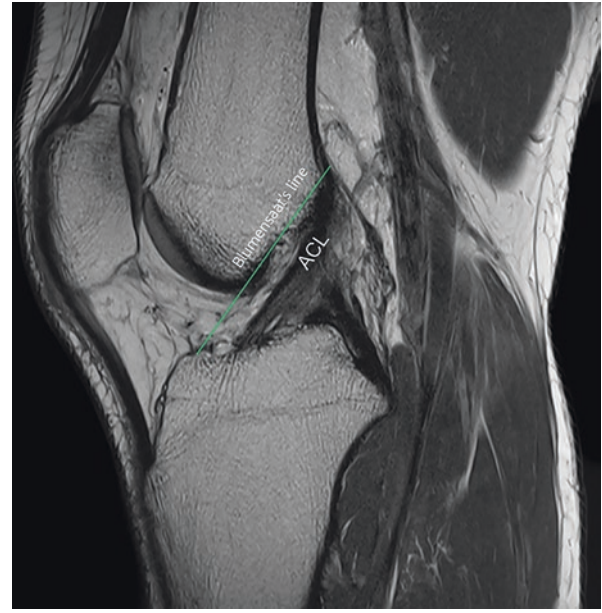


Fig. 3.30 Blumensaat line always runs anterior to the anterior cruciate ligament (ACL) attachment sites as seen on MRI and CT (MRI shown)

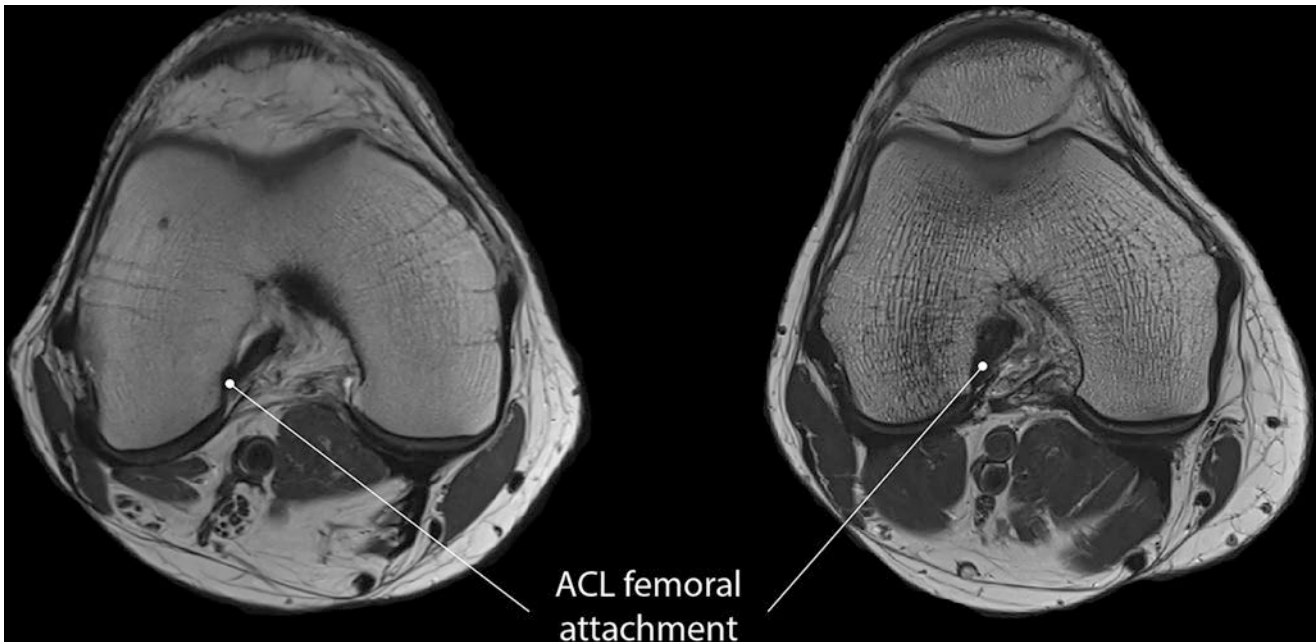


Fig. 3.29 Anterior cruciate ligament (ACL) femoral attachments as seen on axial MRI images

3.5.4 Meniscomfemoral Ligaments (Ligaments of Humphrey and Wrisberg)

The **meniscomfemoral ligaments** (also known as *Humphrey's* and *Wrisberg's ligaments*) connect the posterior horn of the lateral meniscus to the inner side of the medial femoral condyle posteriorly. The ligament of Humphrey is in front of the

PCL (see Fig. 3.40). The ligament of Wrisberg courses behind the PCL (see Fig. 3.41).

The function of both meniscomfemoral ligaments is to draw the posterior horn of the lateral meniscus in a medial direction as internal rotation of tibia occurs with flexion of knee with simultaneous contraction of popliteus.

They also provide stability to tibia [10–12].

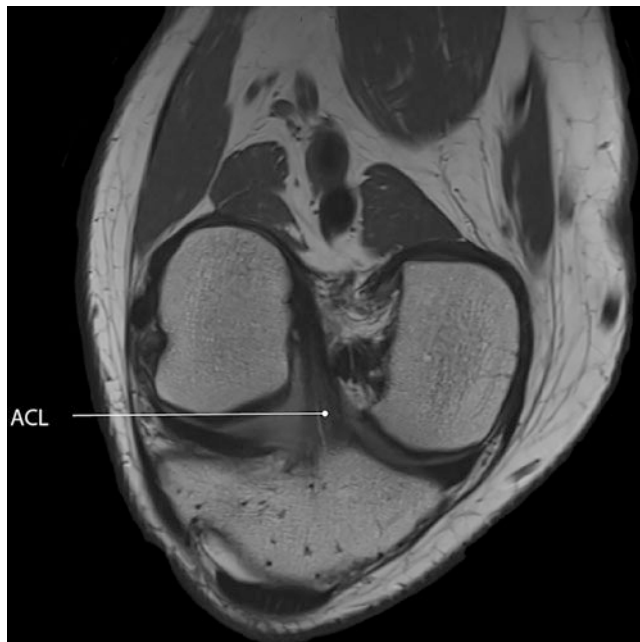


Fig. 3.31 Due to the rotation and oblique course of the anterior cruciate ligament (ACL), it is best seen on oblique coronal cross-section views that are adapted to the course of the ligament



Fig. 3.32 Cross section of anterior cruciate ligament taken with macro lens

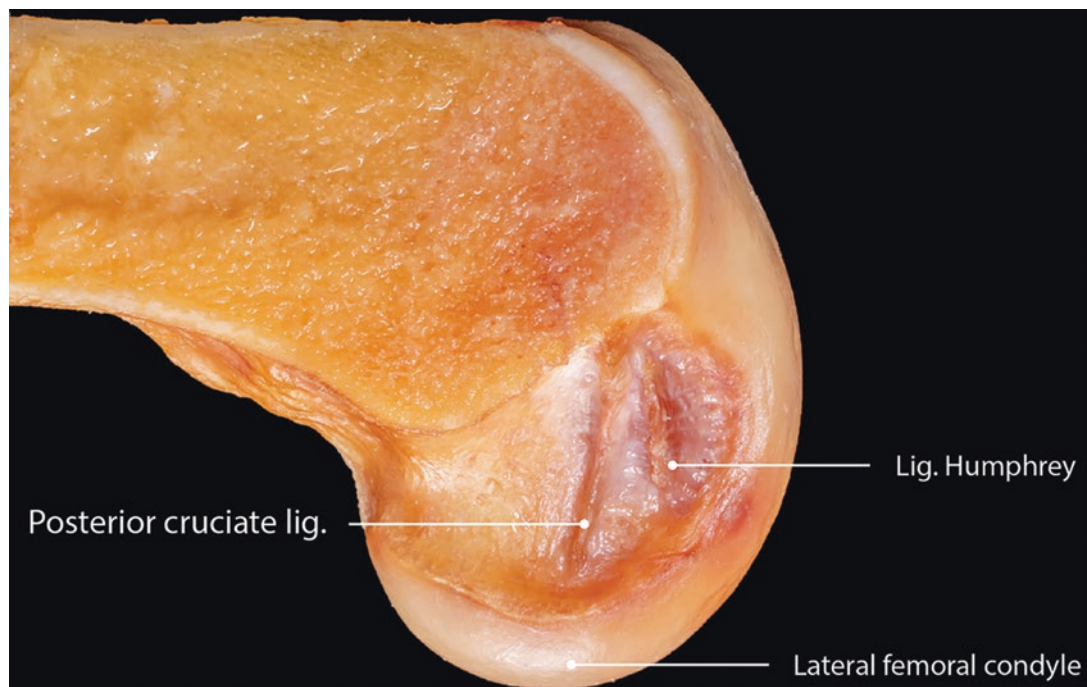


Fig. 3.33 Right knee: Cut section of medial femoral condyle showing posterior cruciate ligament (PCL) attachment site to the intercondylar notch anteriorly

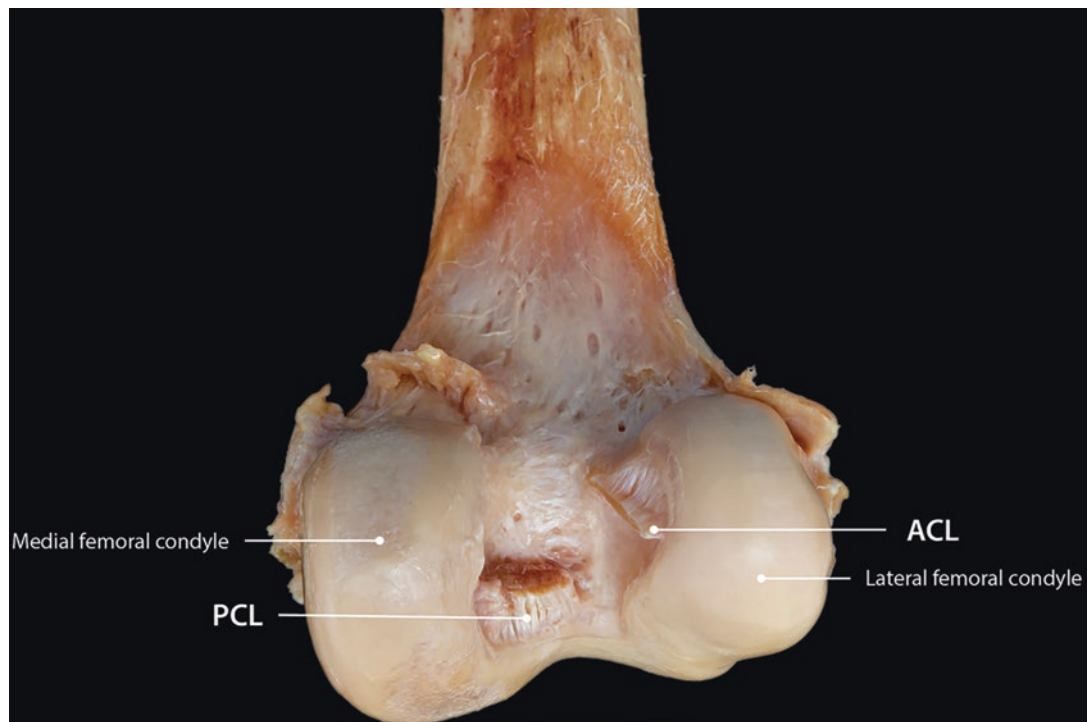


Fig. 3.34 Right distal femur, posterior view showing femoral attachment sites of anterior (ACL) and posterior (PCL) cruciate ligaments

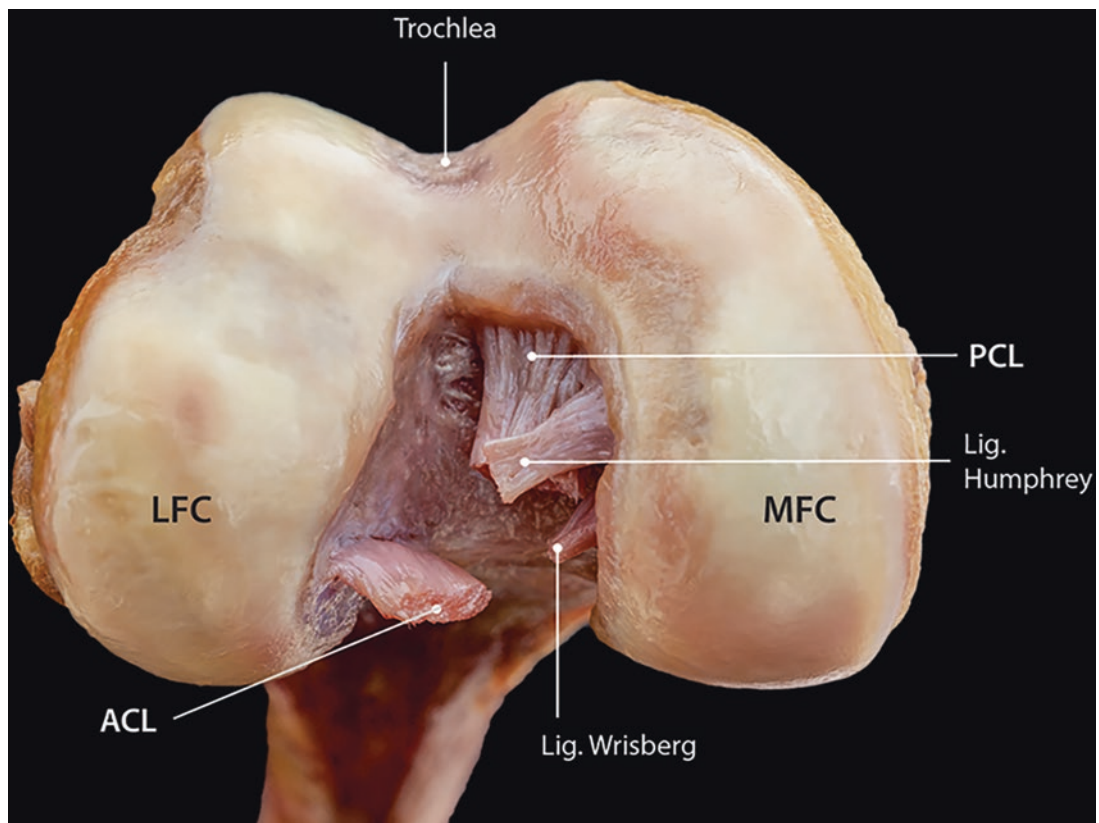


Fig. 3.35 Right distal femur from below showing cruciate ligament stumps

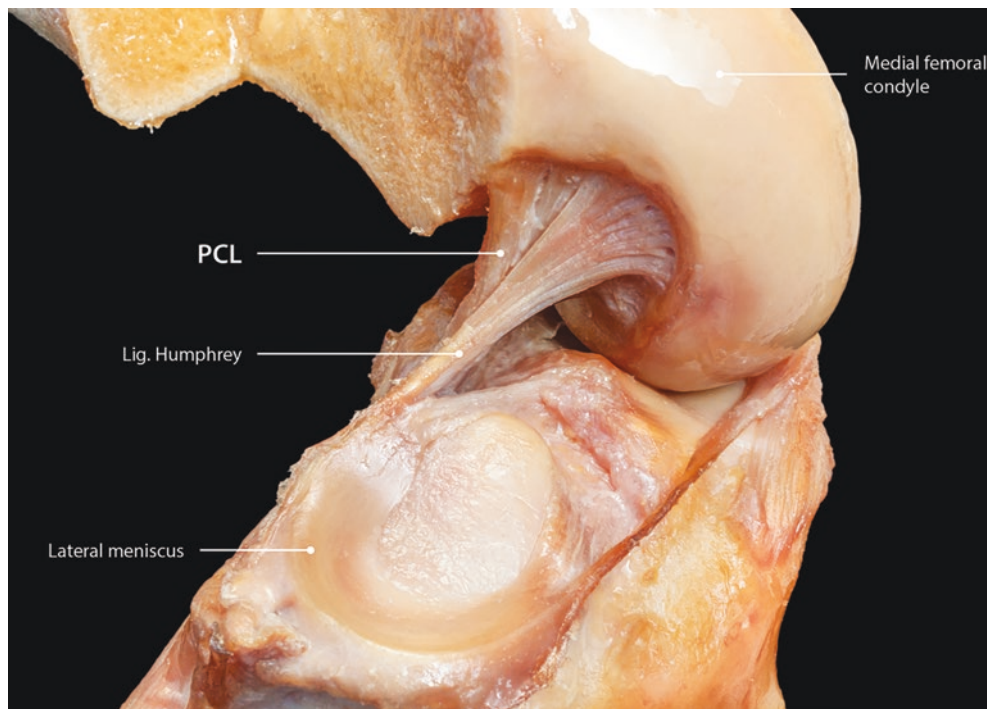


Fig. 3.36 Right knee, lateral femoral condyle removed showing course of posterior cruciate ligament (PCL) and ligament of Humphrey

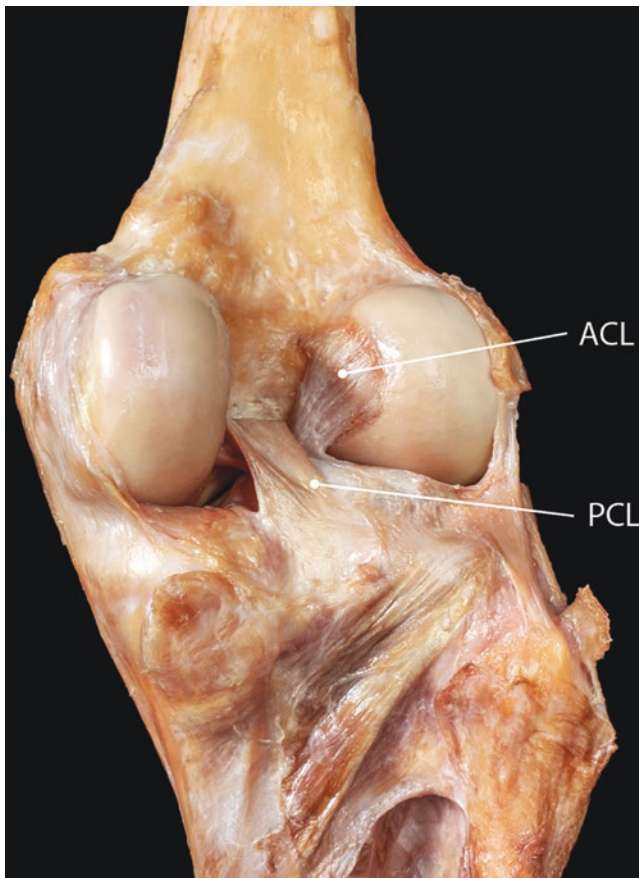


Fig. 3.37 Right knee, posterior view of intercondylar area showing cruciate ligaments

3.5.5 Oblique Popliteal Ligament

The **oblique popliteal ligament** (*ligamentum popliteum obliquum*; *posterior ligament*) is a thickening of the posterior capsule. It passes obliquely upward and outward from the back of the medial tibial condyle, where its superficial fibers are a continuation of the insertion of the semimembranosus tendon. It attaches to an upper surface of the lateral femoral condyle. The deeper portion blends with the posterior capsule and posterior cruciate ligament (*see Fig. 8.29*).

3.5.6 Arcuate Popliteal Ligament

The **arcuate popliteal ligament** (arcuate ligament) is a Y-shaped thickening of the posterior capsule that is found in about 65% of knees [13, 14]. The medial limb curves over the popliteus muscle to join the oblique popliteal ligament, and the lateral limb joins the capsule near the lateral head of gastrocnemius muscle (*see Fig. 8.29*). If there is a large fabella, the arcuate ligament can be replaced by a fabellofibular ligament.

3.5.7 Popliteofibular Ligament

The popliteofibular ligament is an inconsistent thickening of the posterolateral capsule. It is attached proximally at the musculotendinous junction of the popliteus and distally to the fibular head and styloid process [15].



Fig. 3.38 Posterior cruciate ligament (PCL) attachment sites marked on MRI image

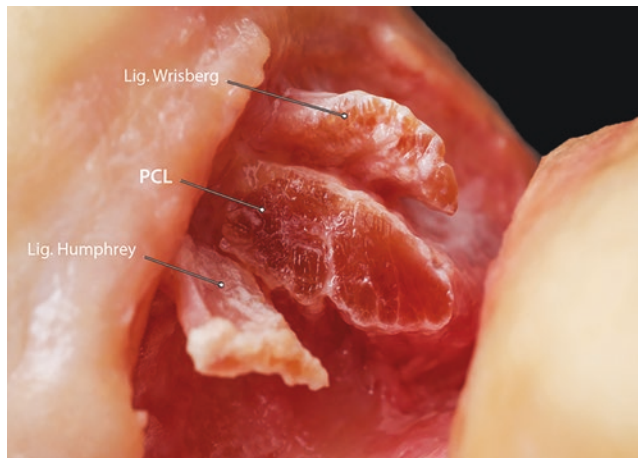


Fig. 3.39 Cross section of posterior cruciate ligament (PCL) taken with macro lens. This knee has both anterior (Humphrey) and posterior (Wrisberg) meniscofemoral ligaments

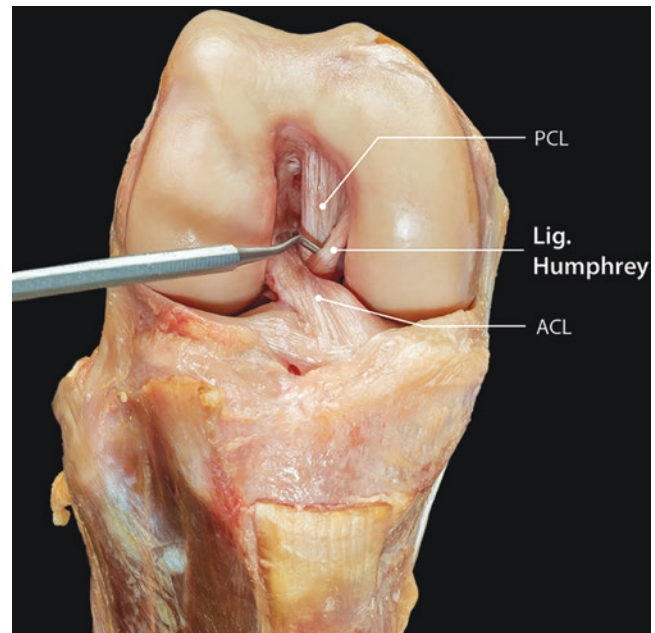


Fig. 3.40 Right knee, anterior. The anterior meniscofemoral ligament (lig. Humphrey) arises from the posterior horn of the lateral meniscus and passes in front of the PCL to attach to the medial femoral condyle

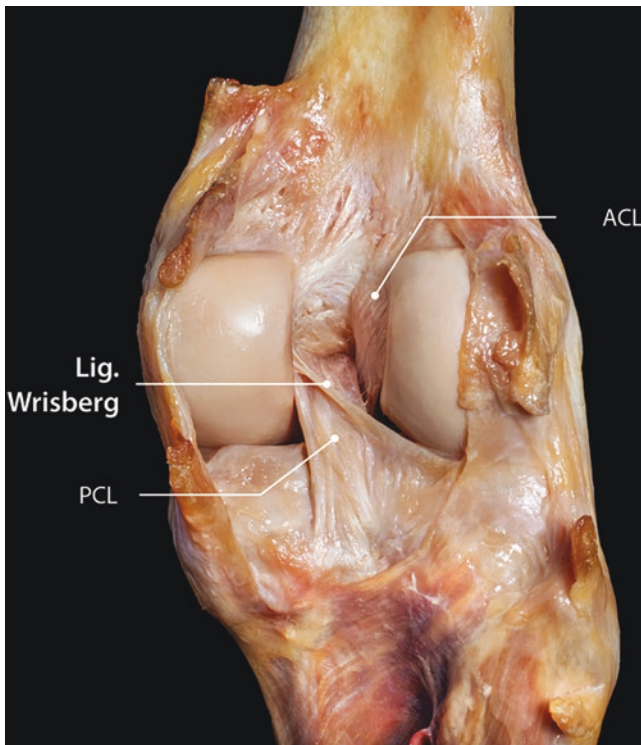


Fig. 3.41 Right knee, posterior. The posterior meniscomfemoral ligament (lig. Wrisberg) goes from the posterior horn of the lateral meniscus, behind the PCL, to the medial femoral condyle

3.5.8 Transverse Knee Ligament

The **transverse knee ligament** (*ligamentum transversum genu*) (also known as the **intermeniscal ligament**) connects the anterior horn of the lateral meniscus to the anterior horn of the medial meniscus. It is present in about 90% of knees (see Figs. 3.42 and 3.43).

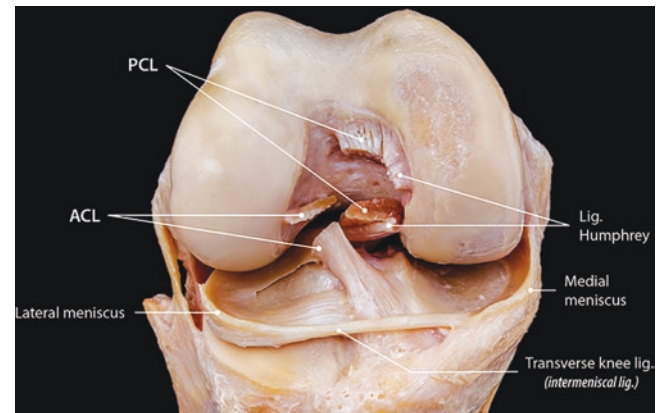


Fig. 3.43 Right knee. The transverse knee ligament (intermeniscal ligament) connects the anterior horns of the lateral and medial menisci. Note the cut ends of the cruciate ligaments

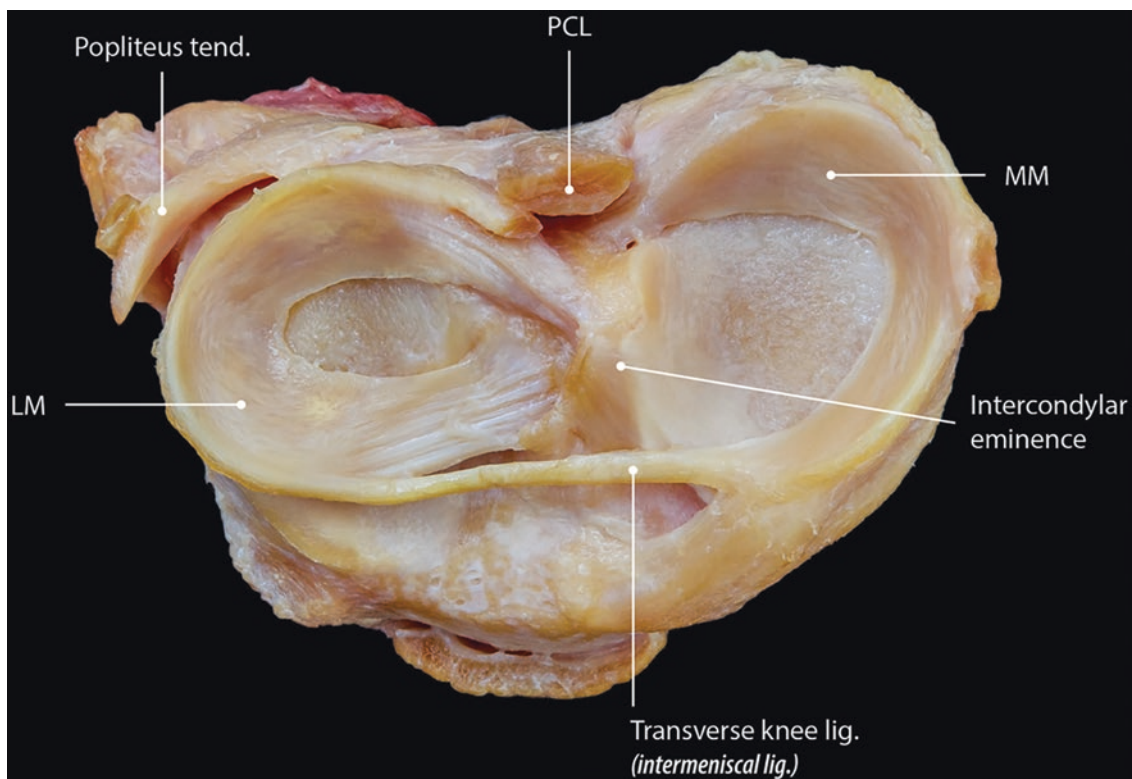


Fig. 3.42 Top of tibia

3.6 Menisci

Terminology

The term meniscus “**root**” has come into use to describe the attachments of the anterior and posterior **horns** of the menisci to the tibia. It is a misnomer. Anatomically speaking, there is no root that goes from the meniscus into the subchondral bone, such as the root of a plant. There are firm **attachments**.

The menisci are crescent-shaped fibrocartilaginous structures that fill in the spaces at the curved edges of the tibiofemoral joint.

The medial meniscus displaces forward with knee extension by the action of patella-meniscal ligaments (expansions of the extensor retinaculum) and by rolling action of the femoral condyles. With flexion, the medial meniscus moves posteromedially due to the muscular action of the semimembranosus as well as rolling action of femoral condyles.

The lateral meniscus is not attached to the tibia as firmly as the medial. It displaces a greater distance than the medial with flexion. In 1941, Brantigan and Voshell reported the medial meniscus to move an average 2 mm compared to the lateral, which moved 10 mm in the anterior-posterior direction during knee flexion [16] (see Fig. 3.44). Thompson et al. measured using three-dimensional MRI and found that medial meniscus moved 5.1 mm compared to the lateral meniscus, which moved 11.2 mm. The ratio was 1:2 (medial to lateral) [17].

Vedi et al. studied meniscal movement under load in normal knees using dynamic MR. The anterior horn of the medial meniscus moved an average of 7.1 mm and the posterior horn 3.9 mm, with 3.6 mm of medial-lateral radial displacement. The anterior horn of the lateral meniscus moved 9.5 mm and the posterior horn 5.6 mm, with 3.7 mm of radial displacement [18].

Internal and external rotation moves both menisci in opposing directions on the tibial plateau. In internal rotation, most meniscus movements were found in the mid-portion of the lateral meniscus. In external rotation, the mid-portion of the medial meniscus showed the greatest mobility [19].

3.6.1 Medial Meniscus

The **medial meniscus** is large in the antero-posterior direction and is C-shaped. This contour conforms to the shape of the medial compartment. Its anterior and posterior horns are widely separated. The posterior horn of the medial meniscus is much larger than the anterior horn. The

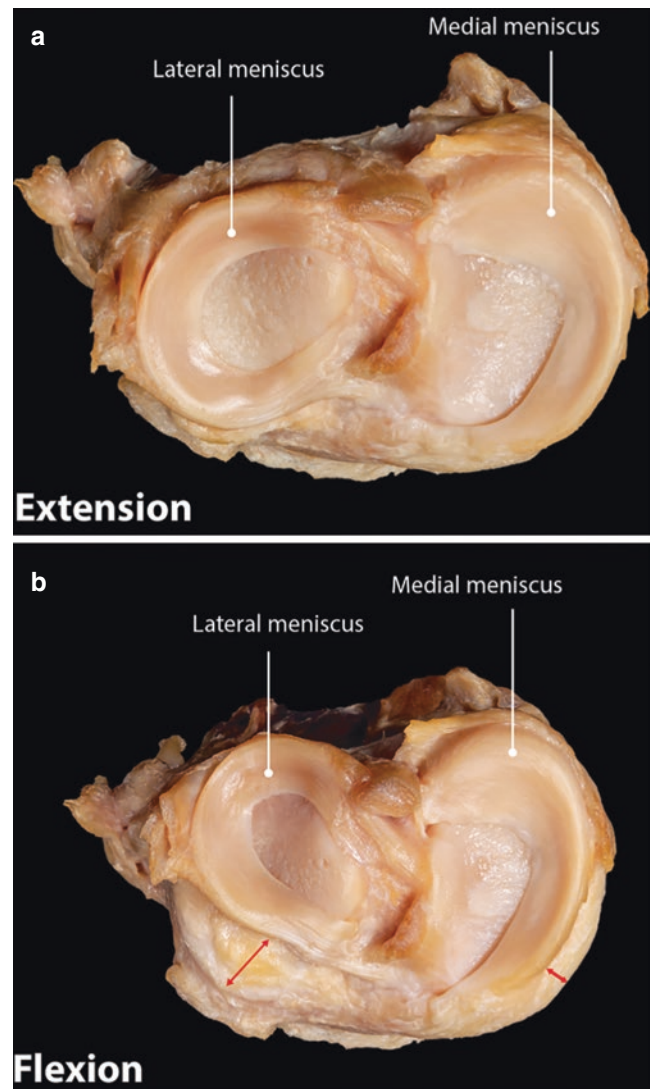


Fig. 3.44 Right knee. Superior surface of tibia. (a) Extension. (b) Full flexion. Note the displacements of the medial and lateral menisci in flexion (arrows)

anterior horn attaches to the tibia in the anterior intercondylar area immediately anterior to the tibial attachment of the anterior cruciate ligament. The posterior horn attaches to the tibia in the posterior intercondylar area between the posterior cruciate ligament and the attachment of the posterior horn of the lateral meniscus (see Fig. 3.45). The medial meniscus has firm peripheral attachments to the capsule and coronary ligament and has little motion (see Fig. 3.46).

3.6.2 Lateral Meniscus

The **lateral meniscus** is smaller than the medial and is nearly circular in shape. The anterior and posterior horns are attached closely to together and are of similar size. The anterior horn

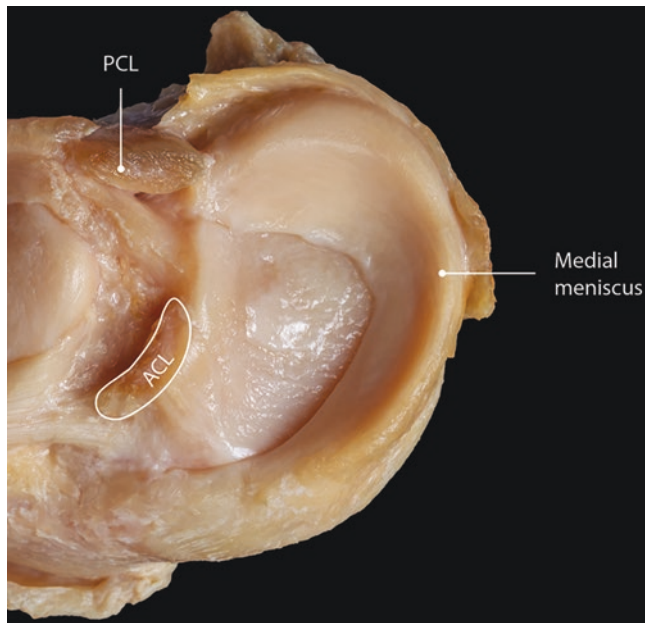


Fig. 3.45 Right knee, medial meniscus



Fig. 3.46 Right knee. Cross section of medial meniscus showing attachment to capsule

of the lateral meniscus blends with the tibial attachment of the anterior cruciate ligament (*see* Fig. 3.43). The posterior horn attaches to the tibia behind the intercondylar eminence also blending with the tibial attachment of the anterior cruciate ligament (*see* Fig. 3.45). The lateral meniscus is not attached to the lateral capsule for its entire circumference. Its peripheral attachment is interrupted posterolaterally by the passage of the popliteus tendon from inside to outside the knee joint.

Popliteomeniscal fascicles connect the mid and posterior portions of the lateral meniscus to the popliteus tendon. The posterosuperior fascicle goes from the posterior horn of the lateral meniscus to the medial fibers of the popliteus tendon aponeurosis. The anteroinferior fascicle is a coronary liga-

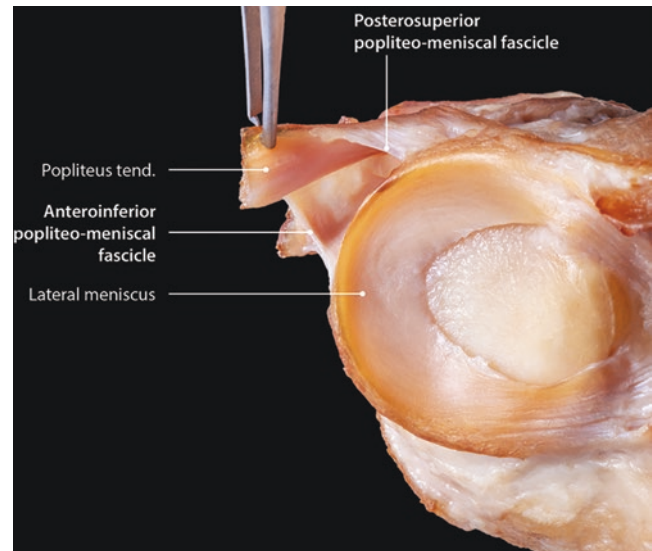


Fig. 3.47 Right knee, superior aspect of lateral tibia plateau. Note the popliteomeniscal fascicles

ment which connects the lateral meniscus to the edge of the tibia. The fascicles create a tunnel for the popliteus tendon to pass from inside the joint to its extra-articular muscle [20–22] (*see* Fig. 3.47).

The **menisiofibular** ligament connects the posterior third of the lateral meniscus to the apex of the fibular head (*see* Figs. 3.48 and 3.49).

3.6.3 Vascularity of Menisci

The genicular arteries provide the major vascularization to the menisci. The lateral inferior genicular artery along with its branch to the lateral superior genicular artery are the main blood supply sources for the lateral meniscus. The medial inferior genicular and medial meniscus arteries supply the medial meniscus (*see* Fig. 3.50). The medial meniscus artery is especially important for vascularity of the posterior horn of the medial meniscus in Zones 4 and 5 (*see below*) (*see* Fig. 8.22).

The peripheral 10–30% of the medial meniscus is vascularized compared to 10–25% of the lateral meniscus [23–27]. Not many studies have been published on the vascularity of the menisci since the work of Arnoczky and Warren [23]. The lateral meniscus is more richly supplied by blood vessels than the medial.

3.6.4 Meniscus Zones

Śmigielski et al. have divided both menisci into surgically relevant “zones.” Each zone is characterized by the structure that attaches to the edge of the meniscus, or, as in the case of

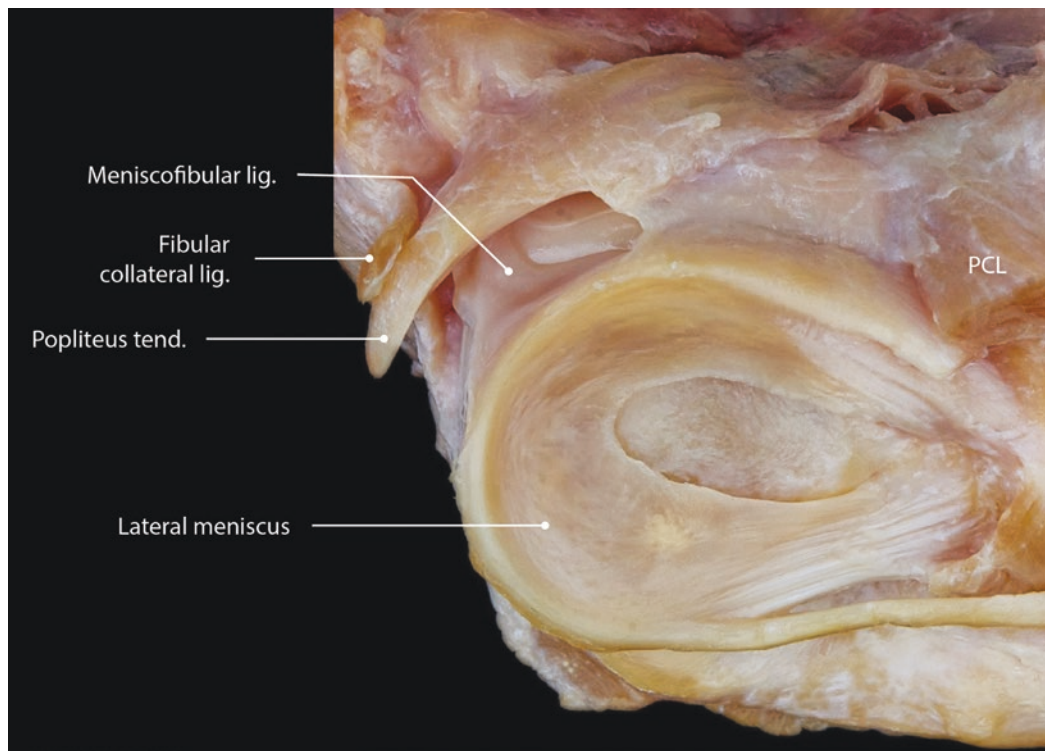


Fig. 3.48 Right knee, lateral tibial plateau, viewed from above. Note the meniscofibular ligament

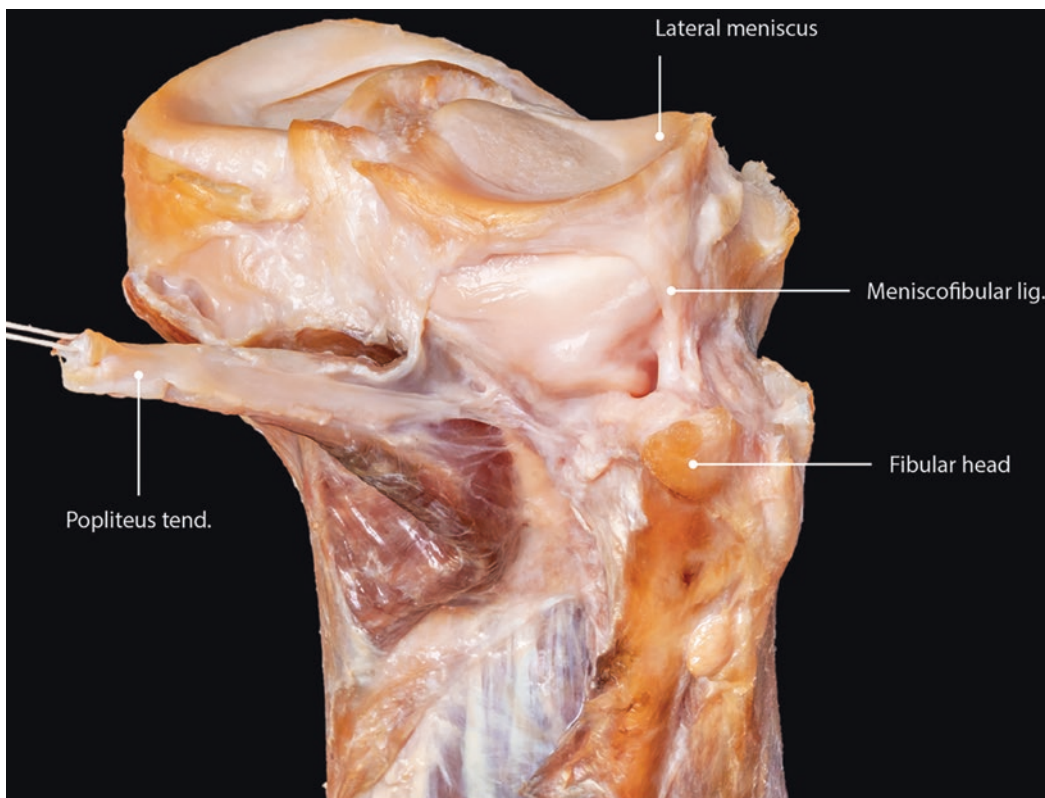


Fig. 3.49 Right knee, posterior aspect. The popliteus tendon and muscle have been lifted to show the meniscofibular ligament

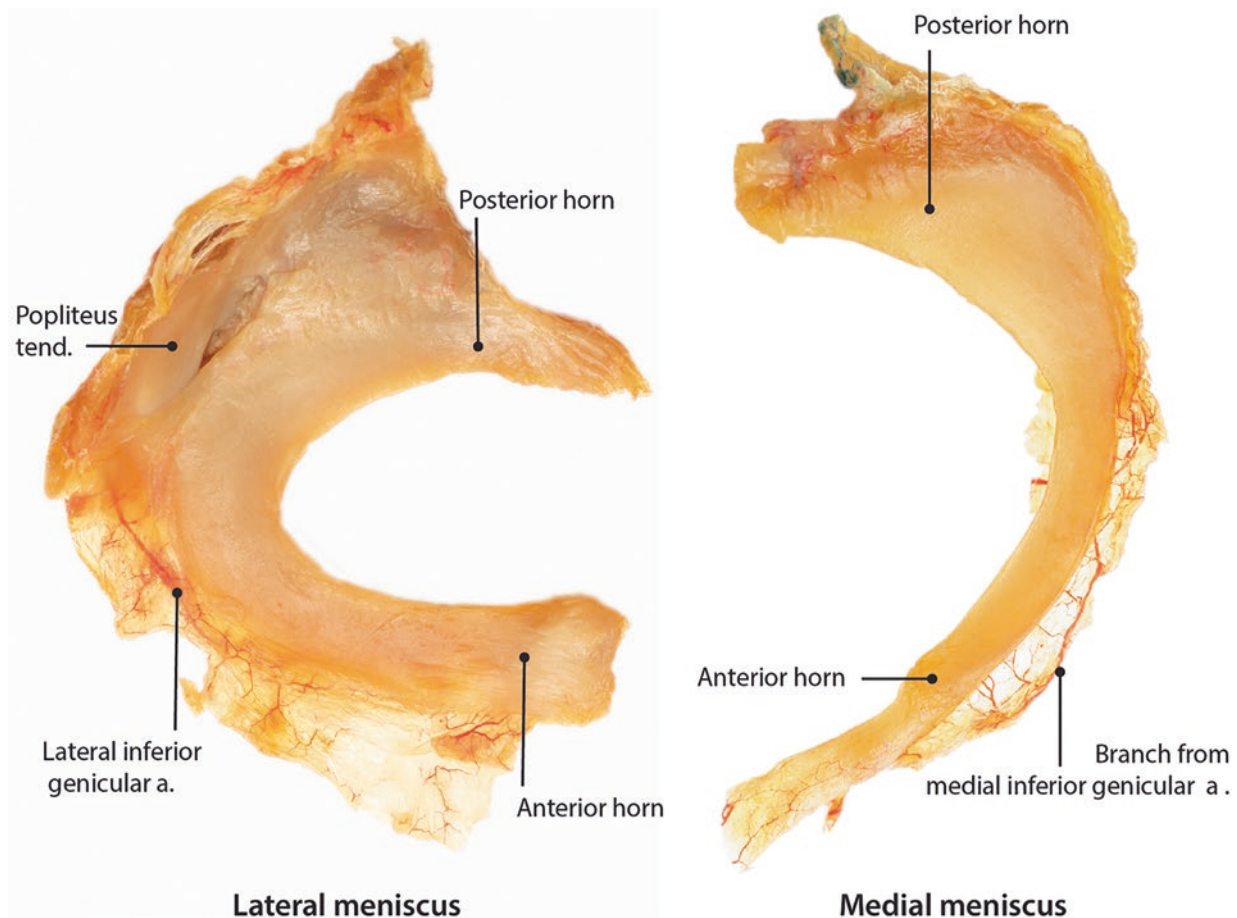


Fig. 3.50 Right knee, lateral and medial menisci, viewed from above, showing vascularity

Zone 2, by its location. The medial meniscus is divided into five zones [28, 29] and the lateral into six [30] (see Fig. 3.51).

Each zone's anatomical features should be considered when performing surgical repair.

3.6.4.1 Medial Meniscus Zones

Zone 1 – Anterior horn. The meniscus is firmly attached to the tibia. It is sometimes called the anterior “root.”

Zone 2 – Anteromedial

- **2a** - From anterior horn to the attachment of transverse ligament
- **2b** - From attachment of transverse ligament to anterior border of tibial collateral ligament.

Zone 3 – Medial. This is the area where the mid-third medial capsule (deep MCL) attaches to the meniscus [11].

Zone 4 – Posterior region. In this zone, the **posteromedial joint capsule does not attach to the superior margin of the medial meniscus but** attaches to the tibia just **below the joint line** [11–13].

Zone 5 – Posterior horn. The meniscus is firmly attached to the tibia. It is sometimes called the posterior “root.” There is no direct attachment of the meniscus to the femur in this zone.

3.6.4.2 Lateral Meniscus Zones

Zone 1 – Anterior horn. It is sometimes called the anterior “root.” It is where the lateral meniscus is firmly attached to the tibia.

Zone 2 – Anterolateral zone. This is the “mobile” part of the lateral meniscus.

- **2a** - From posterior margin of anterior horn to the attachment site of the transverse knee ligament
- **2b** - From attachment site of the transverse knee ligament to anterior border of the popliteus fossa.

Zone 3 – Popliteus hiatus region. The lateral meniscus is not attached to the capsule.

Zone 4 – The popliteomeniscal fascicle region.

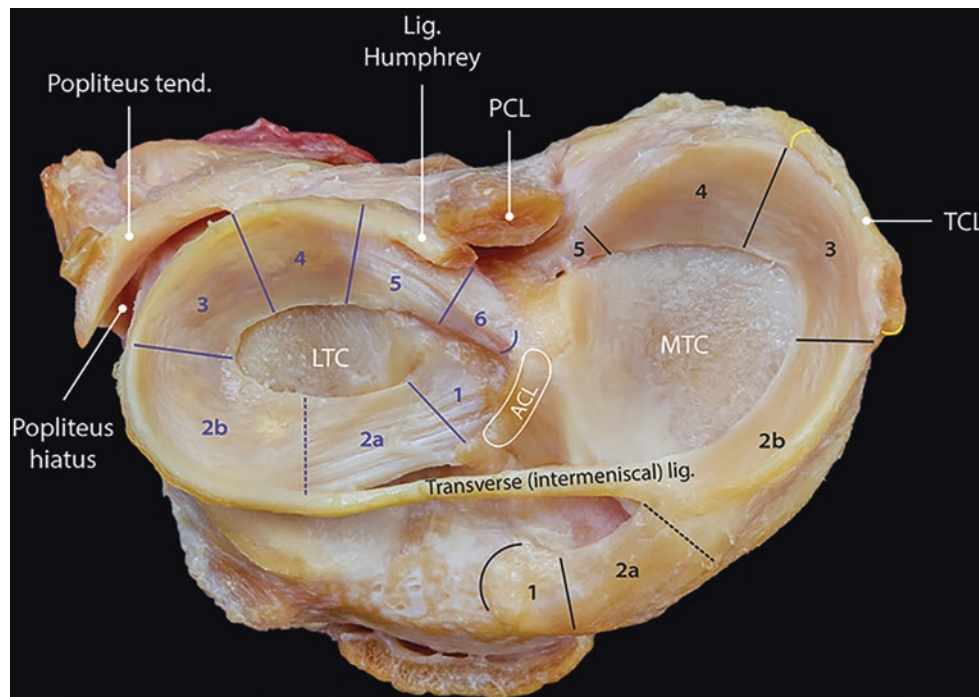


Fig. 3.51 Right knee, top of tibia showing meniscus zones for repair

Zone 5 – Ligamentous area, where the meniscofemoral ligaments attach to the tibia.

Zone 6 – Posterior horn. The meniscus is firmly attached to the tibia. It is sometimes called the posterior “root.”

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Patellofemoral Joint

4

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and Bertram Zarins

4.1 Bony Anatomy (Refer to Chap. 1)

4.1.1 Patella

The lateral patellar facet is usually twice as large as the medial. Each facet can be subdivided into indistinct thirds. A seventh facet medially is the “odd” facet (*see* Figs. 1.6 and 4.1). It contacts the intercondylar surface of the femur only in full knee flexion.

Wiberg [1] described three patellar shapes based on the asymmetry between the medial and lateral patellar facets seen on axial X-rays of the patella (*see* Fig. 4.2).

Type I—symmetrical medial and lateral facets, slightly concave.

Type II—(the most common type) - small medial facet and a large lateral facet, both facets slightly concave.

Type III—large lateral and a very small, somewhat convex, medial facet.

A **fourth type** was mentioned but not classified, described as a “planed patella” with a marked underdevelopment of the femoral condyles. Wiberg concluded that there was an increased tendency to lateral subluxation with increasing size of the lateral facet.

The patellar shape and trochlear morphology are typically congruent and related to one another.

4.1.2 Femoral Trochlea (Patellar Surface of Femur)

Multiple measurements to describe trochlear morphology have been described. In 1964, Brattstrom described the **sulcus angle**, which is a measurement of the angle between the medial and lateral facets of the trochlea. It is an indicator of the depth of the trochlea [2]. The sulcus angle is measured on an axial X-ray view with the knee at 30–45 degrees of flexion. Its normal value is $135^{\circ} \pm 10^{\circ}$ [3] (*see* Fig. 4.3). Since the original description, multiple measurements have been described on both magnetic resonance imaging and computed tomography.

In trochlear dysplasia, the trochlear surface appears flattened, and the concavity is less pronounced. When dysplasia is present, the femoral sulcus is shallow at 30°–50° of flexion, causing it to be less able to protect against lateral patellar displacement. The trochlear surface can be convex in cases of severe dysplasia. Dejour et al. classified trochlear dysplasia as follows [4, 5] (*see* Fig. 4.4):

A: normal shape of the trochlea, but a shallow trochlear groove.

B: markedly flattened or even convex trochlea.

C: trochlear facet asymmetry, with too high lateral facet, and hypoplastic medial face.

D: type C features and a vertical link between facets (“cliff pattern”).

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Fig. 4.1 Right knee, flexed, showing patellofemoral joint. The lateral patellar facet is usually twice as large as the medial. Each facet can be subdivided into indistinct thirds. A seventh facet medially is the “odd” facet. It contacts the intercondylar surface of the femur only in full knee flexion

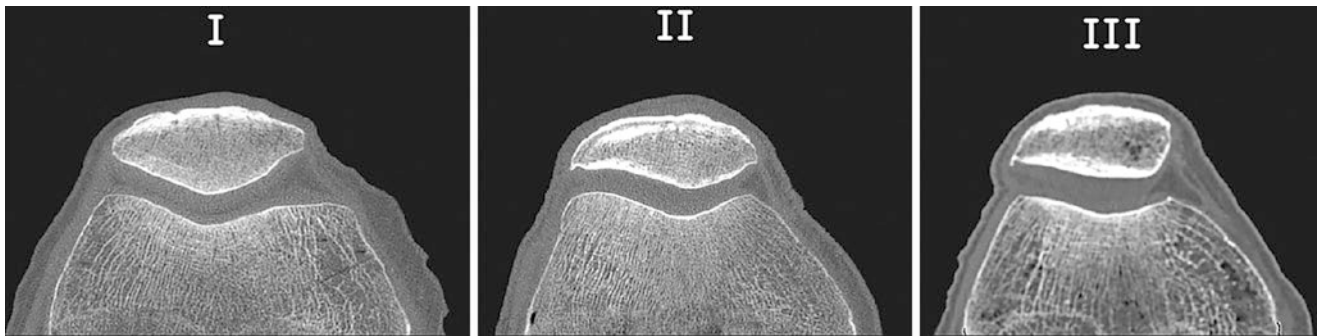
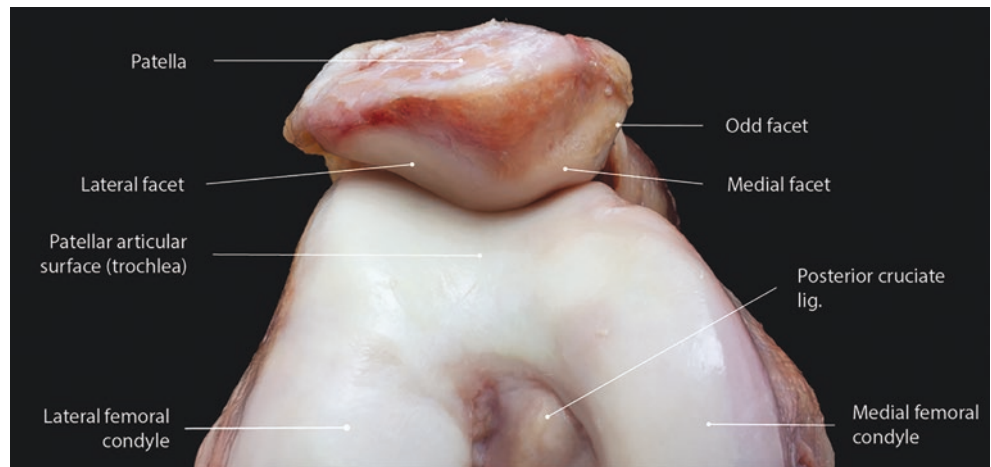


Fig. 4.2 Wiberg patella classification (right knee shown). **Type I**—symmetrical medial and lateral facets, slightly concave. **Type II**—(most common) - small medial facet and a large lateral facet, both facets slightly concave. **Type III**—large lateral and a very small, somewhat convex, medial facet

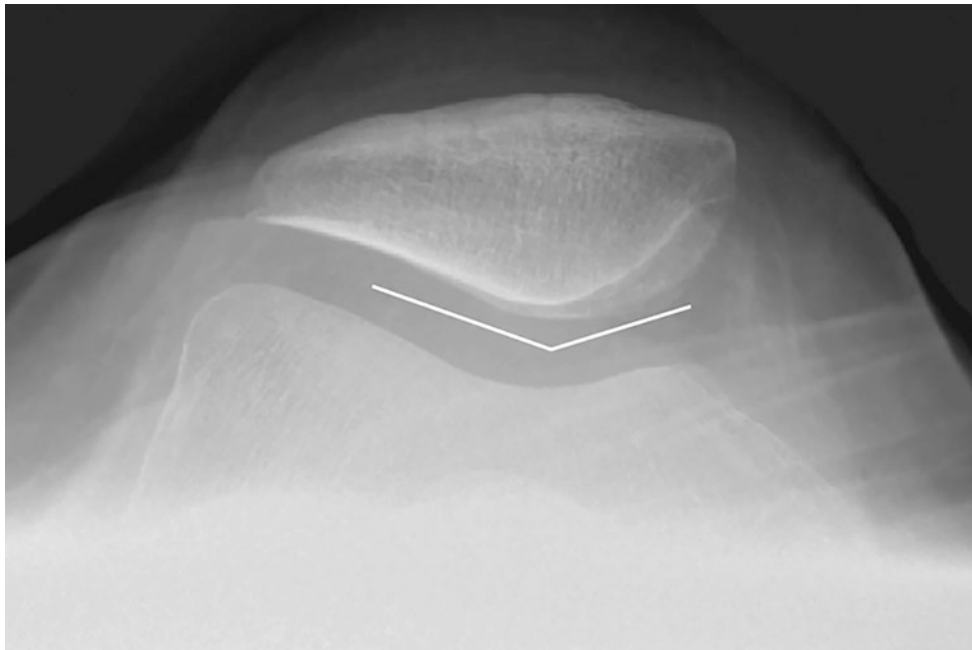
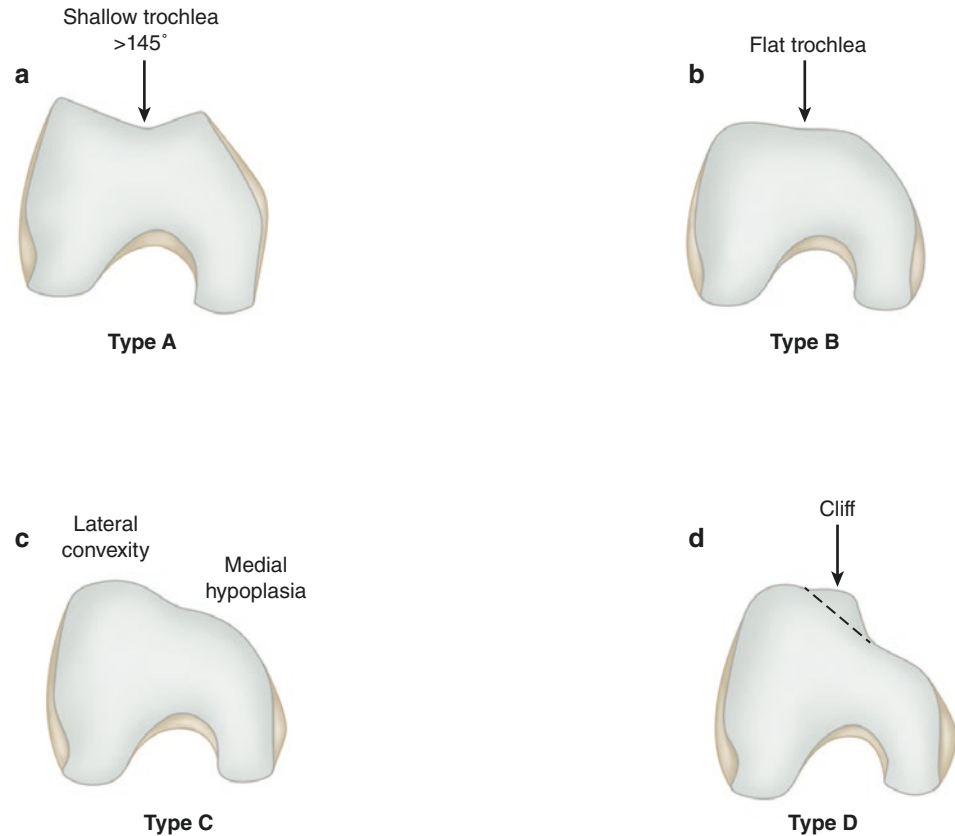


Fig. 4.3 The **sulcus angle** is a measure of the angle between the medial and lateral facets of the trochlea. It is an indicator of the depth of the trochlea. The normal value is $135^\circ \pm 10^\circ$

Fig. 4.4 Trochlear dysplasia as classified by Dejour: (a) Normal shape of the trochlea, but a shallow trochlear groove; (b) markedly flattened, or even convex, trochlea; (c) trochlear facet asymmetry with high lateral facet and hypoplastic medial face; (d) type C features and a vertical link between facets (“cliff pattern”)



4.2 Static Measurements

The **quadriceps (Q) angle** is a clinical measurement formed by a line drawn from the anterior iliac spine to the center of the patella and the center of the patella to the tibial tuberosity (see Fig. 4.5). The Q-angle is greater in extension than in flexion because of the screw-home mechanism, whereby the tibia rotates externally as the knee goes into complete extension. Different values for Q-angle have been reported in literature. The normal range of the Q-angle is 12–20°, though some studies consider values between 8 and 10° to be normal. In general, males show lower Q-angle values than females [6].

The **tibial tuberosity to trochlear groove (TT-TG)** distance is a radiographic measurement of the distance between the tibial tuberosity (TT) and the deepest point of the trochlear groove (TG) on axial images [7, 8] (see Fig. 4.6). Originally described on computed tomography with the knee in extension, normal range of the TT-TG distance value varies among studies performed in Europeans or North Americans from 9.4 ± 0.6 mm to 13.6 ± 8.8 mm [10–12]. Values can be influenced by imaging modalities, knee flexion, or measurement techniques and should be considered when utilizing this measurement for clinical decision-making.

Patella alta is an abnormally high patella (see Fig. 4.7).

Patella baja (*patella infera*) is an abnormally low patella. This finding is typically iatrogenic or post-traumatic in nature (see Fig. 4.8) [13].

Several radiographic measurements have been described to assess the height of the patella. The **Insall-Salvati index** [14, 15] is a ratio of the length of the patella tendon to the length of the patella. The normal ratio is 0.8–1.2 [13, 16] (see Fig. 4.9). The **Caton-Deschamps** index [17, 18] allows for measurement of patellar height independent of the position of the tibial tuberosity. A ratio of greater than 1.2 can be indicative of patella alta.

Lateral **patellar tilt** has been associated with anterior knee pain [19]. Increased tilt and lateral retinacular tightness may be identified by decreased medial excursion of the patella, as well as inability to medially tilt the patella. Lateral patellar compression syndrome has been described in association with this finding, but its diagnosis as a clinical entity has not clearly been supported. Whereas lateral retinacular release had previously been recommended for correction of lateral tilt, this operation has been discredited and largely fallen out of favor [20].

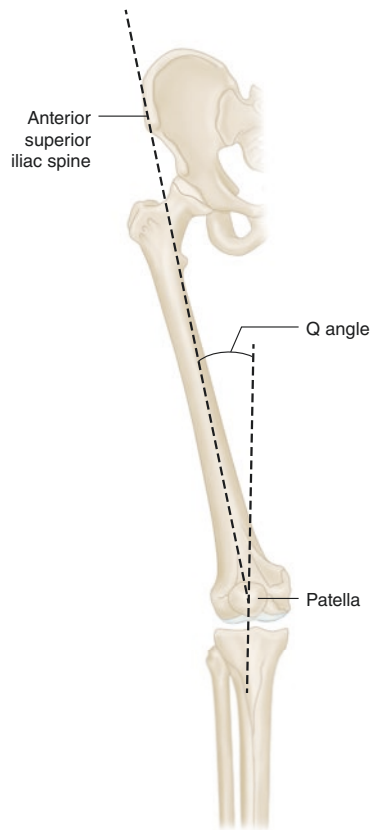


Fig. 4.5 The **quadriceps (Q) angle** is a clinical measurement formed by a line drawn from the anterior iliac spine to the center of the patella and the center of the patella to the tibial tuberosity

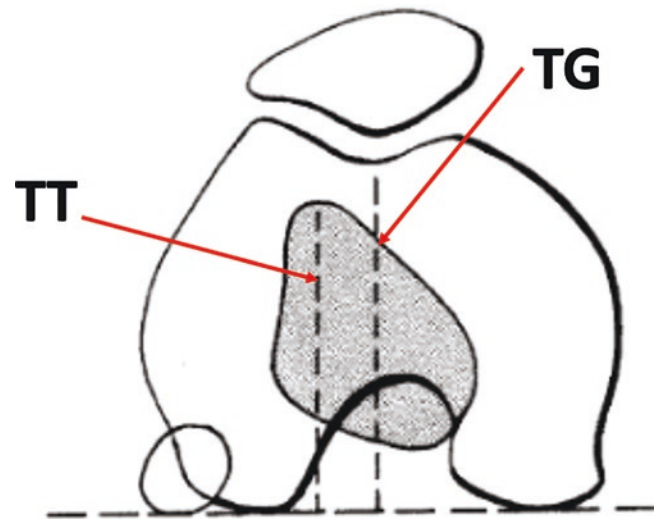


Fig. 4.6 The tibial tuberosity to trochlear groove (**TT-TG**) distance is a radiographic measurement of the distance between the tibial tuberosity (**TT**) and the deepest point of the trochlear groove (**TG**) on axial images



Fig. 4.7 **Patella alta**—a high-riding patella

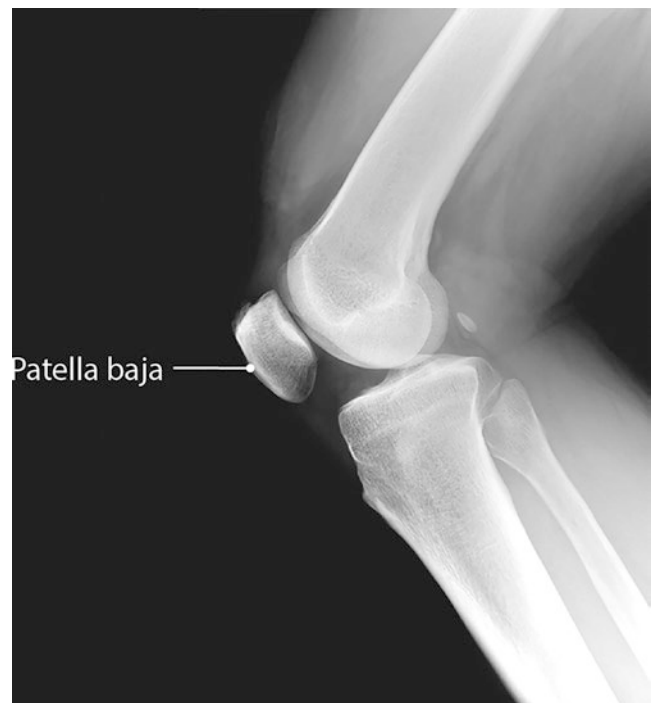


Fig. 4.8 **Patella baja** (*patella infera*) is an abnormally low-riding patella



Fig. 4.9 The **Insall-Salvati index** is a ratio of the length of the patella tendon to the length of the patella. The normal ratio is 0.8–1.2

4.3 Dynamic Assessment of Patellofemoral Articulation

The alignment of the patellofemoral joint changes as the tibia rotates internally and externally. The effect of this rotational change on stability of the patella can be demonstrated clinically with the **tibial external rotation test (TERT)** [9] (see Fig. 4.10). The TERT can simulate the result of surgery to medialize the tibial tuberosity.

4.4 Soft Tissue Stabilizers—Medial

The **deep fascia** of the anterior knee envelops the extensor mechanism but does not attach to the patella. It passes over the anterior surface of the patella, where it splits to form the pre-patellar bursa (see Fig. 4.11).

Deep to the deep fascia medially is the **medial patellar retinaculum**. It is a fibrous expansion of the medial parapatellar connective tissues. The superficial layer of the medial patellar retinaculum is composed of vertical fibers that are continuations of the vastus medialis tendon (see Fig. 4.12). Deep to this are horizontal fibers that make up the **medial patellofemoral complex** (see Figs. 4.13 and 4.14). The deepest layer is the **medial capsule** (see Fig. 4.15). All three layers merge as they attach to the medial border of the patella (see Fig. 4.16).

Terminology – A Note from the Editors

Strictly speaking, the term “**medial patellofemoral complex (MPFC)**” is not a correct anatomical term. When used as a noun, a “complex” is “a whole made up of complicated or interrelated parts.”

The fibrous structure that connects the femur to the medial aspect of the patella is the **medial patellofemoral ligament (MPFL)**. A portion of the MPFL usually attaches to the medial aspect of the distal quadriceps tendon, so “MPFL” could be a misnomer.

In this chapter the authors make the distinction between the two attachments of the ligament and call it MPFC. However, common usage refers to it as MPFL, which we do in other parts of this atlas.

The **medial patellofemoral ligament complex (MPFC)** is composed of transverse thickenings of the proximal medial retinaculum [21–24] (see Figs. 4.17 and 4.18). The attachment of the MPFC to the quadriceps tendon and patella is broad and measures 30 mm in length [25–27]. The proximal part of the MPFC attaches to the medial distal edge of the quadriceps tendon and has been called the medial quadriceps tendon femoral ligament (MQTFL). It can be thought of as the tendinous attachment of the medial patellofemoral ligament. The distal part of the MPFC attaches to the proximal one-third of the medial border of the patella and is properly called the **medial patellofemoral ligament (MPFL)**. The two parts are contiguous and have been collectively called the **medial patellofemoral complex (MPFC)** [28].

The MPFC is very thin and measures only 0.6 mm in thickness (see Fig. 4.19).

The main blood supply to the medial retinaculum comes from the descending genicular artery, which courses along the medial edge of the adductor magnus tendon (see Fig. 4.20). A branch of this artery passes under the MPFC (see Fig. 4.21).

The MPFC serves as the primary static stabilizer to lateral patellar translation, and reconstruction of this ligament has been shown to have good results in the treatment of patellar instability [23, 24, 29]. The variable and complex anatomy of this ligament has led to multiple variations in reconstructive techniques. In a cadaveric study of 33 knees, 57.3% of the fibers attaching to the extensor mechanism were found to attach to the patella, whereas the rest attached to the quadriceps tendon [27]. However, this study also noted considerable variability in the distribution of these fibers, with one knee having 100% of its fibers attaching to the patella, and another with 100% of its fibers attaching to the quadriceps tendon. Despite the broad and variable attachment of this ligament to the extensor mechanism, the midpoint of the MPFC has been described to be consistently at the junction of the medial border of the quadriceps tendon and the articu-

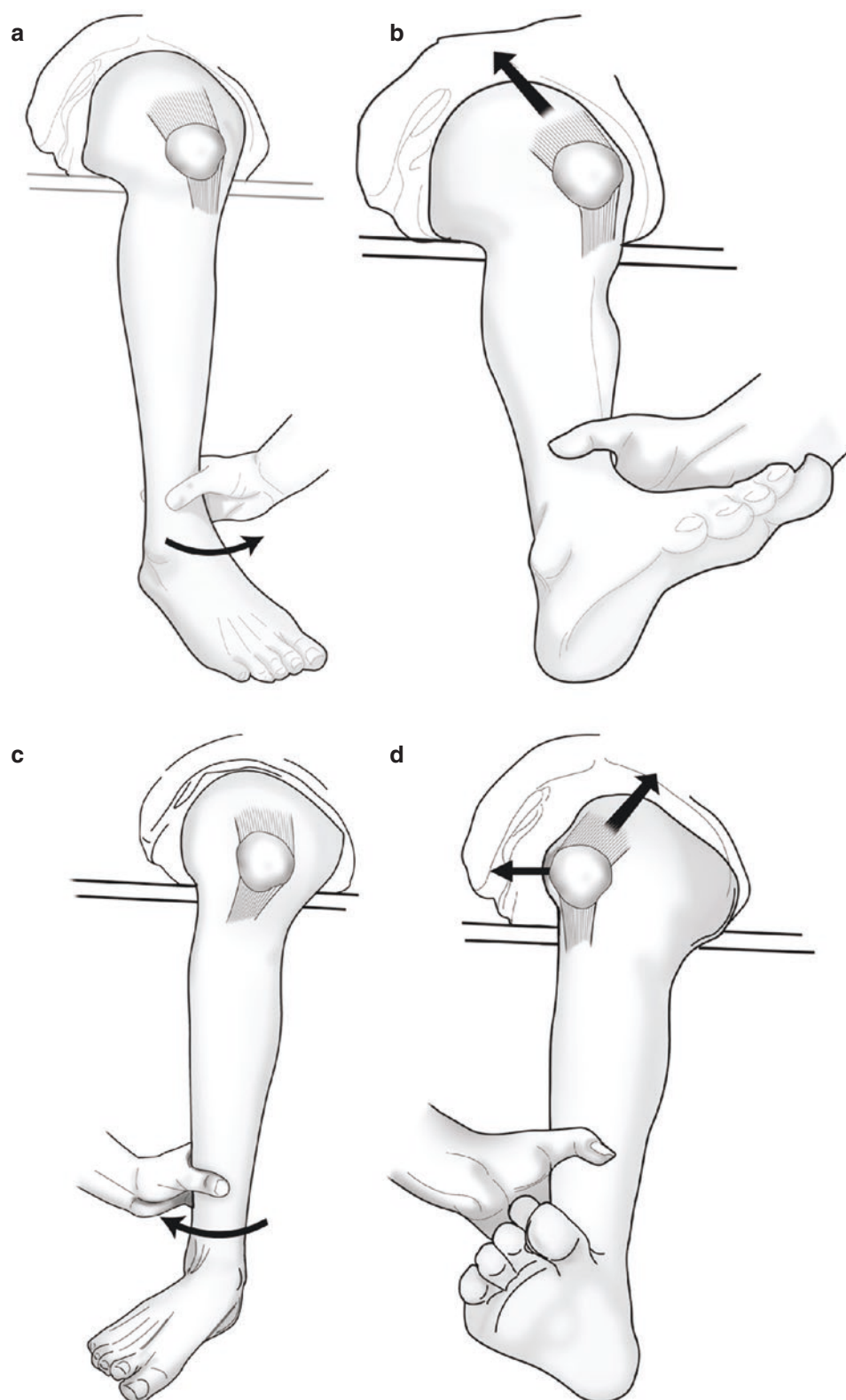


Fig. 4.10 The Q-angle, changes when the tibia rotates internally (a) and externally (c). The effect of this rotational change on stability of the patella can be demonstrated clinically with the **tibial external rotation test (TERT)**. With the tibia held in internal rotation (b), the patient actively extends the knee against the examiner's resistance. In a positive

TERT test, as the knee approaches full extension, the patella subluxates laterally or the patient feels apprehensive that it might subluxate (d). The TERT can simulate the result of surgery to medialize the tibial tuberosity [Reprinted from Zarins B. Tibial External Rotation Test for Patellar Instability. *J Bone Jt Surg.* 2022;104:e16 with permission]

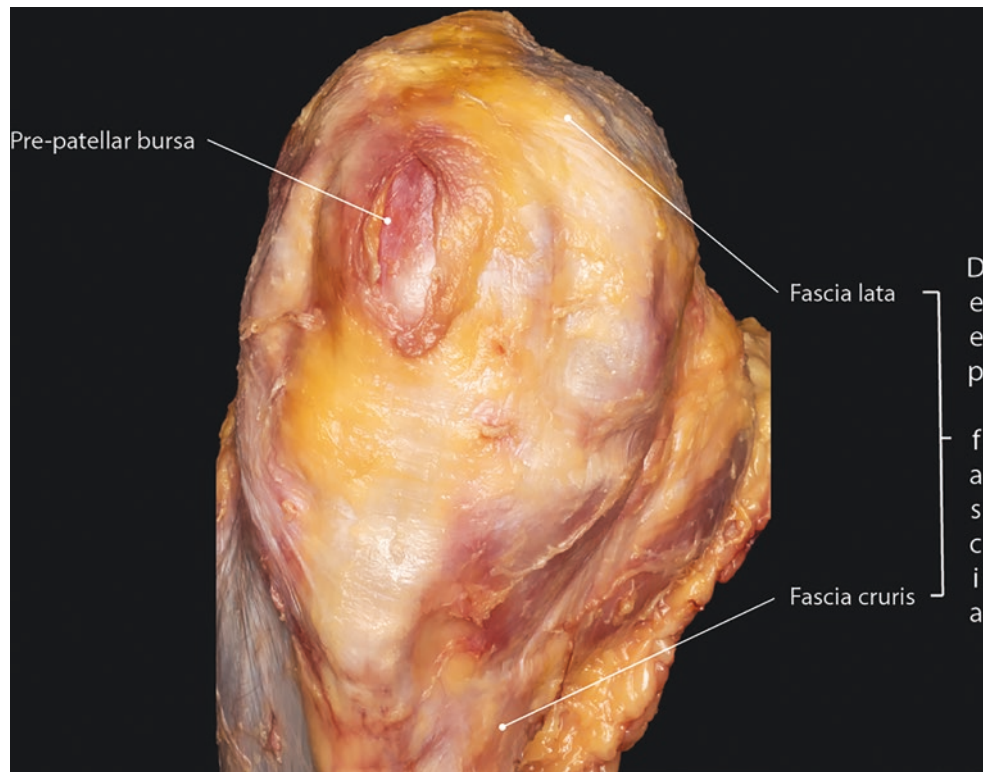


Fig. 4.11 The **deep fascia** of the anterior knee does not attach directly to the patella. It passes over the anterior surface of the patella, where it splits to form the pre-patellar bursa

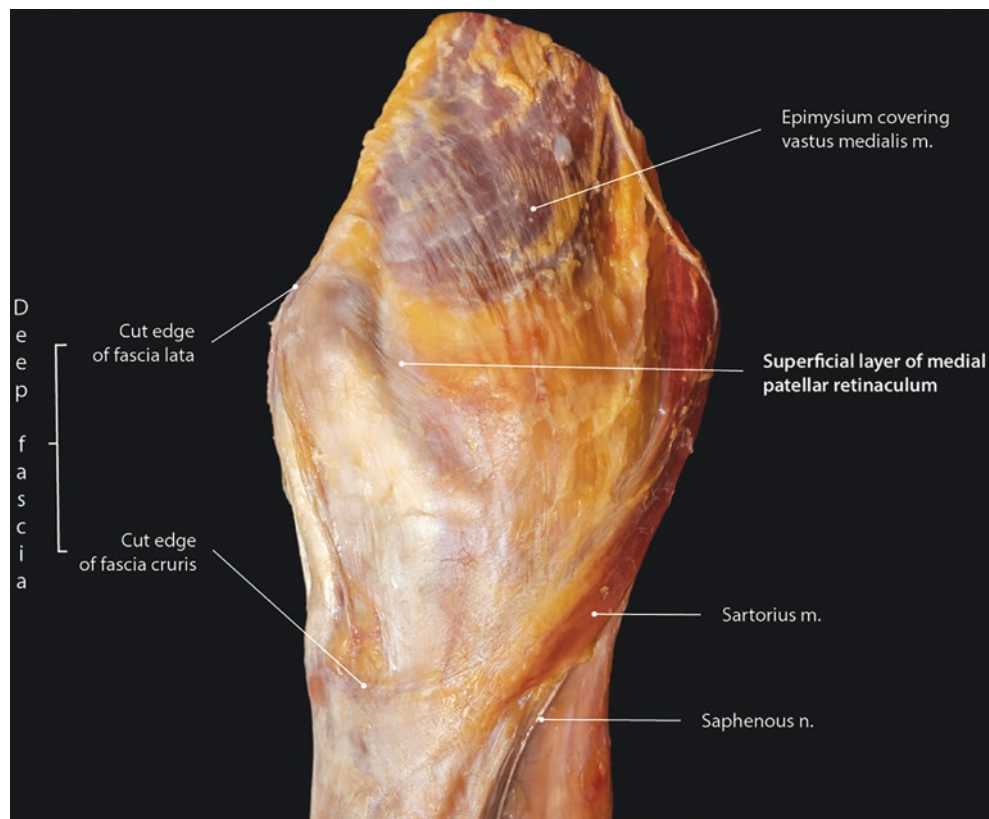


Fig. 4.12 The deep fascia has been removed revealing the **superficial layer of the medial patellar retinaculum**



Fig. 4.13 Horizontal fibers of the **medial patellofemoral complex** make up the middle layer of the medial patellar retinaculum

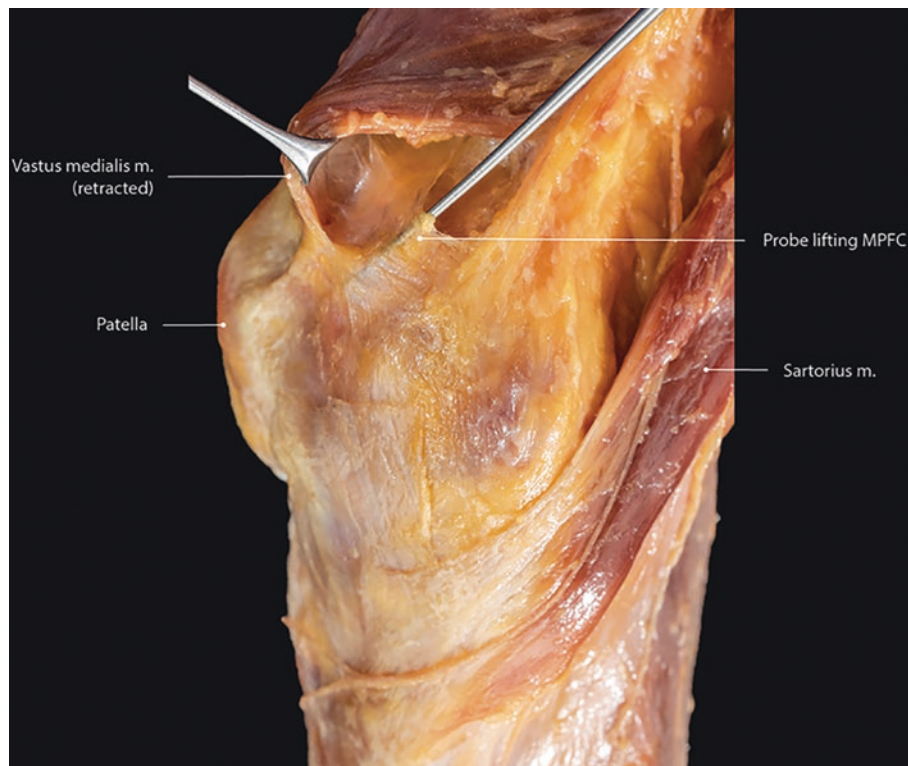


Fig. 4.14 Right knee, anteromedial aspect. The vastus medialis muscle is retracted. The medial patellofemoral complex (MPFC) is lifted with a probe

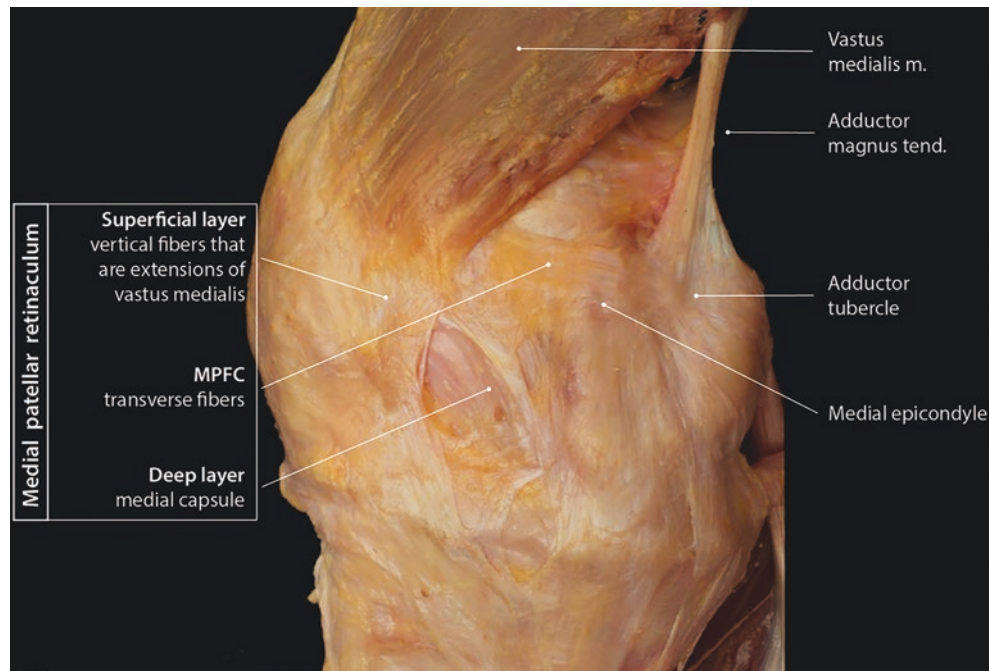


Fig. 4.15 Medial patellar retinaculum: The superficial layer consists of vertical fibers that are continuous with the vastus medialis tendon. Deep to it are transverse fibers that make up the medial patellofemoral

complex (MPFC). The deep layer is the medial capsule (*From Ge et al. [21]; with permission*)

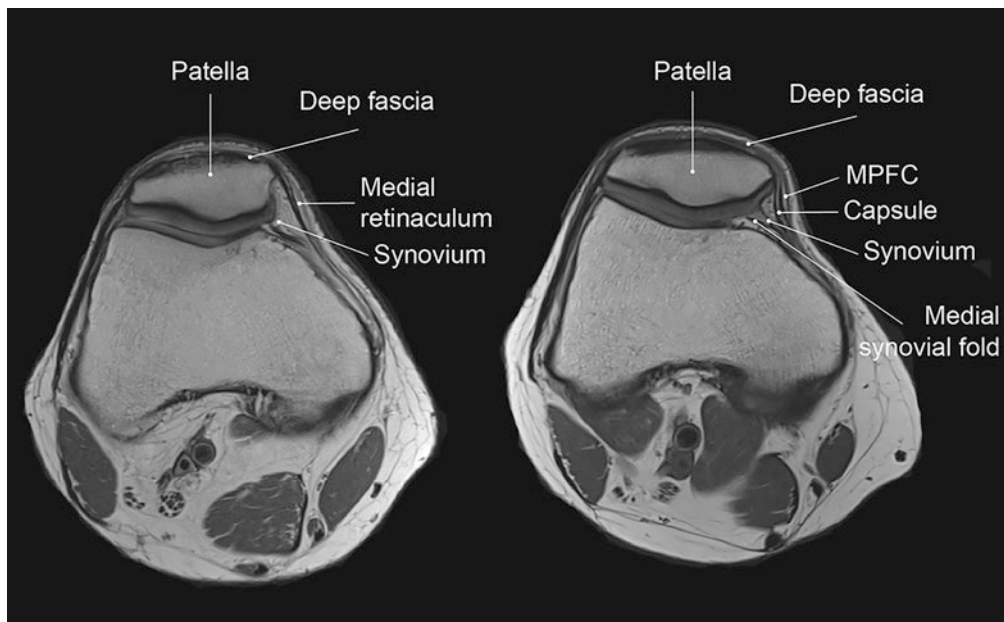


Fig. 4.16 MRI images of right knee showing medial patellar retinaculum

lar surface of the patella [28]. This implies that a single bundle graft may be secured to the patella or to the quadriceps tendon during anatomic reconstruction of this ligament, and that this surgical landmark may be used for identification of the anatomic midpoint [30].

The MPFC can be found in the middle layer of the medial patellar retinaculum. The fibers can be visualized on the undersurface of the vastus medialis obliquus (VMO) and are

directly adherent to the VMO aponeurosis. They can be separated from the synovial layer. During MPFC reconstruction, the graft is placed between these layers to recreate the anatomy of this ligament.

On the femoral side, the MPFC attaches to the femur in a shallow depression just posterior to the medial epicondyle and distal to the adductor tubercle. This location has been described to be 14.9 mm from the medial epicondyle,

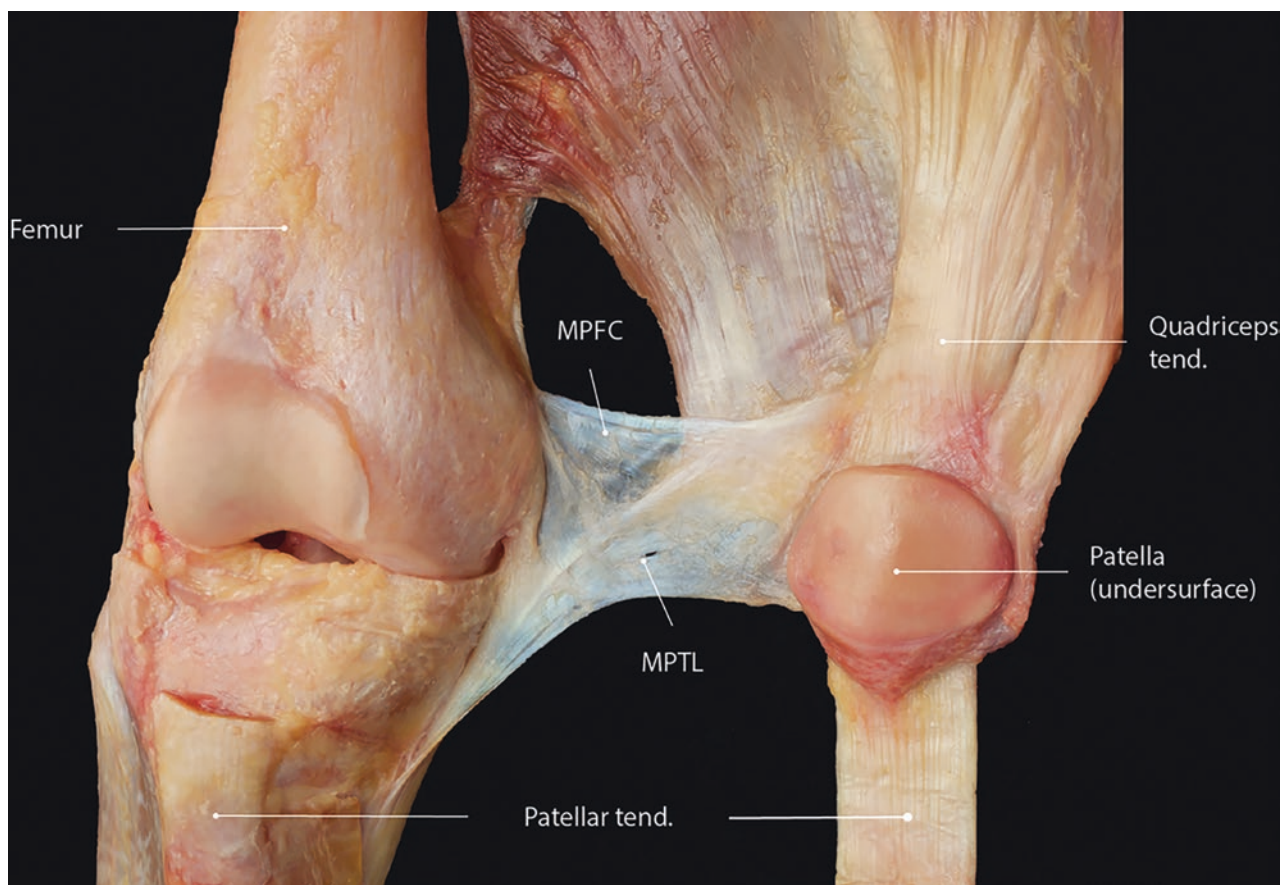


Fig. 4.17 Anterior view of the knee with the patella rotated away to show the medial patellofemoral ligament complex (MPFC) and medial patellotibial ligament (MPTL). They are the main stabilizing soft tissues of the patella medially (*From Ge et al. [21]; with permission*)

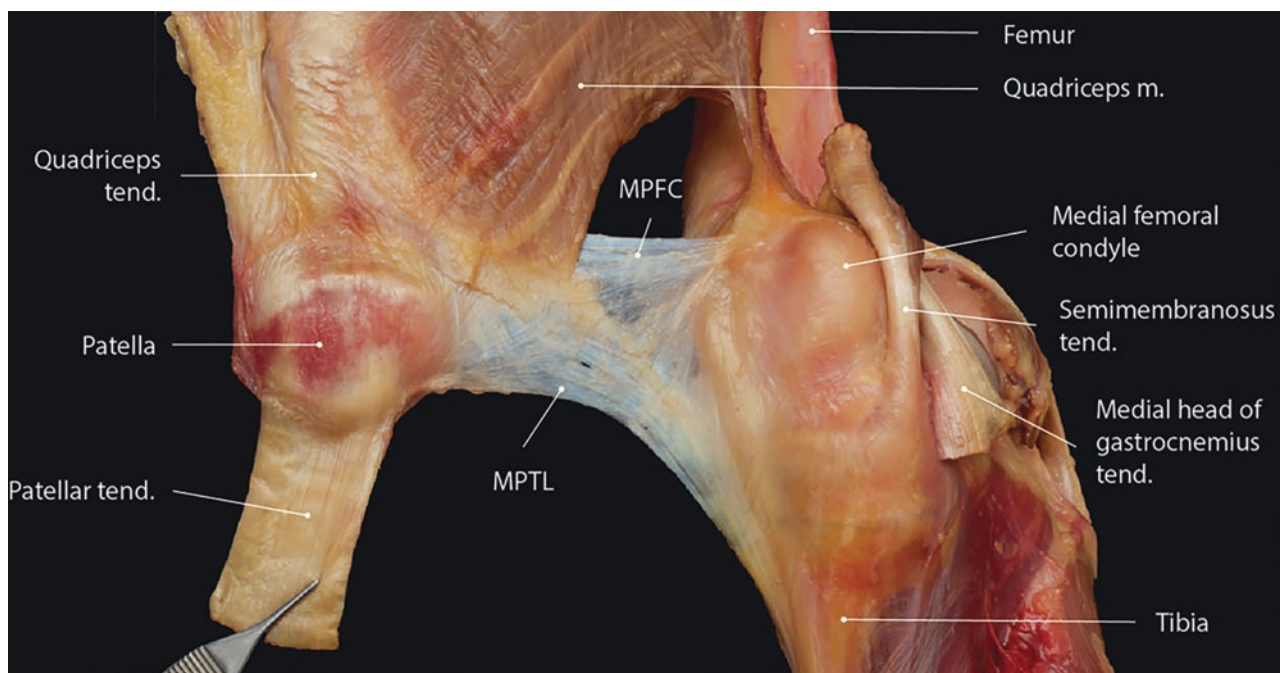


Fig. 4.18 Anterior view of the patella with tibia rotated away to show the attachments of the medial patellofemoral complex (MPFC) and medial patellotibial ligament (MPTL)

10.4 mm from the adductor tubercle, and 11.1 mm from the gastrocnemius tubercle [31]. Fujino [32] has described the center of the MPFC footprint to be consistently 1 cm distal to the adductor tubercle, which can be a helpful surgical landmark during surgical reconstruction. However, this anatomic location may be difficult to identify, and intraoperative radiographs can be helpful to ensure ana-

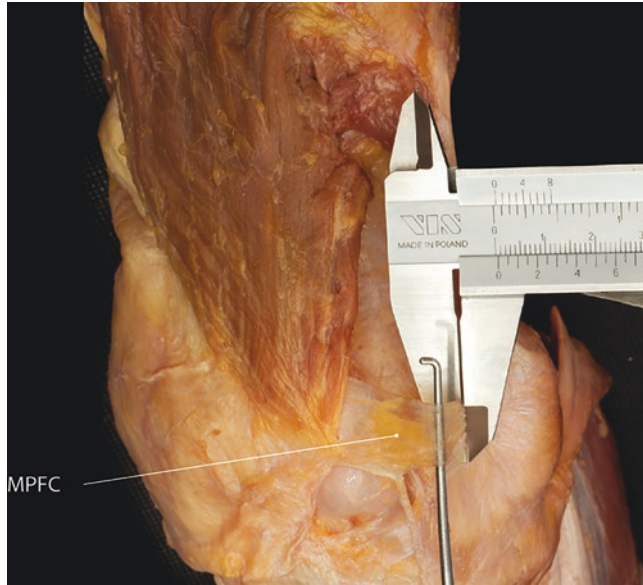


Fig. 4.19 The medial patellofemoral complex (MPFC) has been lifted with a probe. It measures only 0.6 mm in thickness (From Ge et al. [21]; with permission)

tomic reconstruction [33]. The commonly cited radiographic position by Schottle represents the midpoint of the femoral attachment as 1.3 mm anterior to the posterior cortical line and 2.5 mm distal to the proximal posterior femoral condyle [34]. In addition to its bony attachments, soft tissue attachments to the medial collateral ligament (MCL) and adductor tendon have been noted. The femoral footprint has been described as ribbon shaped, with a length of 11.7 mm and a width of 1.7 mm, with a thickness of 0.6 mm at the mid-substance of the ligament [21, 35]. The length of the femoral footprint suggests that the optimal location for anatomic reconstruction on the medial femur extends beyond a single “point” [36].

The **medial patellotibial ligament** is a secondary distal restraint to lateral patellar translation. It is an oblique thickening of the retinaculum, comprised of the medial patellotibial ligament (MPTL) (see Figs. 4.17 and 4.18) and the medial patellomeniscal ligament (MPML). This combination of distal ligaments attaches to the inferior third of the patella anteriorly and to the anterior portion of the coronary ligament (which is attached to the medial meniscus) and tibia. The MPTL attaches 3.1 mm from the medial part of the tibial tuberosity. The MPML runs deep to the MPTL, attaching to the anterior horn of the medial meniscus. It is adherent to the medial joint capsule [31, 37–39]. The MPTL fibers have been shown to run posterior to the patellar tendon fibers, supporting the reconstruction technique that utilizes the medial third of the patellar tendon.

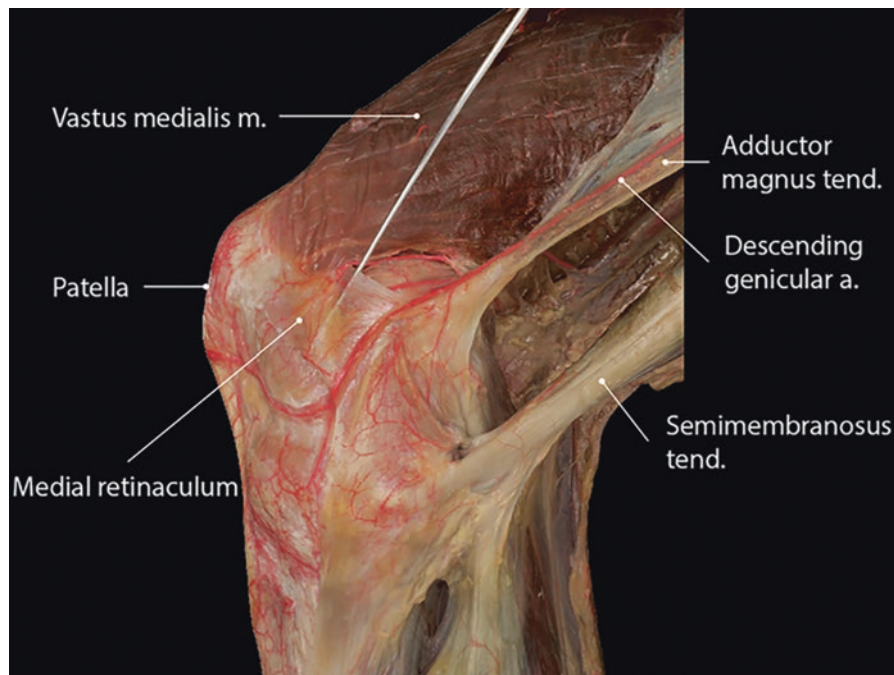


Fig. 4.20 The main circulation to the medial retinaculum comes from the descending genicular artery, which courses along the medial edge of the adductor magnus tendon. The probe is lifting the medial patellofemoral complex

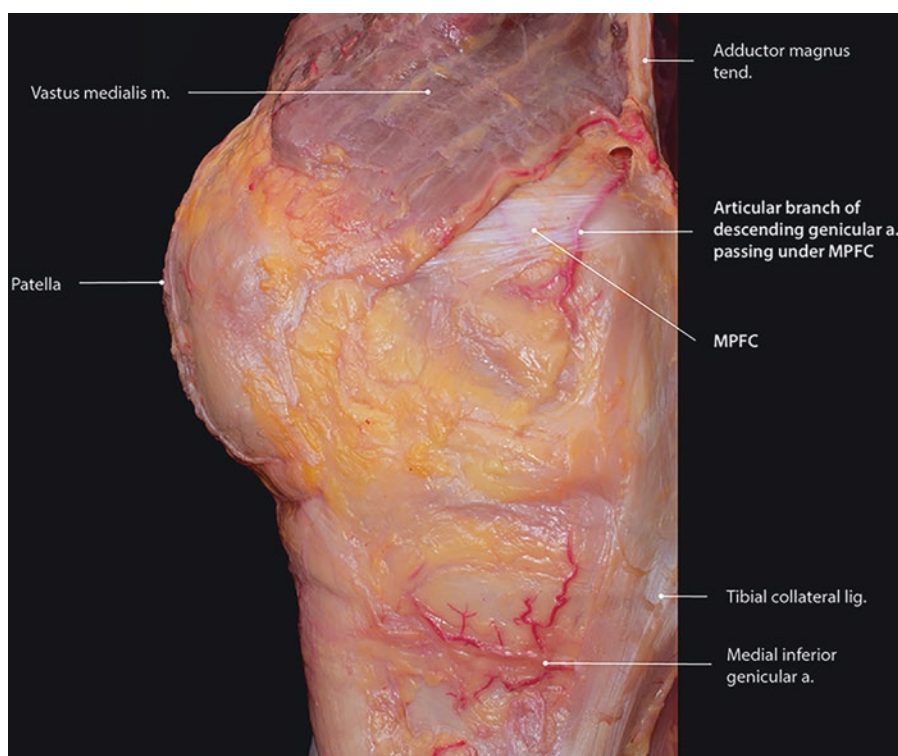


Fig. 4.21 A branch of the descending genicular artery passes under the medial patellofemoral complex (MPFC)

4.5 Soft Tissue Stabilizers—Lateral

As on the anteromedial side of the knee, the deep fascia anterolaterally does not attach directly to the patella but passes over its anterior surface (*refer to Chap. 7*) (*see Fig. 4.22*).

The underlying **lateral patellar retinaculum** varies in thickness in various parts. The superficial layer is an extension of the fascia lata (*see Figs. 4.22 and 7.6*). Thick horizontal fibers constitute the **lateral patellofemoral ligament (LPFL)** and **lateral patellotibial ligament (LPTL)** (*see Figs. 4.23 and 4.24*). The tendinous aponeurosis of the vastus lateralis muscle inserts onto the lateral border of the patella, blending with the quadriceps femoris tendon. The deepest layer is the **joint capsule**. At the lateral border of the patella, the layers blend into one, but posteriorly the deepest layer continues as the capsule (*see Fig. 4.24*).

The LPFL is a condensation of retinacular fibers that extend from the lateral femur to the central portion of the lateral border of the patella, with a broad attachment of 22.5 mm [40]. The lateral fibrous tissues contribute to stabilizing the patella against lateral translation, in addition to medial translation [41]. Cancienne et al. demonstrated in a cadaveric study that release of the lateral retinaculum can result in increased lateral patellar translation by 30% [42]. A study using a computational model also demonstrated that lateral release could lead to multidirectional patellar instability [43]. Therefore, a lateral release should not be performed for the treatment of patellar instability. In the setting

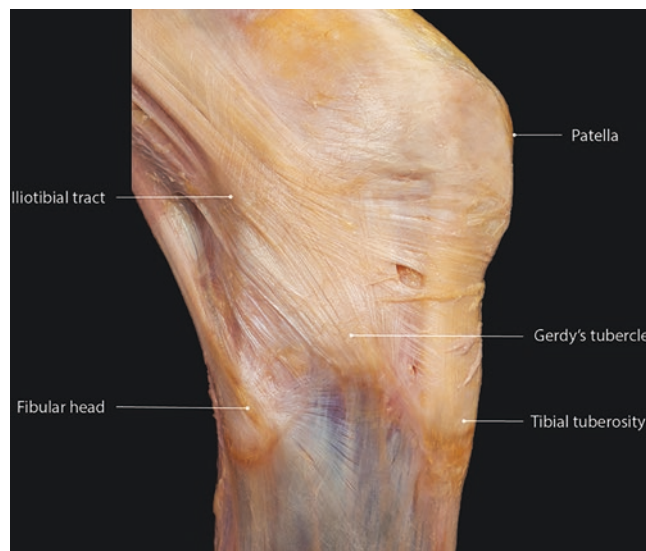


Fig. 4.22 The deep fascia of the thigh is the fascia lata. Laterally it is called the iliotibial tract (ITT or band) (ITB). The superficial fibers of the ITT do not attach directly to the patella but pass over its anterior surface

of an overly tight lateral retinaculum, lateral lengthening can be performed to avoid the risk of medial instability.

The **lateral patellotibial ligament** extends from the distal patella to the tibia, attaching proximal and medial to Gerdy's tubercle, 8.1 mm from the tuberosity [40]. If a lateral retinacular release is done distal to the articular border of the patella, the LPTL is cut. This can lead to medial patellar instability.

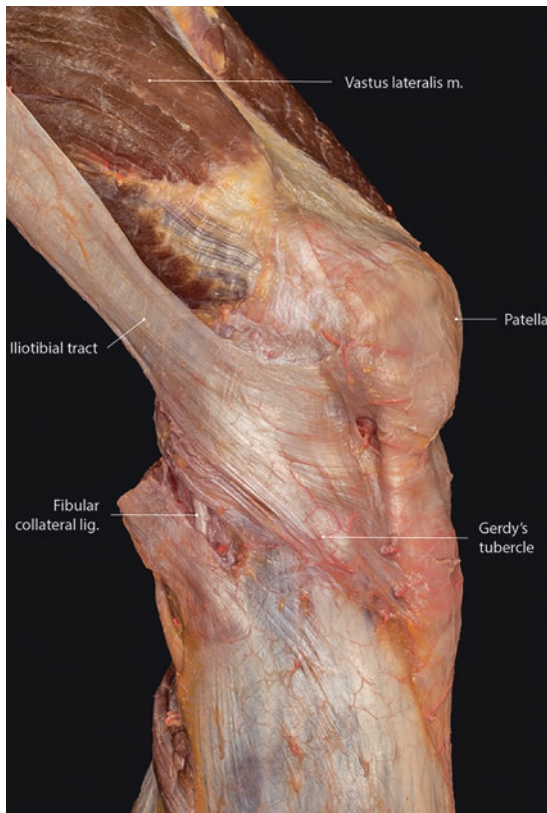


Fig. 4.23 Right knee, lateral aspect. The fascia lata has been removed except for the posterior fibers of the iliotibial tract (ITT). They continue as the superficial fibers of the lateral patellar retinaculum

4.6 Patellofemoral Contact Areas

A maximum of two patellar facets can be in contact with the femur at any one time.

When the knee is extended (0° flexion), the inferior pole of the articular surface of the patella contacts the proximal edge of the trochlear surface of the femur (see Figs. 4.25 and 4.26). At 30° flexion, the contact area moves proximally on the patella and distally on the trochlea (see Figs. 4.27 and 4.28). At 45° flexion, the mid portion of the patella articulates with the mid portion of the trochlea (see Figs. 4.29 and 4.30). At 60° knee flexion, the patellofemoral contact areas are larger and have moved further distally (see Figs. 4.31 and 4.32). At 90° flexion, the patella articulates with the distal femoral trochlea, just above the intercondylar notch (see Figs. 4.33 and 4.34). At 120° flexion, most of the contact is between the lateral facet of the patella and the corresponding lateral femoral condyle (see Figs. 4.35 and 4.36). Finally, at 135° flexion, the odd facet of the patella is in contact with the medial intercondylar notch. The lateral facet of the patella articulates with the inner part of the lateral femoral condyle (see Figs. 4.37 and 4.38). These descriptions are based on normal anatomy in static positions, and further studies are needed to identify patterns in contact areas in knees with patellofemoral pathology.

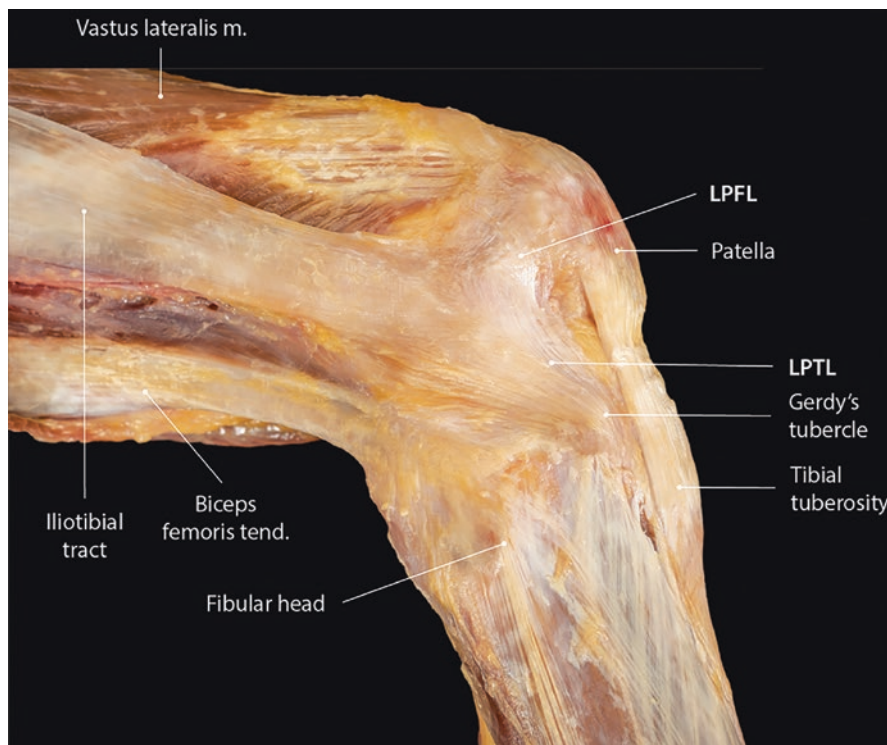


Fig. 4.24 Lateral aspect of knee in flexion with most of the fascia lata removed showing the lateral patellofemoral ligament (LPFL) and lateral patellotibial ligament (LPTL). The deep fibers of the iliotibial tract remain

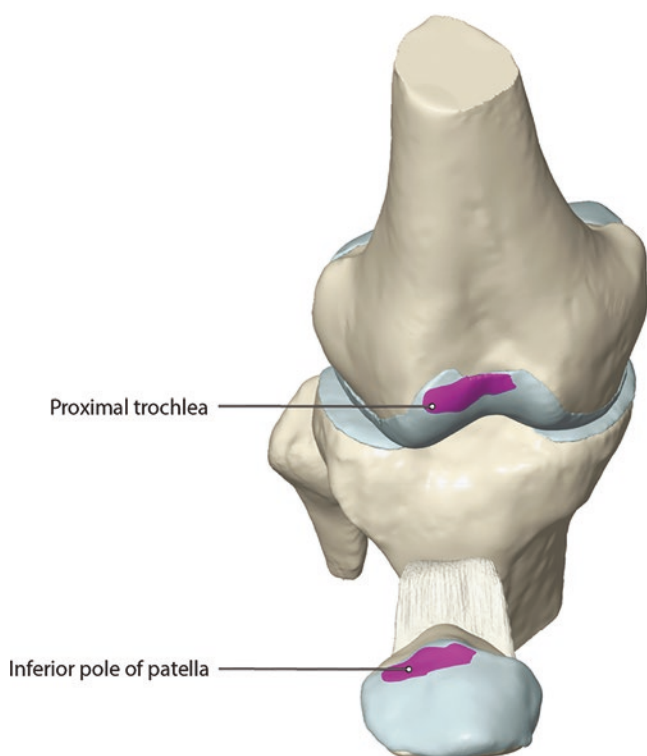


Fig. 4.25 In extension (0° flexion), the inferior articular surface of the patella contacts the superior edge of the trochlea

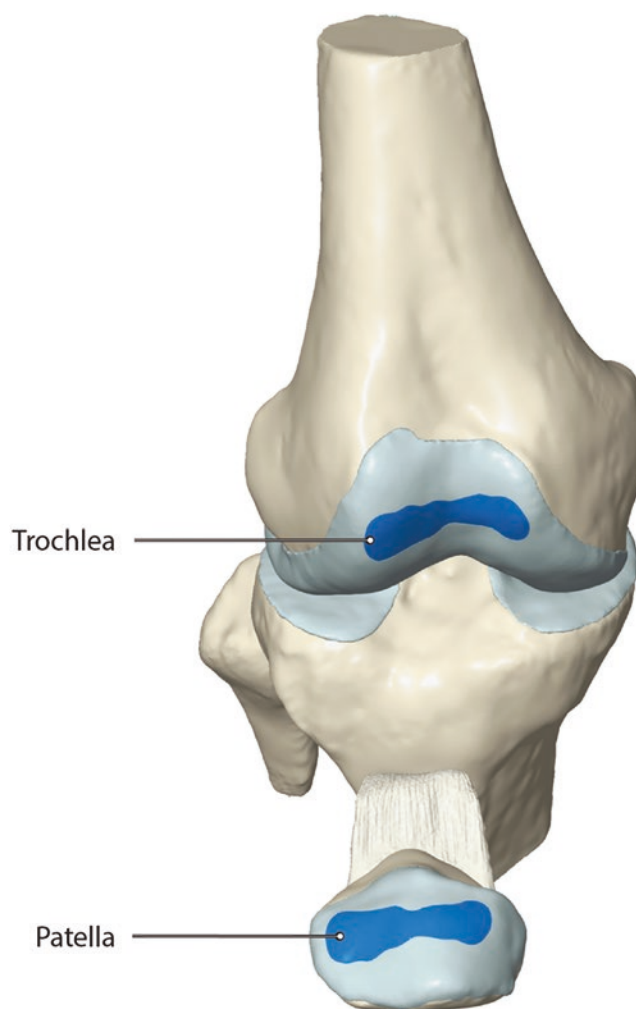


Fig. 4.27 At 30° flexion, the contact area has moved up on the patella and down on the trochlea

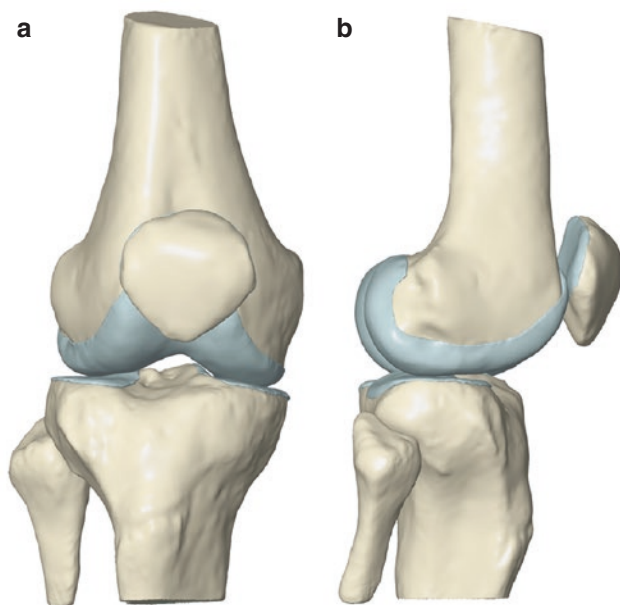


Fig. 4.26 In extension (0° flexion), the inferior pole of the articular surface of the patella is in contact with the upper trochlear surface of the femur. (a) Anterior and (b) lateral

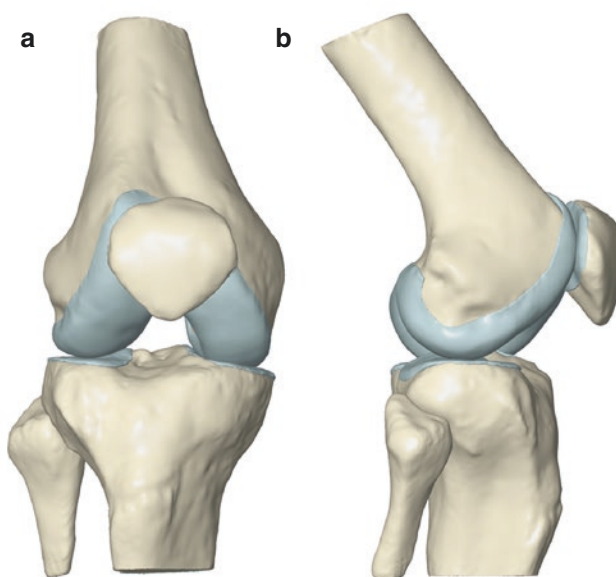


Fig. 4.28 At 30° flexion, the contact area has moved proximally on the patella and distal on the trochlea. (a) Anterior and (b) lateral

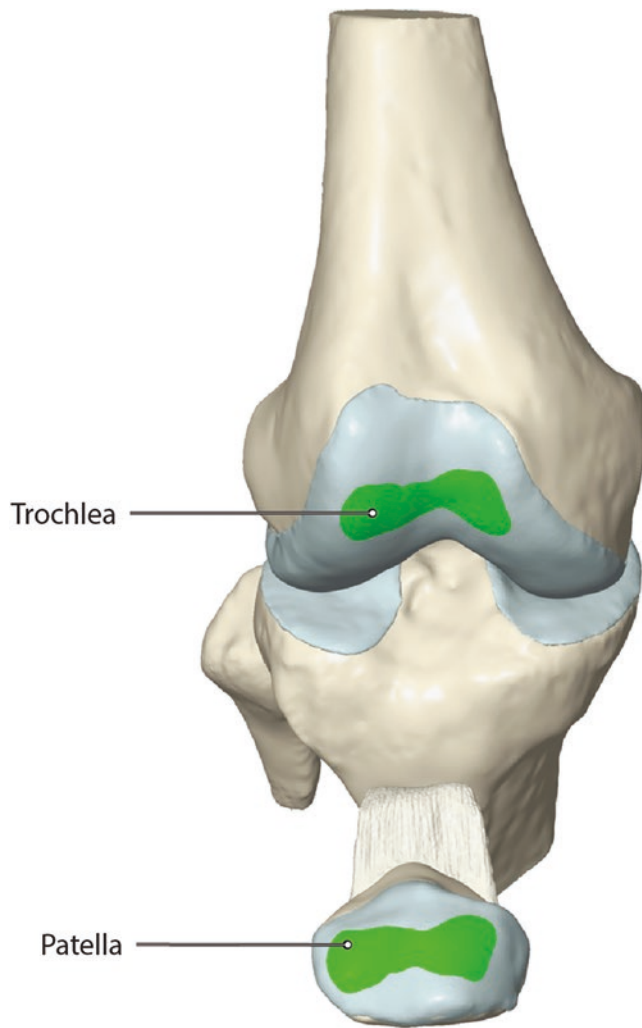


Fig. 4.29 At 45° flexion, the mid portion of the patella articulates with the mid portion of the trochlea

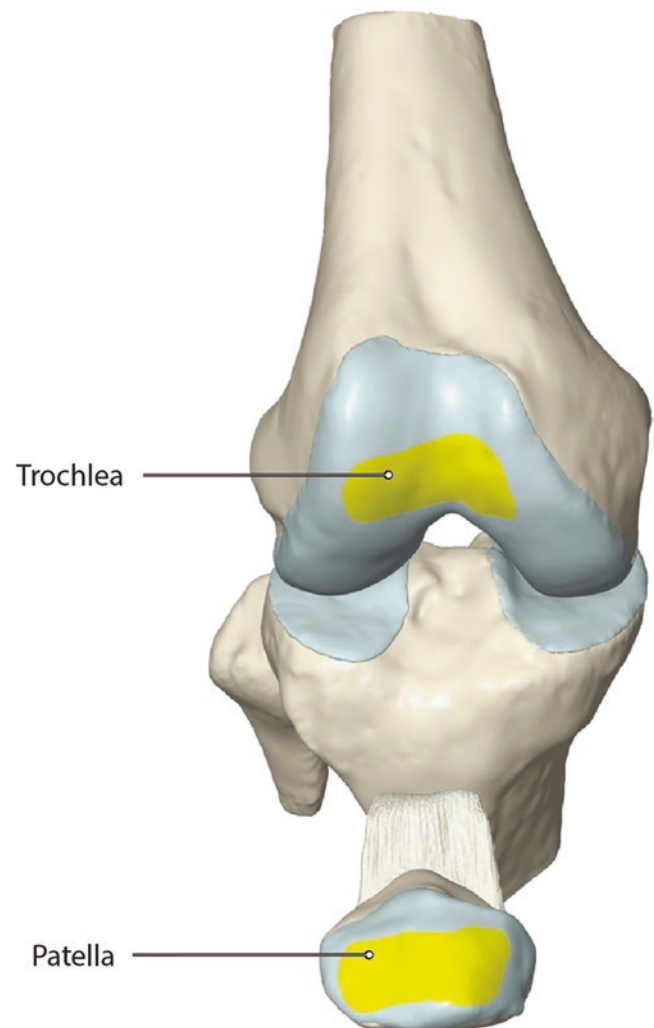


Fig. 4.31 At 60° flexion, the patellofemoral contact areas are larger and have moved a little further

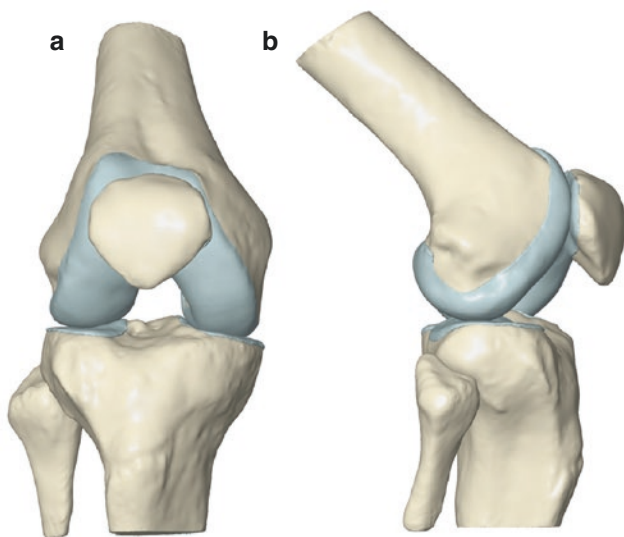


Fig. 4.30 When the knee is at 45° flexion, the mid portion of the patella articulates with the mid portion of the trochlea. (a) Anterior and (b) lateral

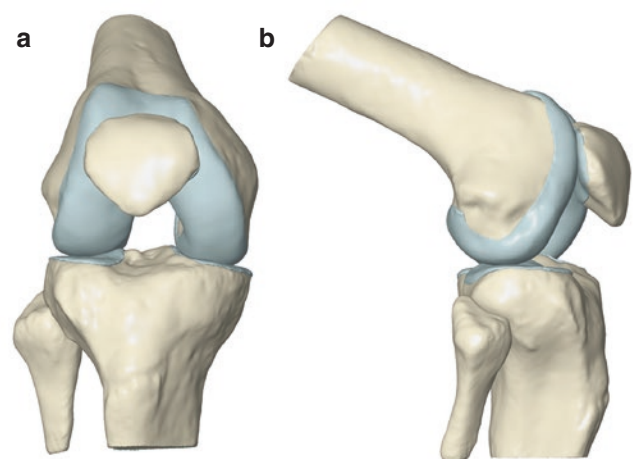


Fig. 4.32 At 60° flexion, the patellofemoral contact areas are larger and have moved down a little further. (a) Anterior and (b) lateral

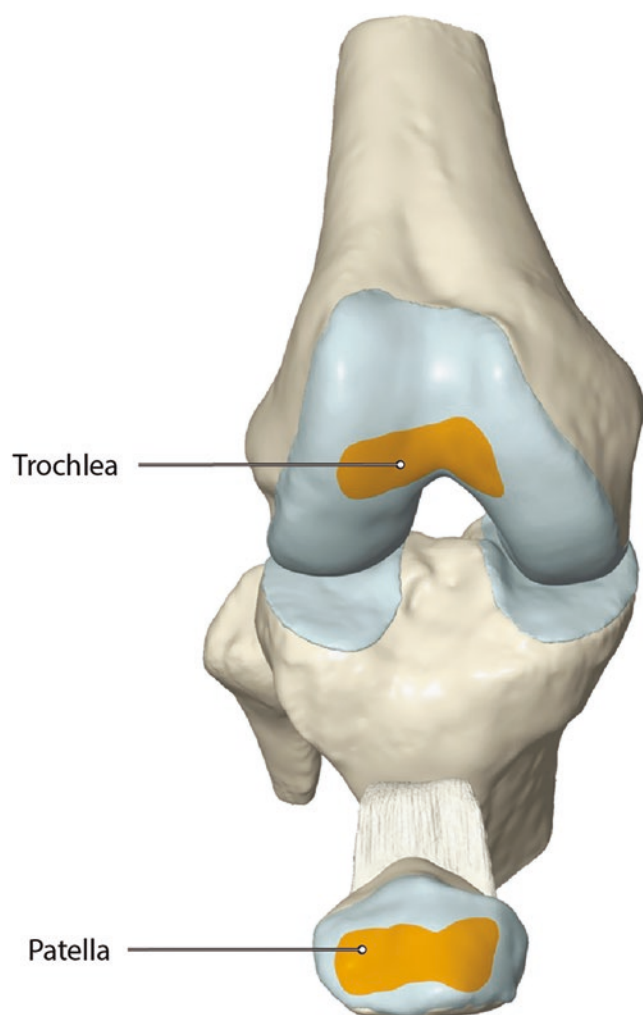


Fig. 4.33 At 90° flexion, the patella articulates with the distal femoral trochlea, just above the intercondylar notch

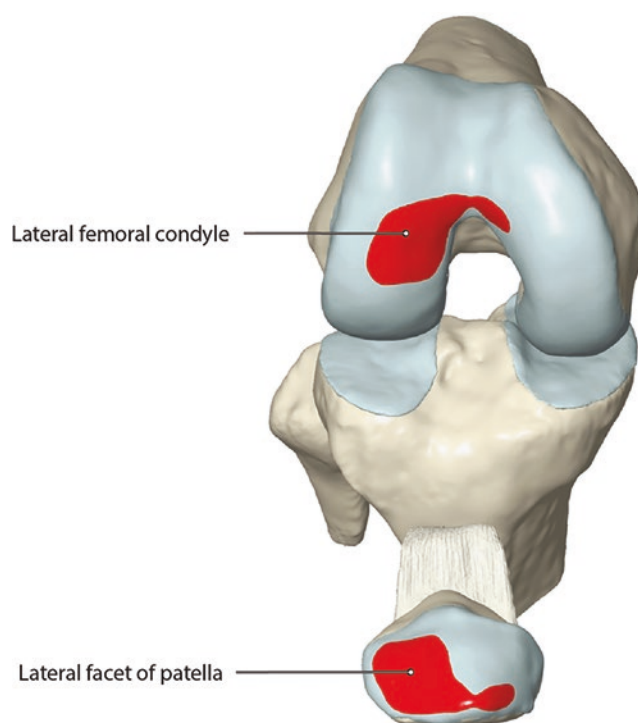


Fig. 4.35 At 120° flexion, most of the contact is between the lateral facet of the patella and the corresponding lateral femoral condyle

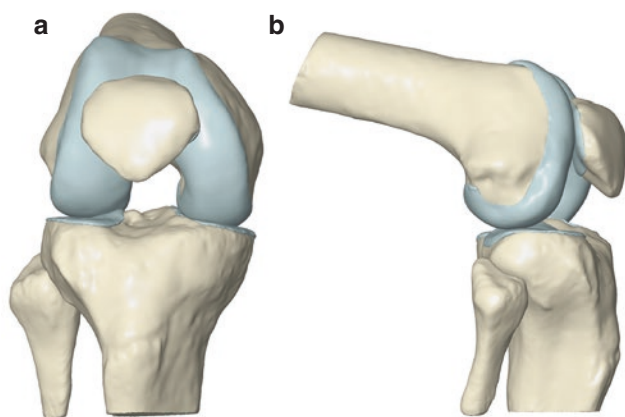


Fig. 4.34 At 90° flexion, the patella articulates with the lower femoral trochlea, just above the intercondylar notch. (a) Anterior and (b) lateral

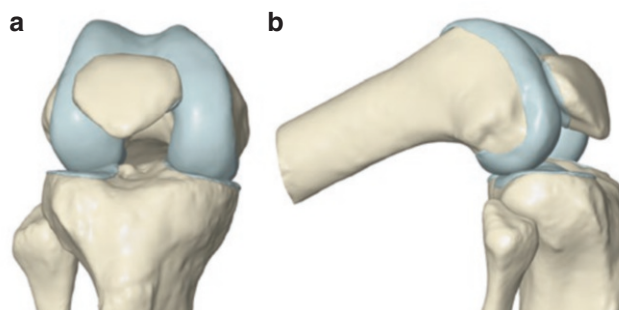


Fig. 4.36 At 120° flexion, most of the contact is between the lateral facet of the patella and the corresponding lateral femoral condyle. (a) Anterior and (b) lateral

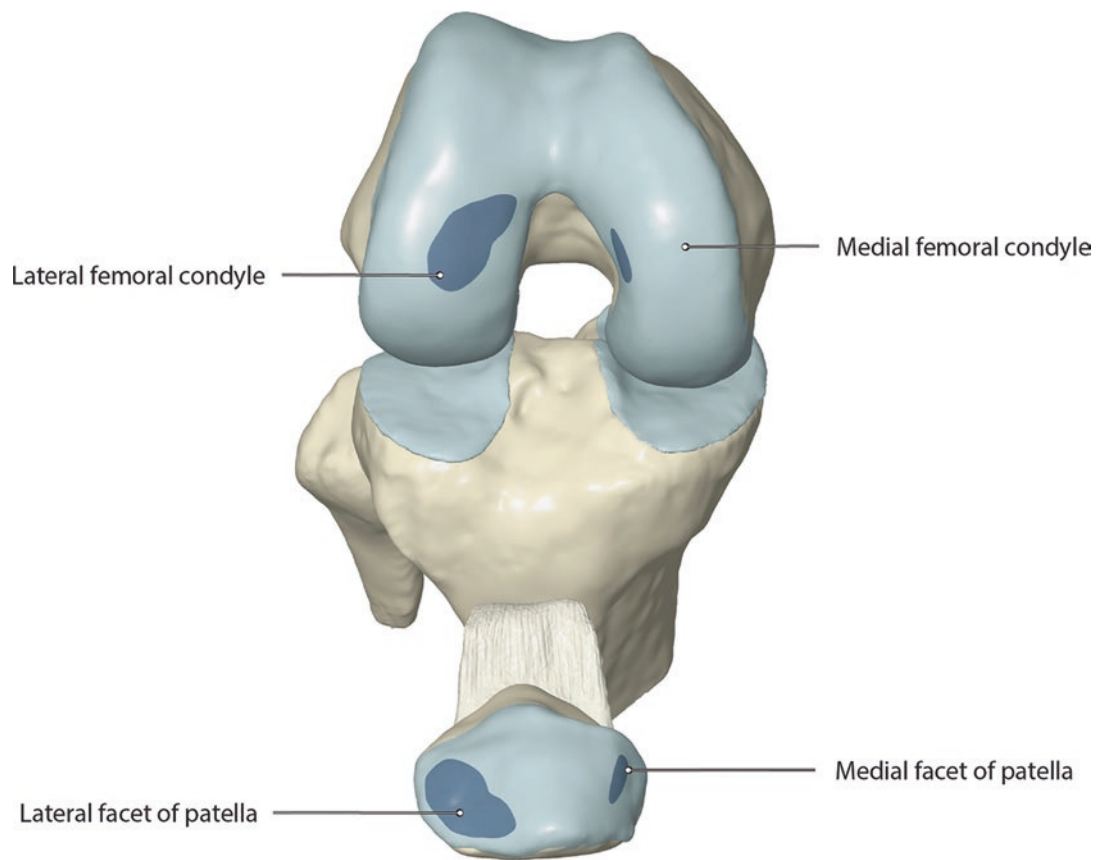


Fig. 4.37 At 135° flexion, the odd facet of the patella is in contact with the medial intercondylar notch. The lateral facet of the patella articulates with the inner part of the lateral femoral condyle

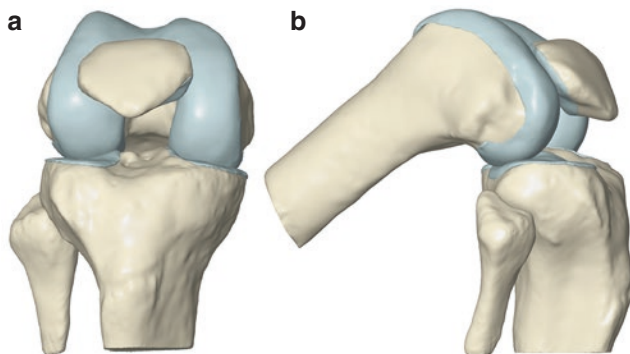


Fig. 4.38 At 135° flexion, the odd facet of the patella is in contact with the medial intercondylar notch. The lateral facet of the patella articulates with the inner part of the lateral femoral condyle. (a) Anterior and (b) lateral

4.7 Patellar Excursion

The osteochondral geometry of the trochlea and congruence of the patellofemoral joint contribute to the stability of the joint (*see* Fig. 4.39). The static and dynamic soft tissue restraints also contribute to the position of the patella in the trochlea. Evaluation of trochlear geometry, as well as changes in articulation based on knee flexion angle, should be consid-

ered when considering the forces that can affect patellar stability.

As the knee moves from 0° extension to 120° flexion, the patella translates distally in relation to the femoral condyles (*see* Fig. 4.40). In extension, the patella may minimally contact the proximal border of the trochlea, whereas at 45° flexion, the patella is in full contact with the trochlear groove (*see* Fig. 4.41).

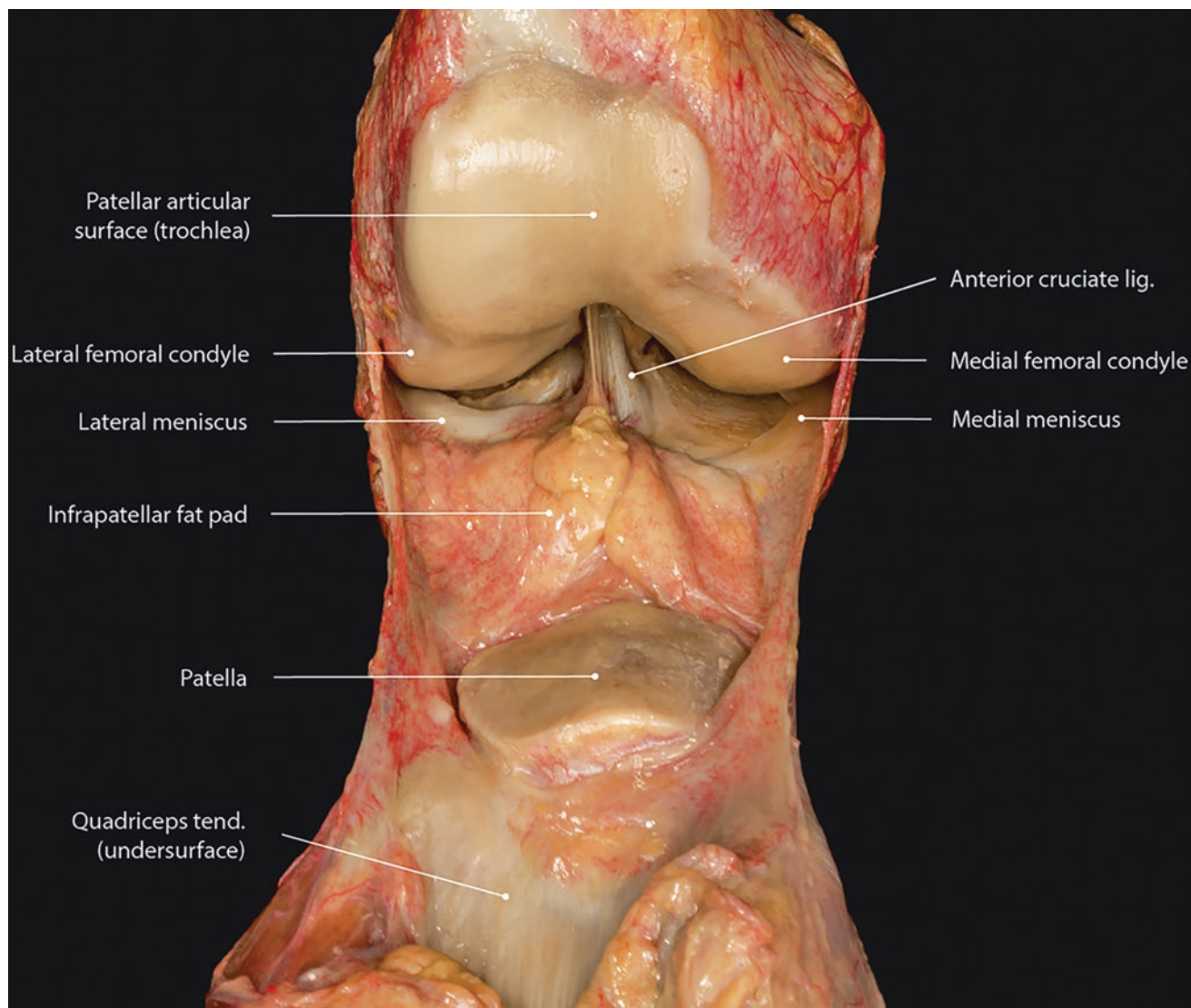


Fig. 4.39 The extensor mechanism has been reflected down to show the patellofemoral joint



Fig. 4.40 When the knee moves through a full range of motion, the patella moves in relation to the femur

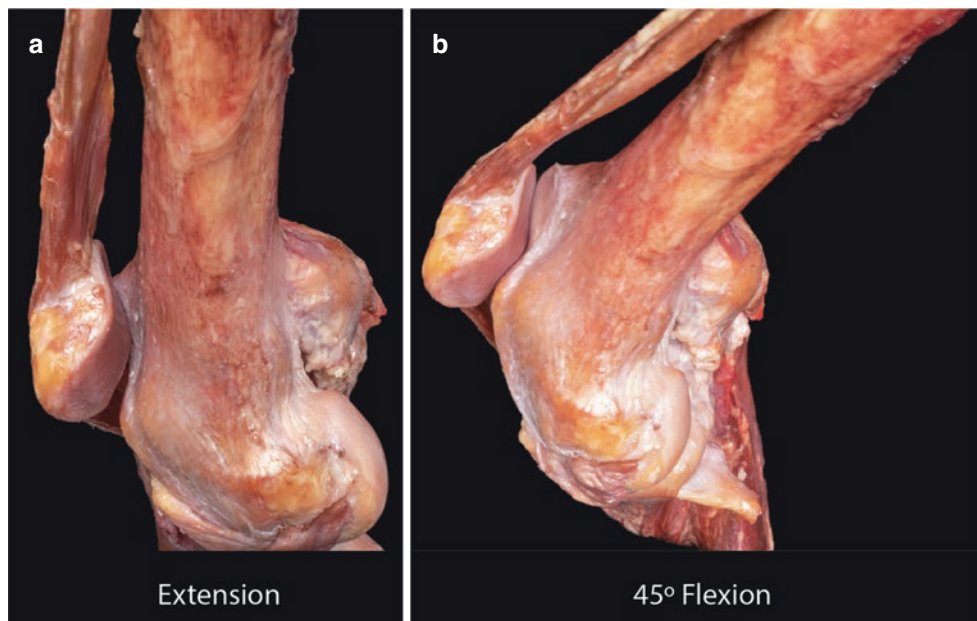


Fig. 4.41 (a) In extension, the patella is minimally in contact with the proximal edge of the trochlea. (b) At 45° flexion, the patella is in full contact with the trochlea

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Part II

Surgical Anatomy of the Knee

Anterior Knee Anatomy

5

Robert Śmigielski and Bertram Zarins

5.1 Layers

Just below the skin lies subcutaneous fat (adipose tissue). Fibrous areolar tissue connects the subcutaneous fat to the deep fascia. A surgical plane can be developed between the

subcutaneous fat and the deep fascia because this connective tissue is loose and weak. The surgical plane is the superficial fascial layer. Superficial arteries, veins, and nerves, as well as a variable thin layer of deep subcutaneous fat, remain loosely attached to the deep fascia (*see* Figs. 5.1 and 5.2).

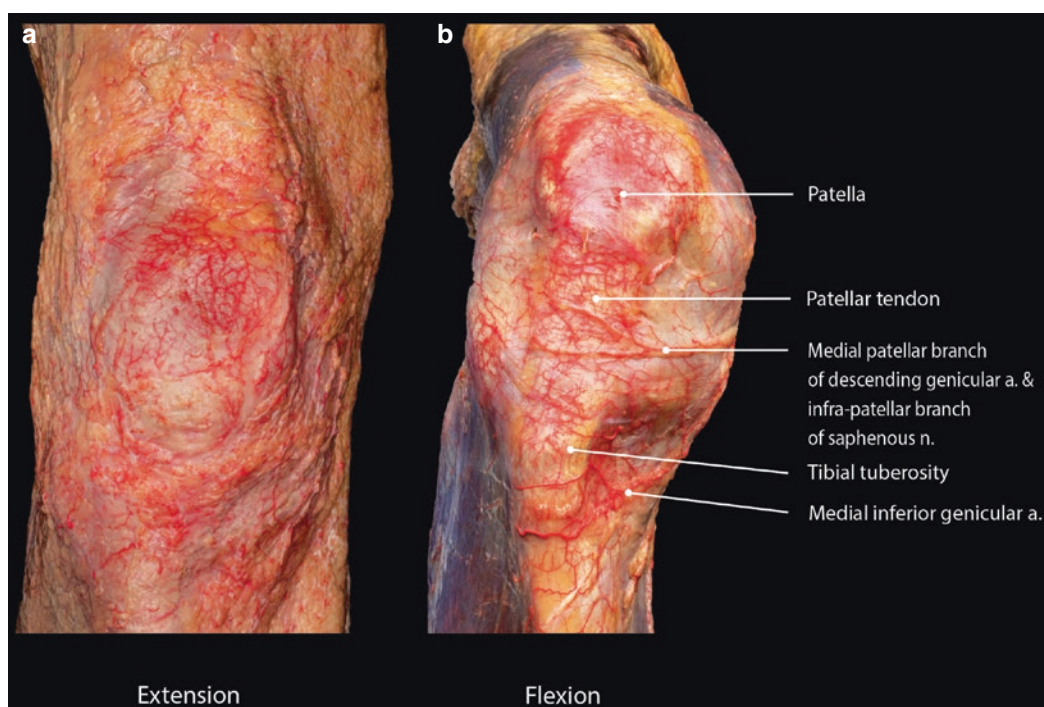


Fig. 5.1 (a) Anterior aspect of the right knee in extension after the skin and superficial subcutaneous fat have been removed. The deep subcutaneous fat remains. (b) The knee is flexed 90°. The fat has been removed.

Superficial arteries, veins, and nerves remain loosely attached to the deep fascia. Note the small artery that accompanies the **infrapatellar branch of the saphenous nerve**. Note the **medial inferior genicular artery**

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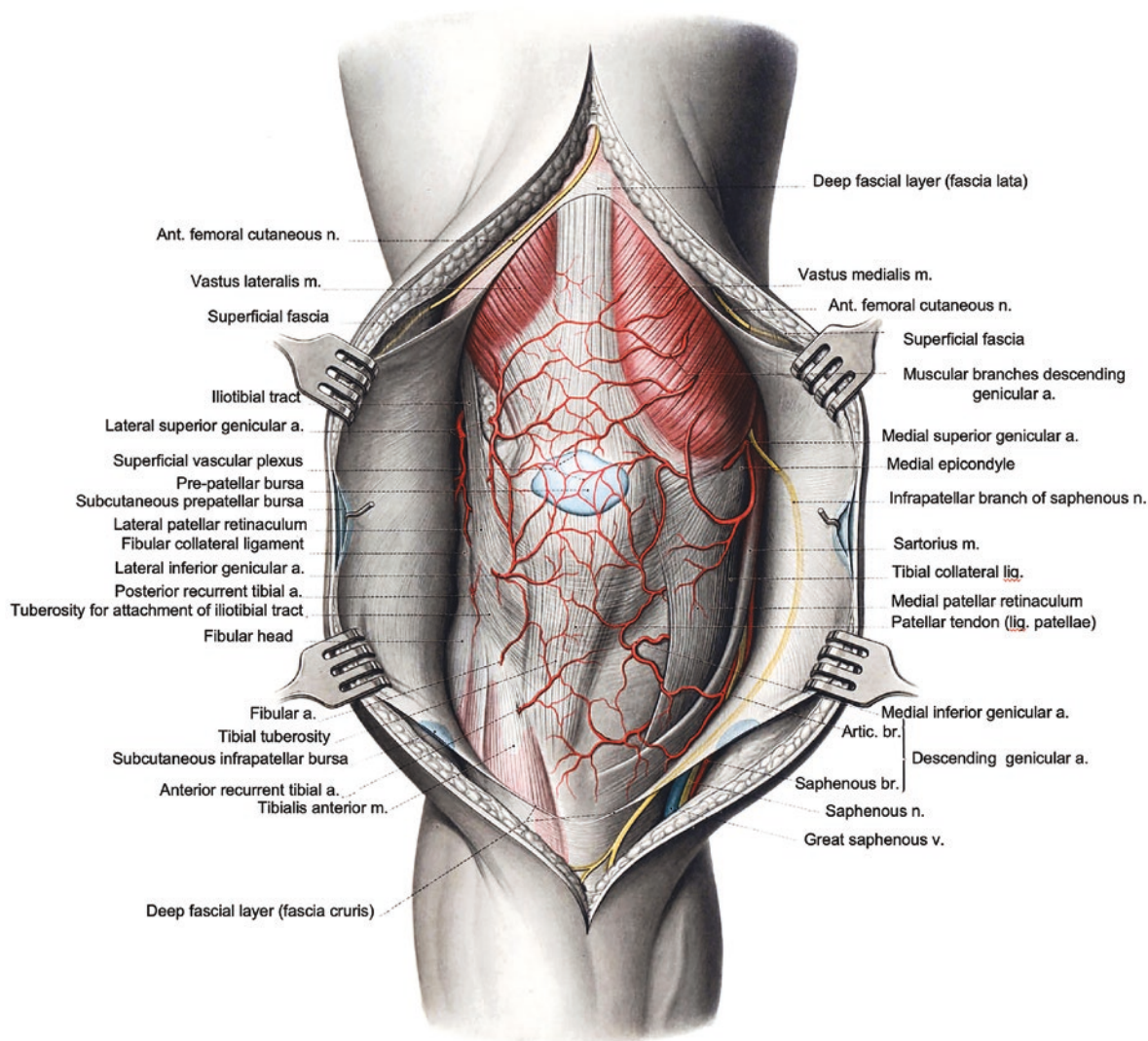


Fig. 5.2 Anterior aspect of right knee illustrating superficial structures (*Modified from Lang and Wachsmuth; with permission*) [4]

5.2 Subcutaneous Prepatellar Bursa

The subcutaneous **prepatellar bursa** is a superficial bursa with a thin synovial lining located between the skin and patella. It lies in a split within the deep fascial layer. It does not communicate with the knee joint (*see Fig. 5.3*).



Fig. 5.3 Anterior aspect right knee. The **subcutaneous prepatellar bursa** lies in a split within the deep fascia in front of the patella. The prepatellar bursa does not communicate with the knee joint

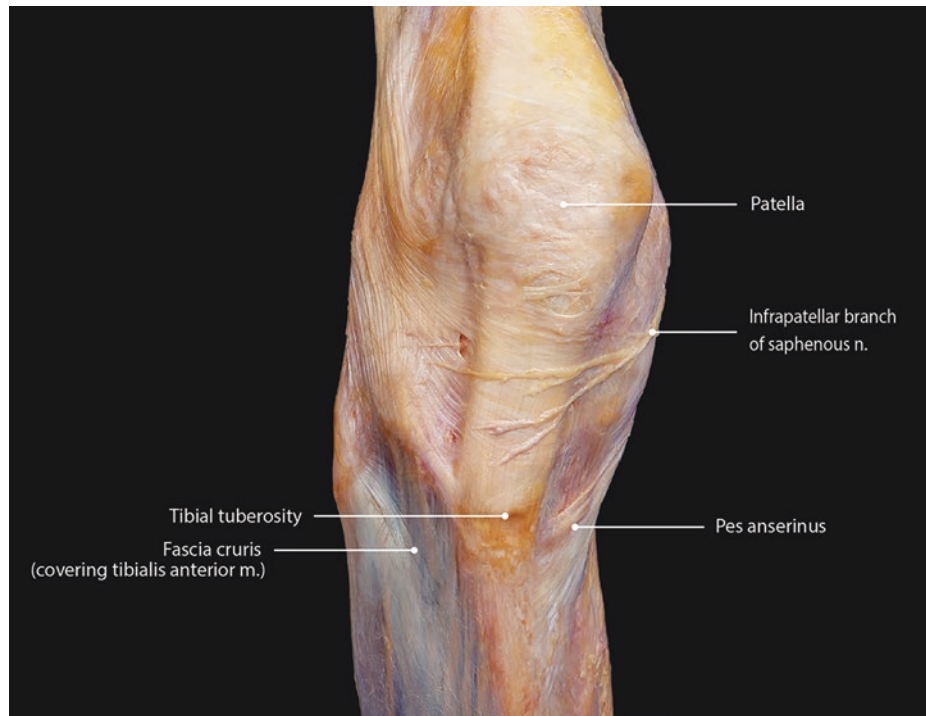


Fig. 5.4 The **infrapatellar (genicular) branch of the saphenous nerve** pierces the deep fascia to become superficial on the medial side of the knee. Note that the superior border of the pes anserinus is located slightly distal to the tibial tuberosity (about three fingerbreadths distal to the joint line)

5.3 Infrapatellar Branch of Saphenous Nerve

The **infrapatellar (genicular) branch of the saphenous nerve** becomes superficial on the medial side of the knee. It joins the subcutaneous patellar network formed by the lateral, intermediate, and medial cutaneous nerves (*see* Fig. 5.4).

5.4 Deep Fascia

The deep fascia of the thigh, **fascia lata**, is continuous with the deep fascia of the leg, the **fascia cruris**. At the posterior knee, it is the **popliteal fascia** (*see* Fig. 5.5).

The deep fascia that invests the knee is multilayered. Its thickness varies. Removing the deep fascia reveals the underlying knee structures (*see* Figs. 5.6 and 5.7).

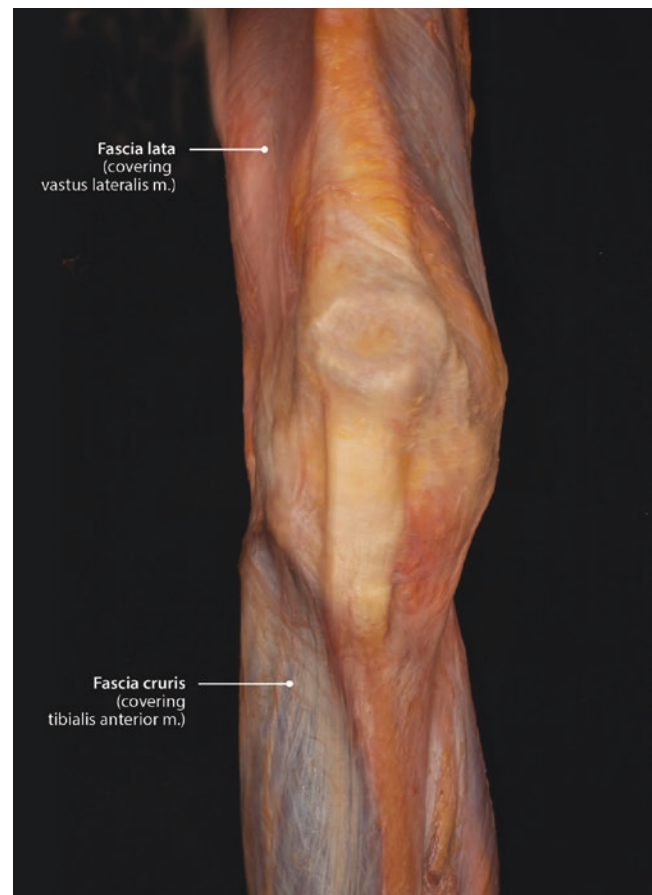


Fig. 5.5 The deep fascia investing the thigh is the **fascia lata**. It continues distally as the deep fascia of the leg, the **fascia cruris**

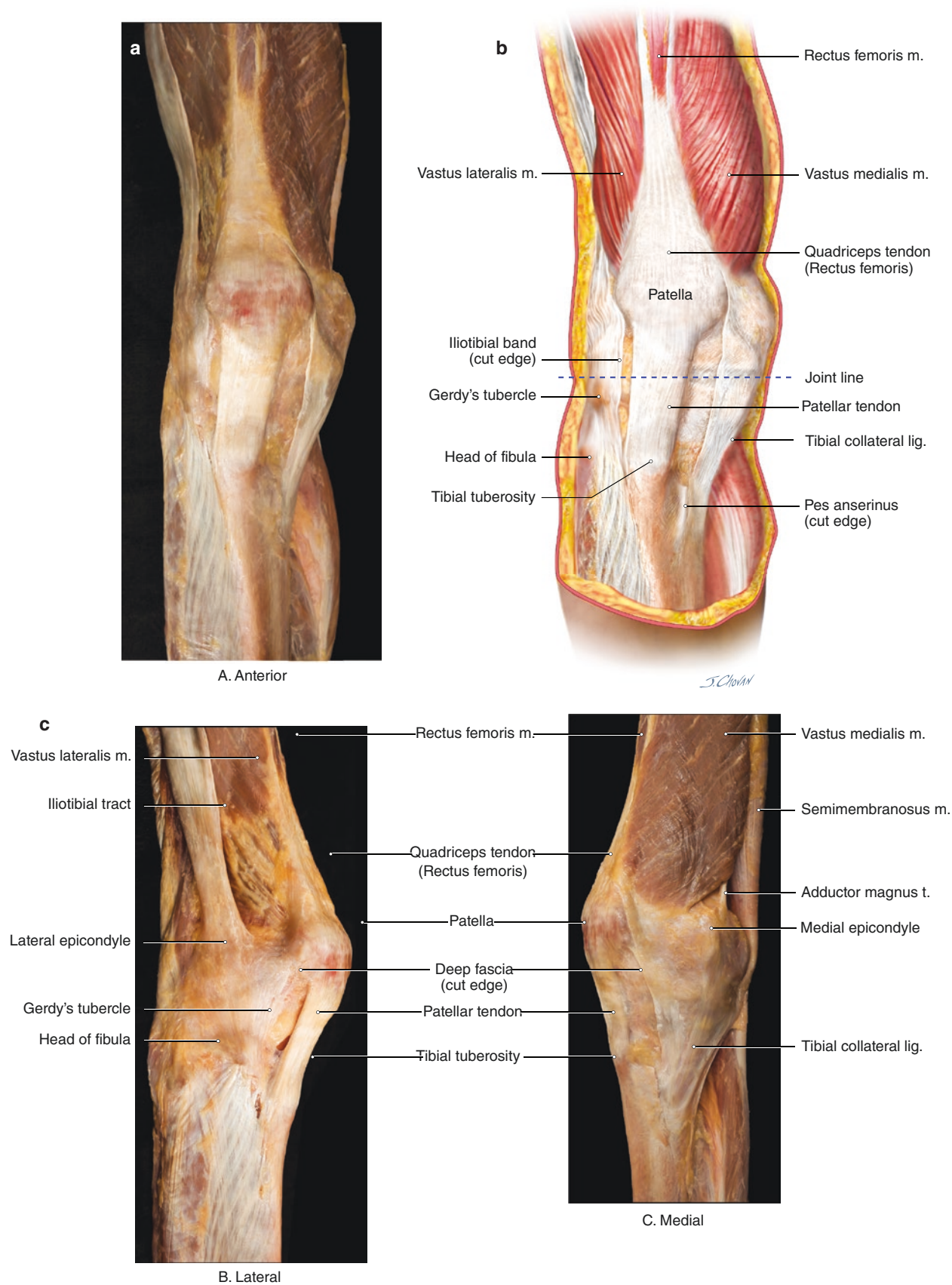


Fig. 5.6 Anterior (a), lateral (b), and medial (c) aspects of extended right knee with the deep fascia removed

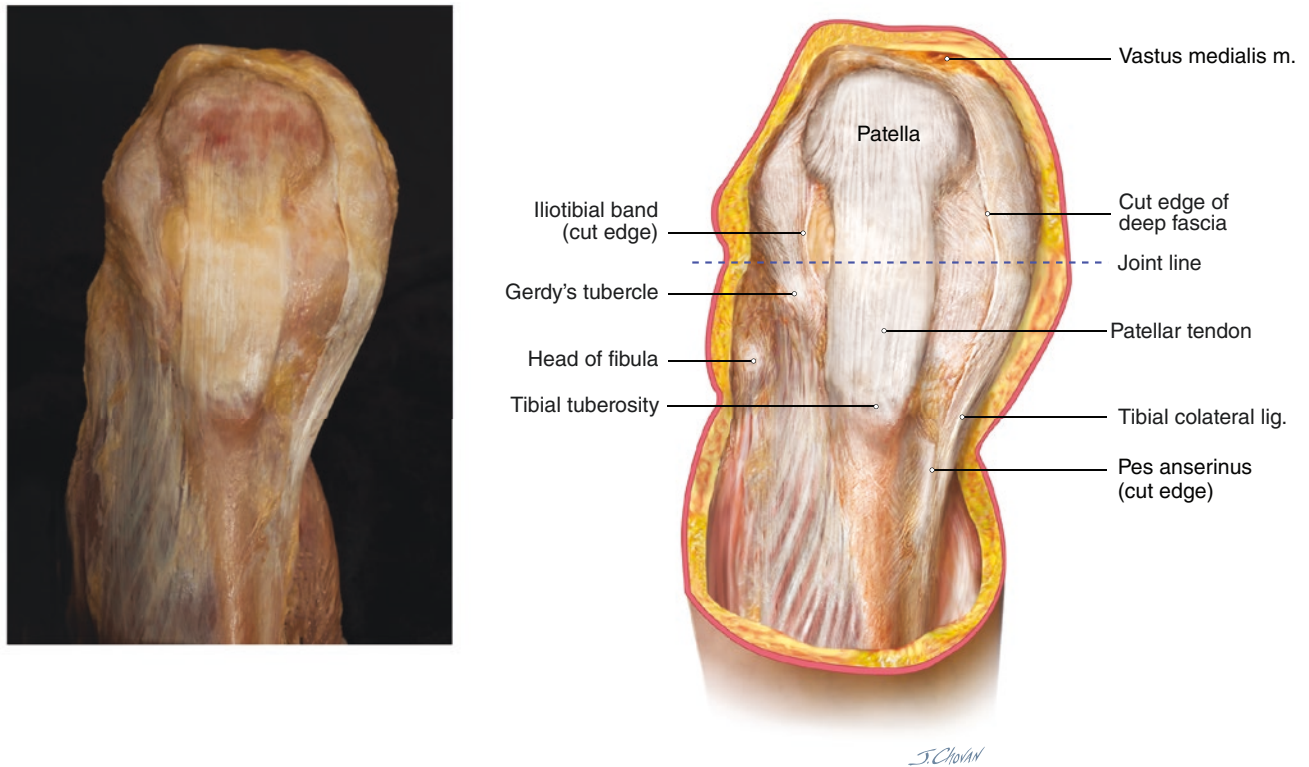


Fig. 5.7 Anterior aspect of the flexed right knee with the deep fascia removed

5.5 Superficial Vascularity

The medial patellar branch of the descending genicular artery gives most of the blood supply to the medial side of the knee and the prepatellar area (*see* Fig. 5.8). There are two

small neurovascular bundles that pierce the deep fascia in the anteromedial and anterolateral aspects of the knee. If they are cut when an arthroscopy portal is made, there will be excess bleeding during the procedure and residual numbness in front of the knee (*see* Fig. 15.1).

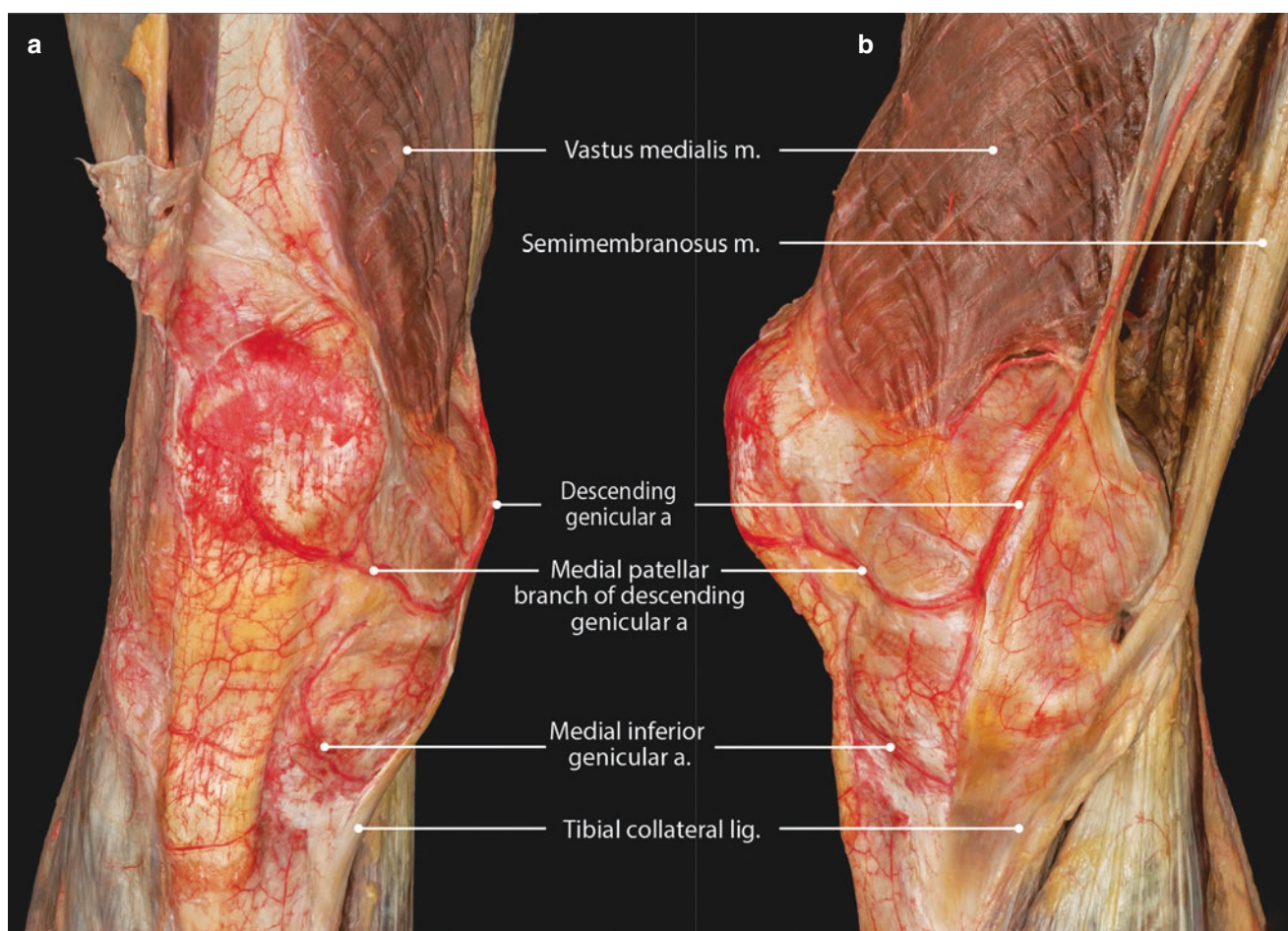


Fig. 5.8 Anterior (a) and medial (b) aspects of the right knee showing the superficial vascularity in the superficial facial layer. The medial patellar branch of the descending genicular artery gives most of the blood supply to the medial side of the knee and the prepatellar area

5.6 Quadriceps Tendon

The four components of the quadriceps mechanism form a trilaminar tendon that coalesces and inserts on the proximal part of the patella. The tendon of the **rectus femoris** flattens immediately above the patella and becomes the anterior lamina. This inserts onto the anterior edge of the proximal pole of the patella. Most of the fibers of the rectus femoris tendon continue across the anterior surface of the patella to blend with the periosteum of the patella and then continue

distally as the patellar tendon (*ligamentum patellae*) (see Fig. 5.9).

The middle lamina is formed by the confluent edges of the **vastus lateralis** [*vastus externus*] and **vastus medialis** [*vastus internus*] tendons. They insert directly onto the lateral and medial sides of the patella, respectively (See Fig. 5.10).

The tendon of the **vastus intermedius** [*crureus*] continues downward as the deepest lamina of the quadriceps tendon and inserts onto the posterior edge of the proximal pole of the patella (see Fig. 5.11).

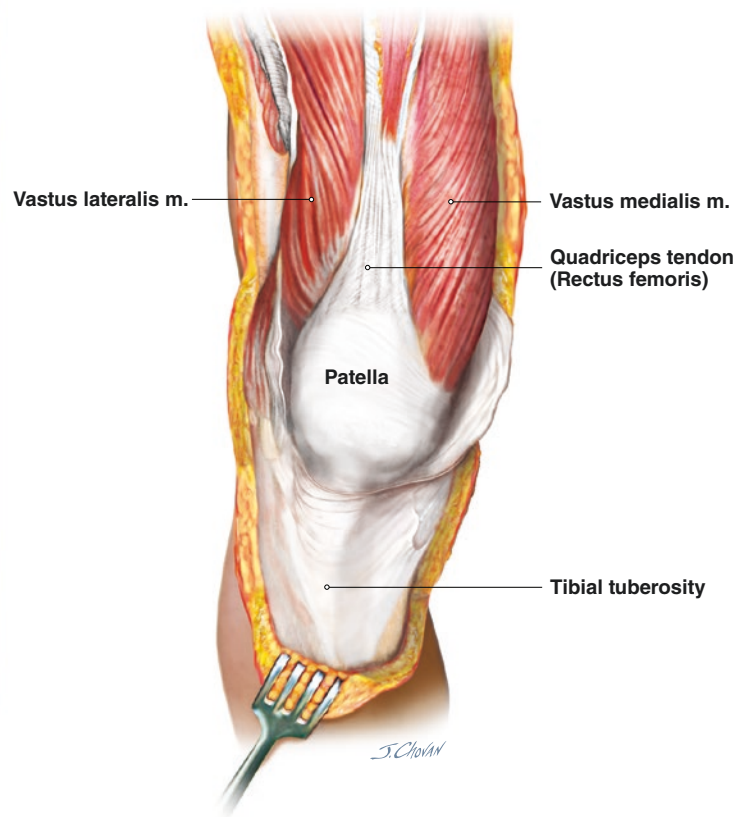


Fig. 5.9 Right knee with deep fascia removed exposing the quadriceps muscles and tendon. The superficial part of the trilaminar quadriceps tendon is the **rectus femoris** tendon

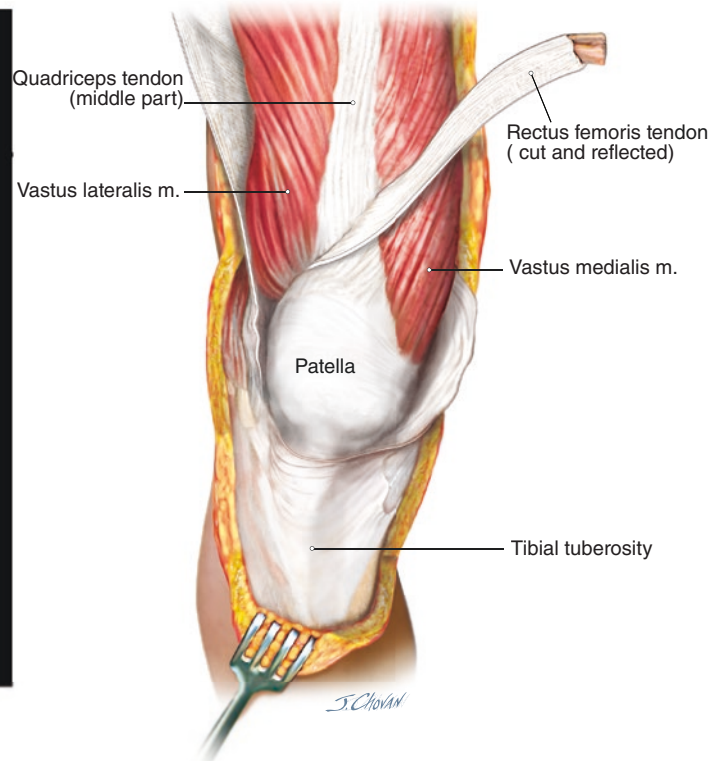


Fig. 5.10 Right knee quadriceps muscle and tendon, middle layer. The rectus femoris tendon has been lifted exposing the middle part of the trilaminar quadriceps tendon, which is the junction of the insertions of the **vastus medialis** and **vastus intermedius** muscles

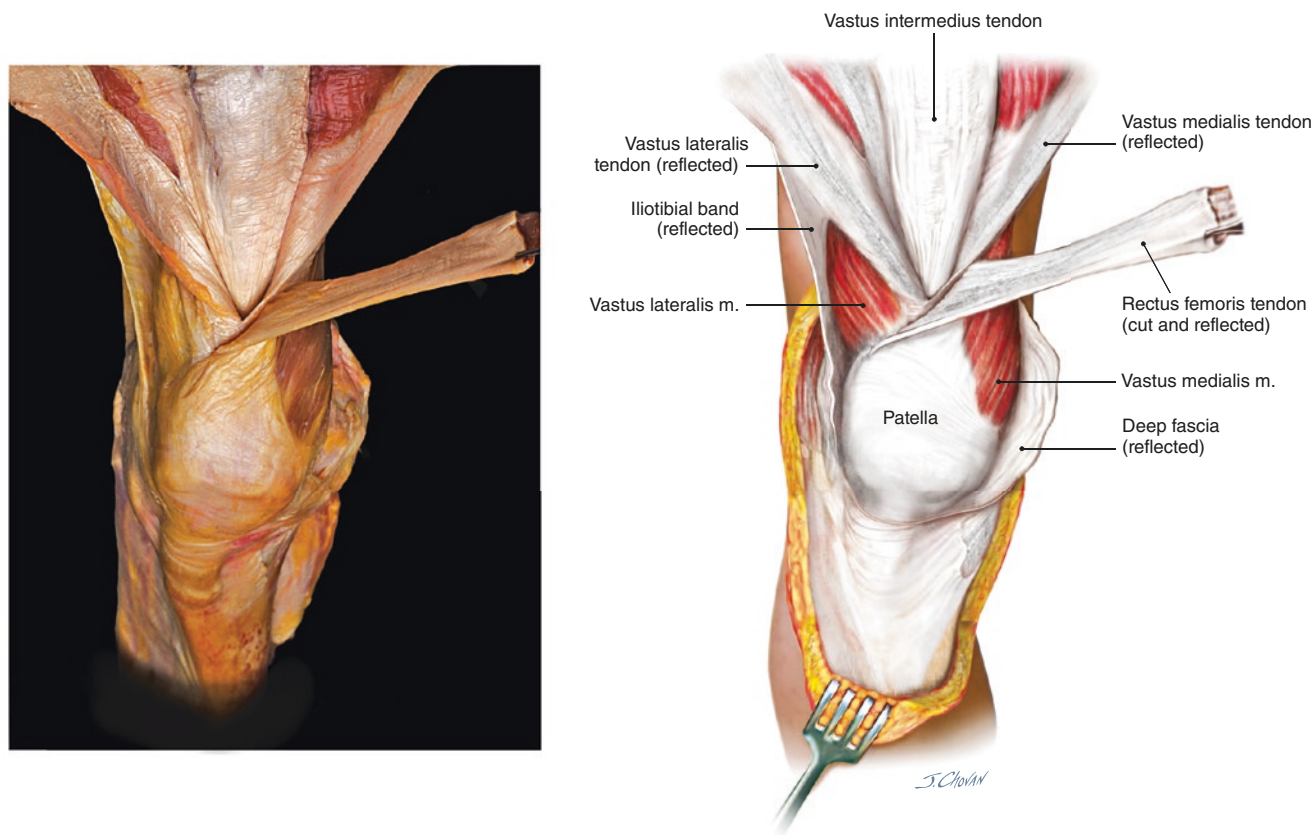


Fig. 5.11 Right knee quadriceps muscle and tendon. The deep part of the trilaminar quadriceps tendon is the tendon of the **vastus intermedius** muscle. Distally all three parts of the quadriceps tendon fuse together as they insert on the superior pole of the patella

5.7 Patella (Refer to Chap. 3 – Patellofemoral Joint)

5.7.1 Patellar Tendon [*Ligamentum Patellae*]

The **patellar tendon** [*ligamentum patellae*; *anterior ligament*] is a continuation of the patellar periosteum, which is continuous with the rectus femoris tendon (see Fig. 5.12).

The patellar tendon [*ligamentum patellae*] attaches to the anterior aspect of the inferior pole of the patella as a continuation of the periosteum of the patella. The patellar tendon attaches distally onto the tibial tuberosity about 3–4 cm distal to the joint line. There is a small bursa, the deep infrapatellar bursa, which lies between the undersurface of the patellar tendon and the upper tibia (see Fig. 5.13).

Terminology

There have been differences in opinion as to whether the fibrous connection between the inferior pole of the patella and the tibia is a ligament or a tendon.

Gray's Anatomy [1] as well as Terminologia Anatomica (second Edition) [2] calls this structure the

“**ligamentum patellae** (*anterior ligament*)” because it connects one bone to another [3]. Many journals, therefore, refer to it as the “**patellar ligament**.”

Since the patella is a sesamoid bone, the structure distal to the patella could be thought of as a continuation of the quadriceps tendon that inserts distally to the tibial tuberosity. Using this argument, the distal portion should also be called the quadriceps tendon. It is peculiar for a tendon (the “patellar tendon”) to have an origin (in this case from the inferior pole of the patella) and an insertion (to the tibia), but to have no muscle. The prepatellar portion is very thin and is a portion of the rectus femoris tendon only. Tendons are made of white fibrous connective tissue, and the collagen fibers are arranged in compact parallel bundles. Ligaments are made of yellow fibrous connective, and the fibers are not arranged in parallel bundles. Histologically, the “patellar tendon” is a ligament.

However, regardless of the anatomy and histology, common usage dictates that we call this structure the “**patellar tendon**.”

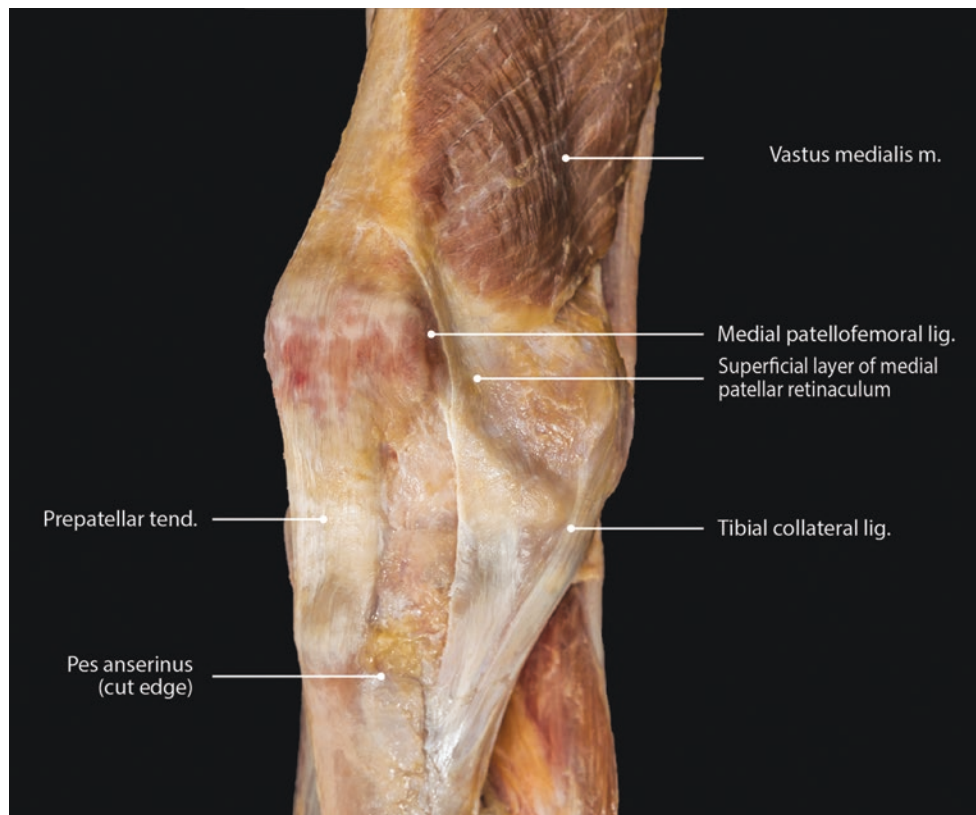


Fig. 5.12 Anteromedial aspect of right knee with the deep fascia cut at the edge of the patellar tendon

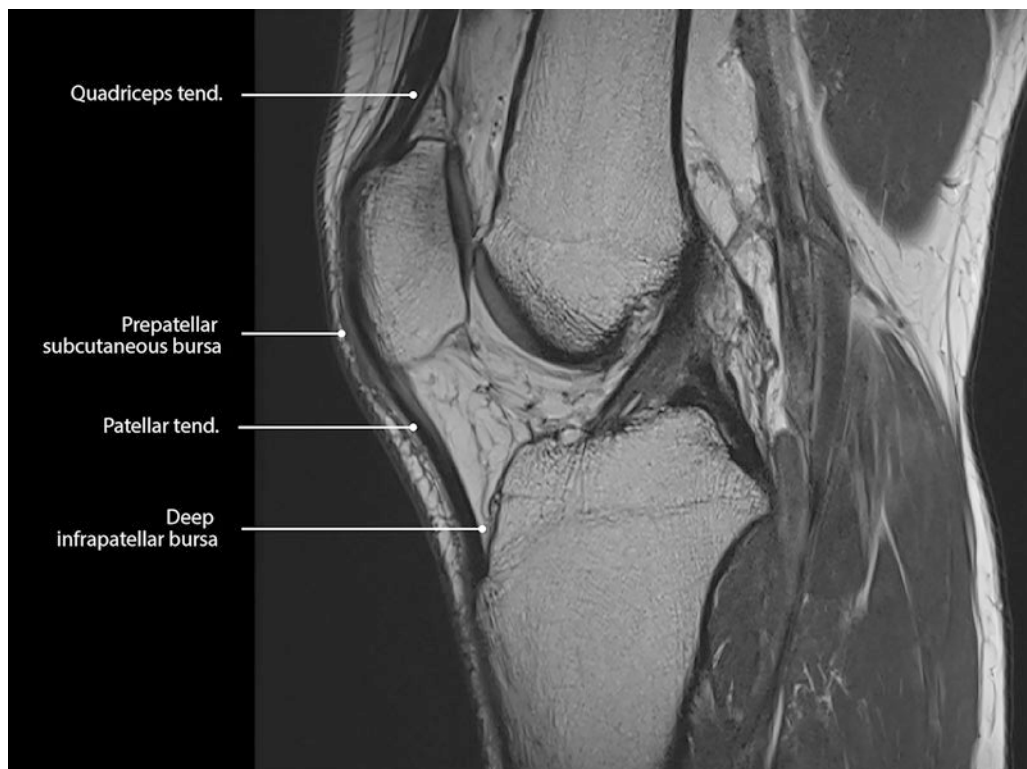


Fig. 5.13 MRI of the knee showing the **quadriceps tendon** inserting on the base (top) of the patella. The anterior fibers continue across the anterior surface of the patella and continue as the **patellar tendon** (*lig. patellae*) to the tibial tuberosity. The patellar tendon does not attach to

the patellar apex (bottom of patella). The **prepatellar subcutaneous bursa** is in front of the knee. It does not communicate with the knee joint. The **deep infrapatellar bursa** lies between the undersurface of the distal patellar tendon and the tibial tuberosity

5.8 Deep Infrapatellar Bursa

The deep infrapatellar bursa is located between the distal patellar tendon and the upper part of the tibial tuberosity (*see* Figs. 3.17 and 5.13).

5.9 Supra-Patellar Bursa

The suprapatellar bursa is not really a bursa but a cul-de-sac beneath the quadriceps tendon. It can be a separate bursa that does not connect to the knee if the suprapatellar plica septum is imperforate (*see* synovial plica).

On either side of the patella, the synovium extends beneath the aponeuroses of the vastus medialis and vastus lateralis.

5.10 Patellar Retinaculum (*Refer to Chap. 3*)

The **medial** and **lateral patellar retinacula** are strong fibrous membranes that attach the medial and lateral edges of the patella. Medially, expansions of the vastus medialis aponeurosis and the articular capsule fuse into a single layer to attach to the patella. Laterally the aponeurosis of the vastus lateralis, iliotibial band and capsule fuse to attach to the lateral edge of the patella.

5.11 Infrapatellar Fat Pad

The **infrapatellar fat pad** fills the space between the patellar tendon, the anterior intercondylar part of the femur and the tibial plateau. It is intra-capsular but extra-synovial. Inflammation of the fat pad has been postulated as a cause of anterior knee pain (Hoffa's disease) (*see* Fig. 5.14).

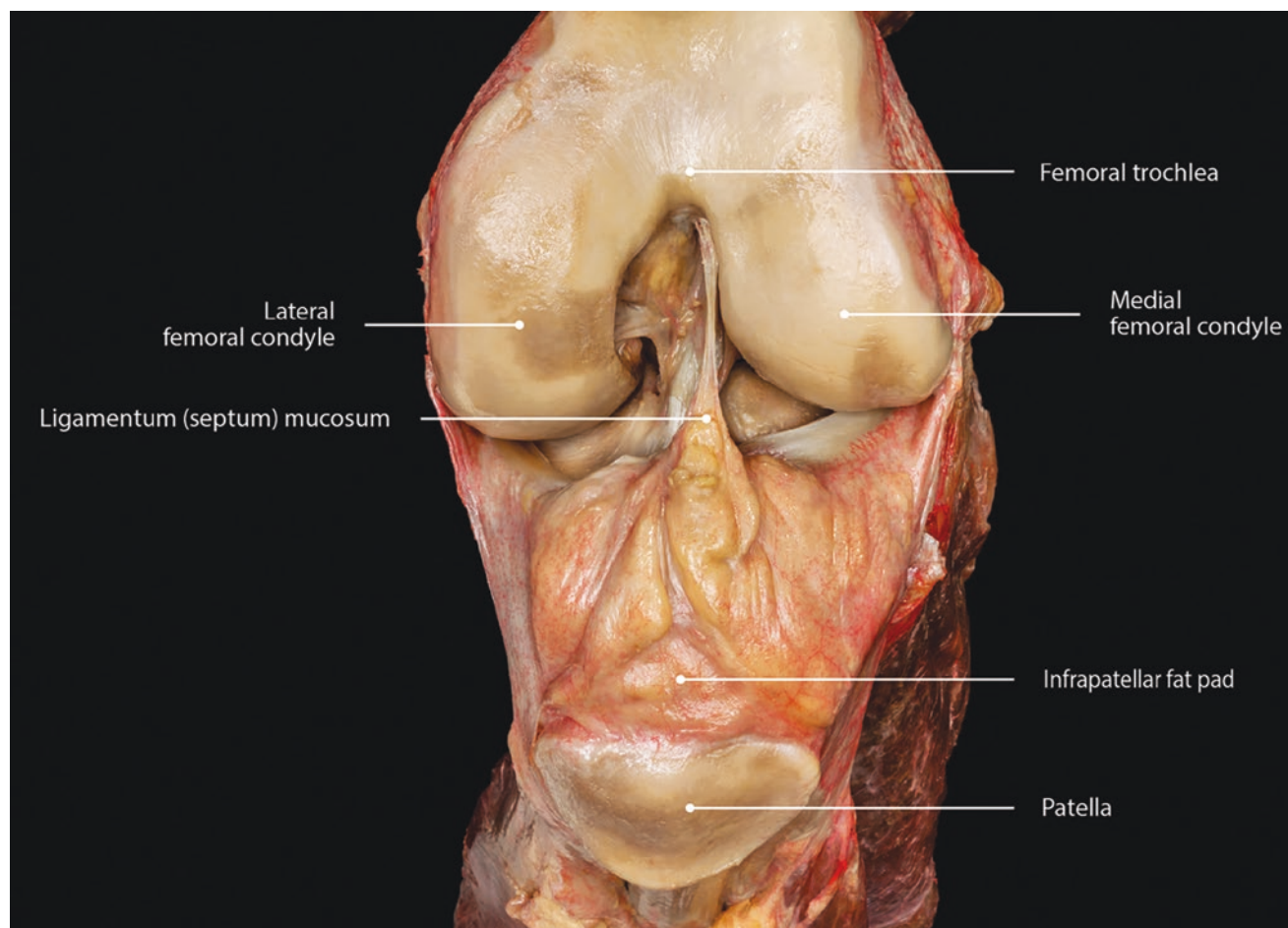


Fig. 5.14 The patella has been flipped down to show the **infrapatellar fat pad**. The ligamentum mucosum can be a complete septum, as it is in this specimen

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6.1 Superficial Structures and Deep Fascia

Just below the skin, within the superficial subcutaneous fat, lies the **great saphenous vein** [*v. saphena magna; long or internal saphenous vein*]. The vein goes up the medial aspect of the leg in company with the saphenous nerve. This large superficial vein communicates with deep veins. The communicating veins have valves. If these valves fail, varicose veins form in the superficial veins. The great saphenous vein continues past the knee and proceeds along the medial thigh to the groin (see Fig. 6.1).

The popliteal fossa has an additional layer of fibrous connective tissue within the subcutaneous fat—the **stratum membranosum**. It separates the superficial subcutaneous fat from the deep subcutaneous fat. This layer is common in other parts of the body, but is not present in the anterior, medial, or lateral aspects of the knee (refer to Chaps. 1 and 13).

Removing the skin and subcutaneous fat exposes the underlying deep fascia. Superficial arteries, veins, and sensory nerves, as well as some deep superficial fat, tend to remain loosely attached to the deep fascia. Every nerve is accompanied by an artery (*vasa nervorum*). The two are inseparable (see Fig. 6.2).

The deep fascia of the body is continuous with the deep fascia of the lower extremity. It varies in thickness around the knee, occasionally splitting into layers, and occasionally blending with adjacent tissues. Proximally, the deep fascia covers the quadriceps and sartorius muscles. Anteriorly, it covers the retinaculum and patellofemoral ligaments. Distally the deep fascia blends with the pes anserinus and tibial periosteum [1] (see Fig. 6.3).

The **saphenous nerve** [*n. saphenous; long or internal saphenous nerve*] is the largest cutaneous branch of the femoral nerve. It descends the medial thigh behind the sartorius muscle.

The **femoral nerve** gives off anterior cutaneous branches in the upper thigh, providing sensation to the lower part of the medial knee and to the lateral side of the patella (see Fig. 6.4).

In lower thigh, the saphenous nerve gives off the **infrapatellar** (or geniculate) **branch** which pierces the sartorius muscle to become superficial. It provides sensation to the anterior and anterolateral aspects of the knee (see Figs. 6.5, 6.6 and 6.22).

Important Point

The infrapatellar branch of the saphenous nerve is routinely cut when performing a medial knee arthrotomy. The result is numbness on the anterolateral aspect of the knee. This is not a major disability but should be explained to the patient before surgery. Much of the sensation returns with time from the plexiform network of anterior branches of the femoral nerve (the *plexus patellae*).

Care should be taken when performing medial meniscus repair to avoid catching the nerve with a suture.

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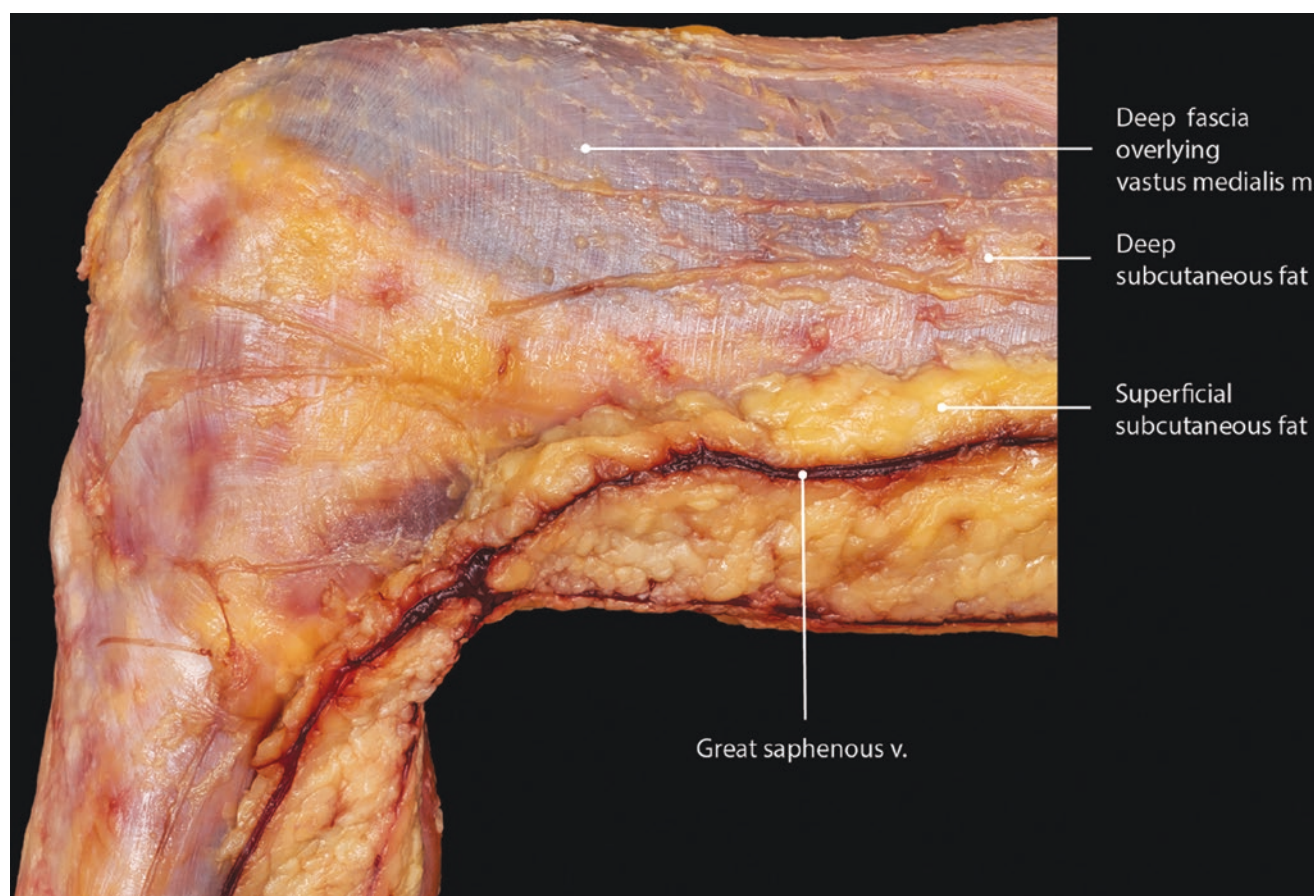


Fig. 6.1 Just below the skin within the superficial subcutaneous fat lies the **great saphenous vein**. In this dissection, most of the superficial subcutaneous fat overlying the vastus medialis muscle has been

removed to show the deep fascial layer with some deep subcutaneous fat and superficial nerves

The **saphenous nerve** leaves the anterior thigh compartment above the medial intermuscular septum and pierces the fascia lata near the posterior border of the sartorius close to its musculocutaneous junction. There is considerable variability on the exact location of the saphenous nerve in the postero-medial aspect of the knee. This is surgically important (*refer to Chap. 11*). The saphenous nerve becomes subcutaneous and continues down the leg to supply sensation to the anterior and medial sides of the leg down to the medial malleolus and medial side of the foot (*see Figs. 6.5, 6.6 and 6.22*).

Important Point

The saphenous nerve is an important structure. Cutting this nerve results in numbness on the medial

side of the leg down to the medial malleolus. This can be a significant disability. The problem is that there is considerable variability in the location of the saphenous nerve on the medial aspect of the knee (*refer to Chap. 11*).

To avoid cutting the saphenous nerve, do not dissect superficially on the medial side of the knee beyond the midline, but incise the deep fascia and proceed posteriorly **under** the deep fascia. The landmark for the incision in the deep fascia is a small sulcus that lies between two bony landmarks: the medial epicondyle and the adductor tubercle. Make a vertical incision through the deep fascial layer at this location and go deep to dissect further posteriorly.

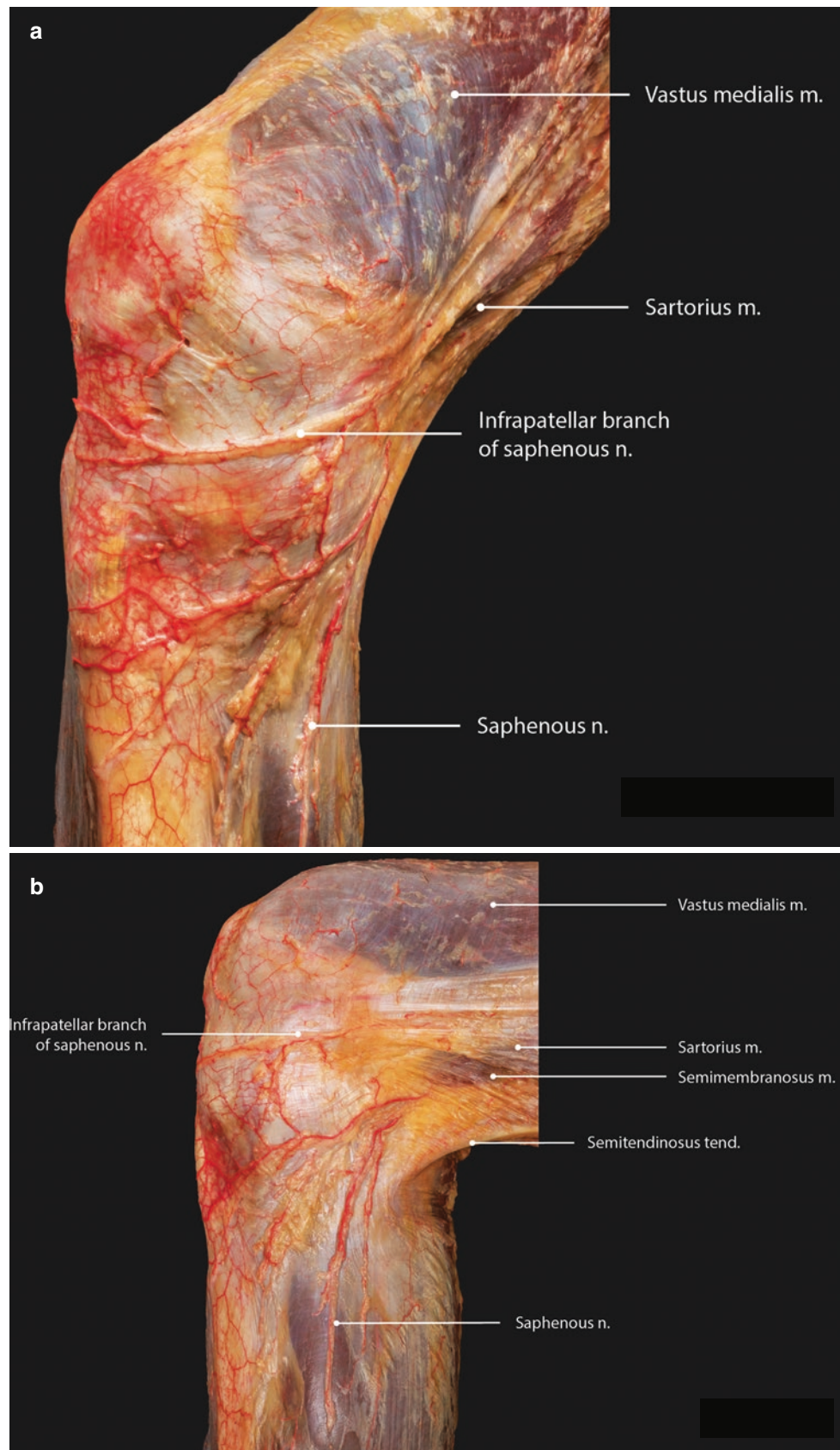


Fig. 6.2 Anteromedial (a) and medial (b) aspects of the right knee. The skin and most of the subcutaneous fat have been removed. The deep fascia has been left intact. Superficial arteries, veins, and sensory

nerves, as well as some deep superficial fat remain loosely attached to the deep fascia. Note that every nerve is accompanied by an artery (*vasa nervorum*). The two are inseparable

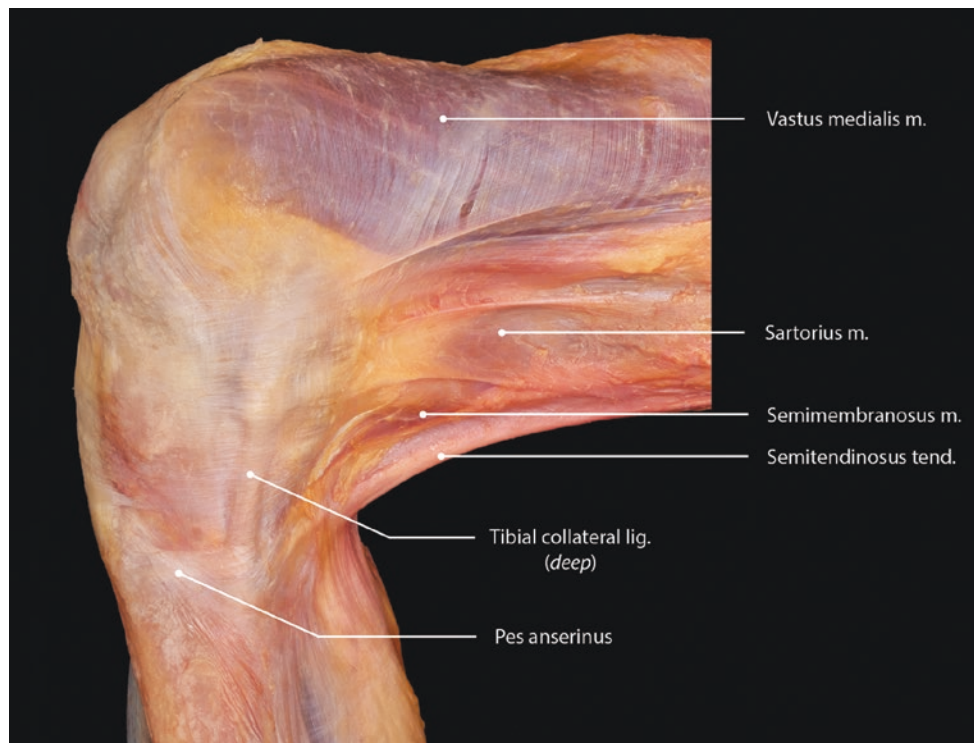


Fig. 6.3 Medial aspect of right knee showing the **deep fascia**

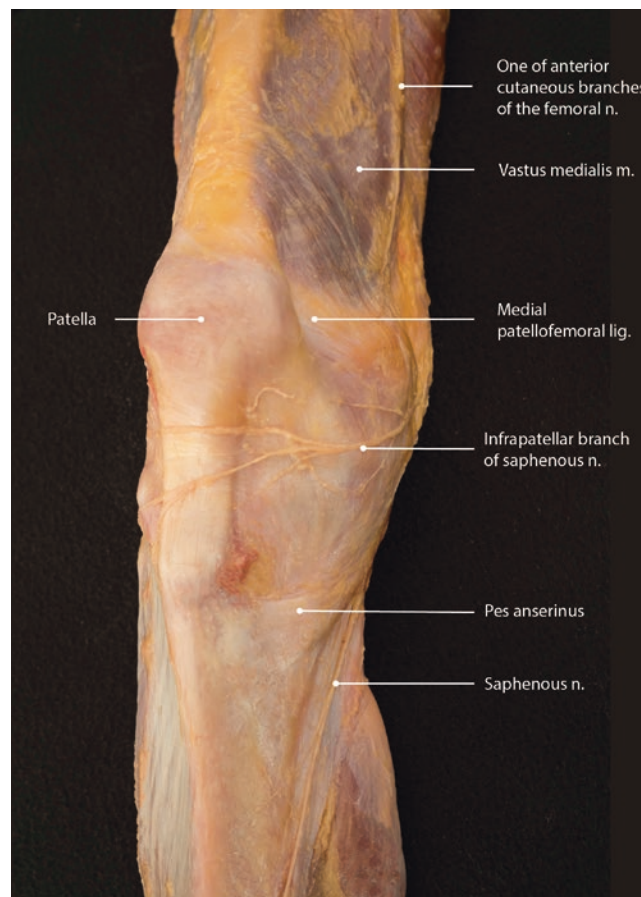


Fig. 6.4 An **anterior cutaneous branch** of the **femoral nerve** provides sensation to the lower part of the medial knee and the lateral side of the patella. The **infrapatellar** (or **geniculate**) **branch of the saphenous nerve** provides sensation to the anterior and anterolateral aspects of the knee

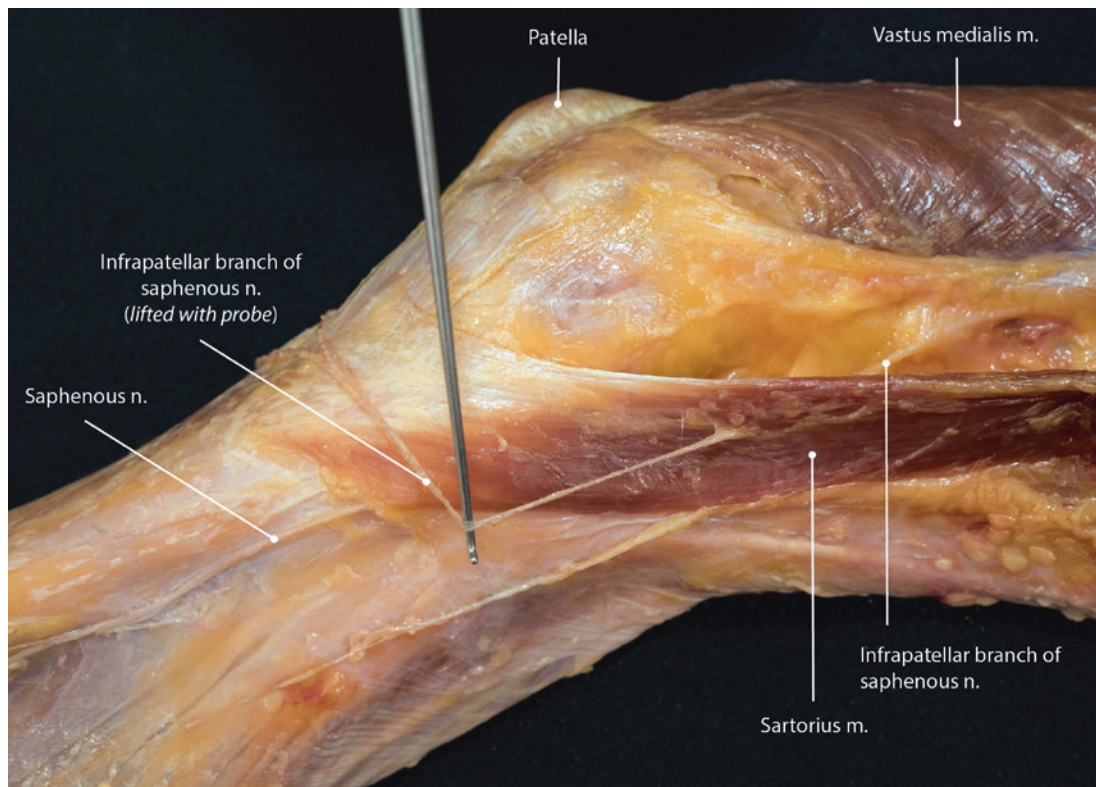


Fig. 6.5 The infrapatellar branch of the saphenous nerve pierces the sartorius muscle to become superficial at the medial aspect of the knee

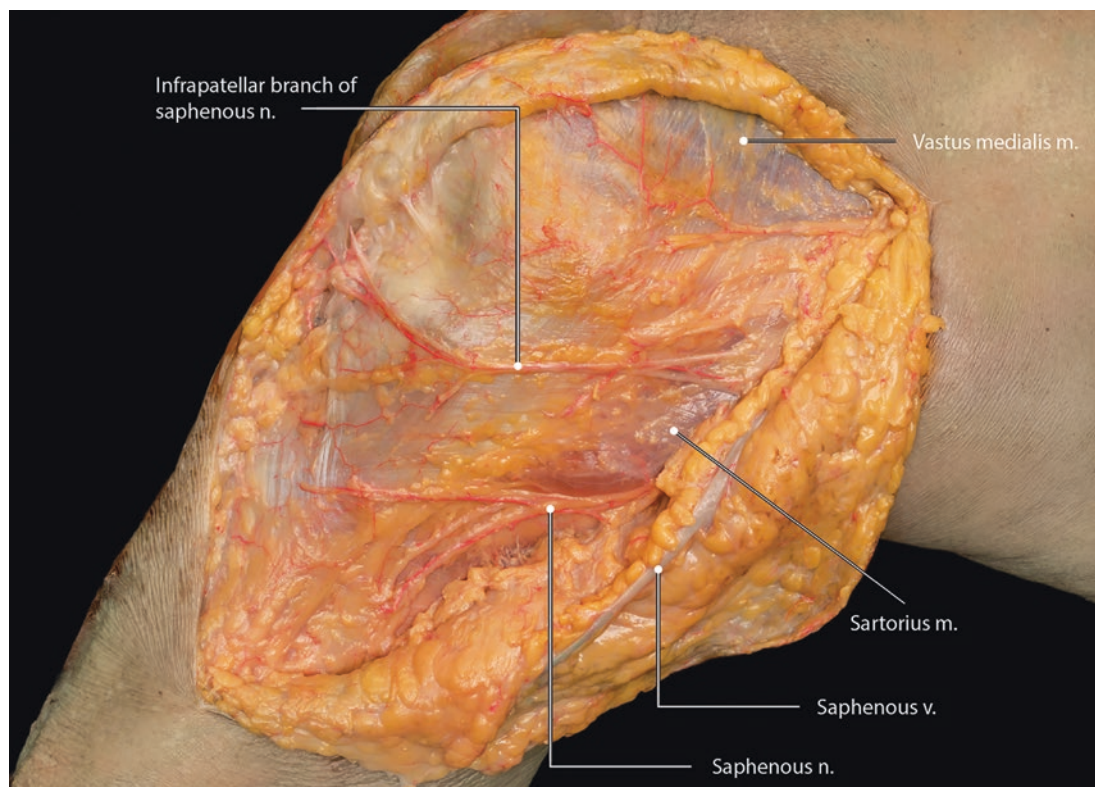


Fig. 6.6 The saphenous nerve pierces the distal sartorius muscle to become superficial and to continue down the medial leg. The saphenous vein lies superficially in the superficial subcutaneous fat

6.2 Vastus Medialis Muscle

The vastus medialis muscle is one of four quadriceps muscles. It is located on the medial thigh. There is controversy whether this is one muscle, the vastus medialis, or two: the vastus medialis longus (VML) proximally and the vastus medialis obliquus (VMO) distally [2–4] (see Fig. 6.7).

6.3 Medial Retinaculum

The **medial patellar retinaculum** is composed of dominating vertical fibers, which are the tendinous continuations of the vastus medialis and horizontal fibers, the **medial patellofemoral ligament** [5]. The medial retinaculum coalesces with the capsule at its attachment to the medial border of the patella (refer to Chap. 3) (see Fig. 6.8).

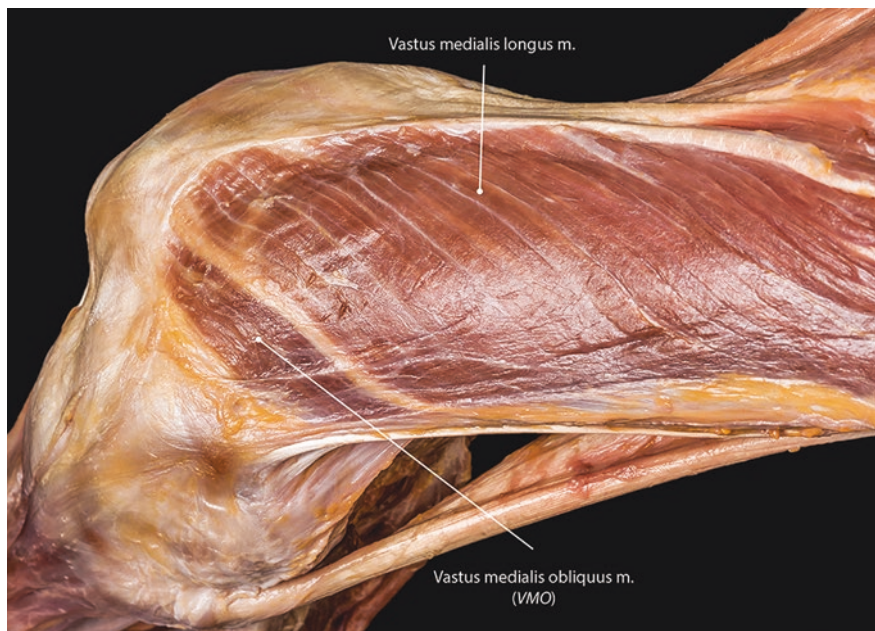


Fig. 6.7 Medial aspect right thigh showing the two portions of the vastus medialis muscle: vastus medialis longus (VML) and vastus medialis obliquus (VMO)

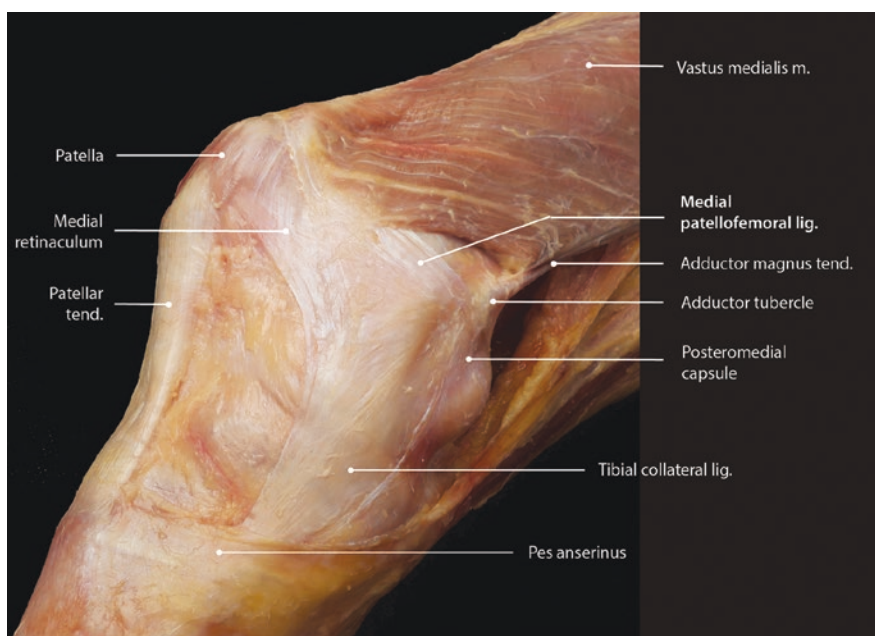


Fig. 6.8 Right knee, superficial anteromedial structures. The deep fascia has been removed. The medial patellar retinaculum has a thickening which forms the **medial patellofemoral ligament** (MPFL)

6.4 Tibial Collateral Ligament (Superficial Medial Collateral Ligament)

The **tibial collateral ligament (TCL)** or **superficial medial collateral ligament** [*ligamentum collaterale tibiale*] is a well-delineated strong flat band that is attached superiorly to the medial epicondyle of the femur. Anterior to the femoral epicondyle it is continuous with the medial patellofemoral ligament. The anterior part of the TCL courses straight downward and is separated from the capsule by loose connective tissue and usually a bursa. The TCL crosses the insertion of the tibial arm of semimembranosus tendon and the medial inferior genicular artery. It is crossed by pes anserinus tendons and is separated from the tendons by a bursa. It attaches to the medial tibia about 6 to 10 centimeters distal to the joint line. The posterior part of the TCL

runs obliquely downward and backward to the level of the medial meniscus, and then obliquely forward to attach to the tibia. The posterior extension of the tibial collateral forms a triangle which blends with the posteromedial capsule and forms a sling about the medial femoral condyle. It is firmly attached to the coronary ligament (*see* Figs. 6.9 and 6.10).

The tension in the tibial collateral ligament, especially the upper portion, varies at different angles of knee flexion (*see* Fig. 6.11).

Terminology

Calcification of the proximal portion of tibial collateral ligament is called **Pellegrini-Stieda disease**.

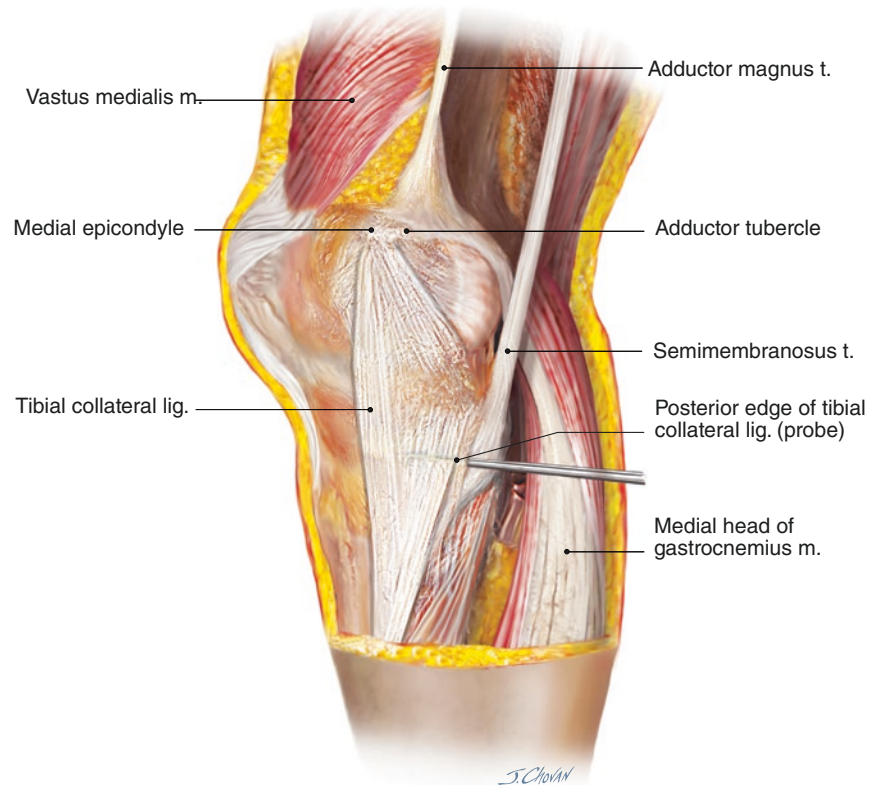
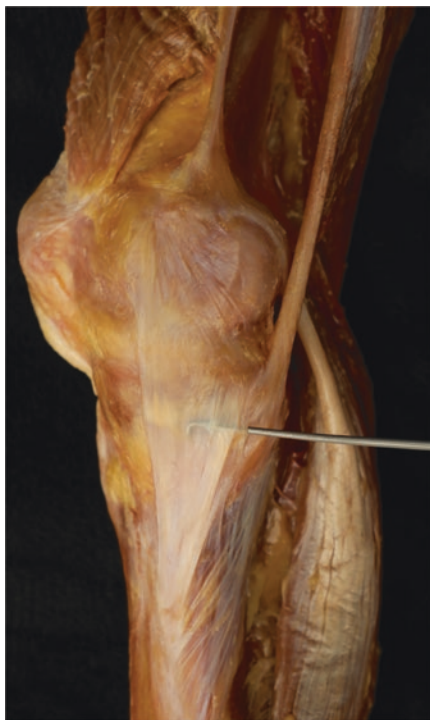


Fig. 6.9 Medial aspect of right knee in extension after removal of deep fascia. The **tibial collateral ligament (TCL)** (superficial medial collateral ligament) is attached superiorly to the medial epicondyle of the femur. It attaches to the tibia 6–10 cm distal to the joint line

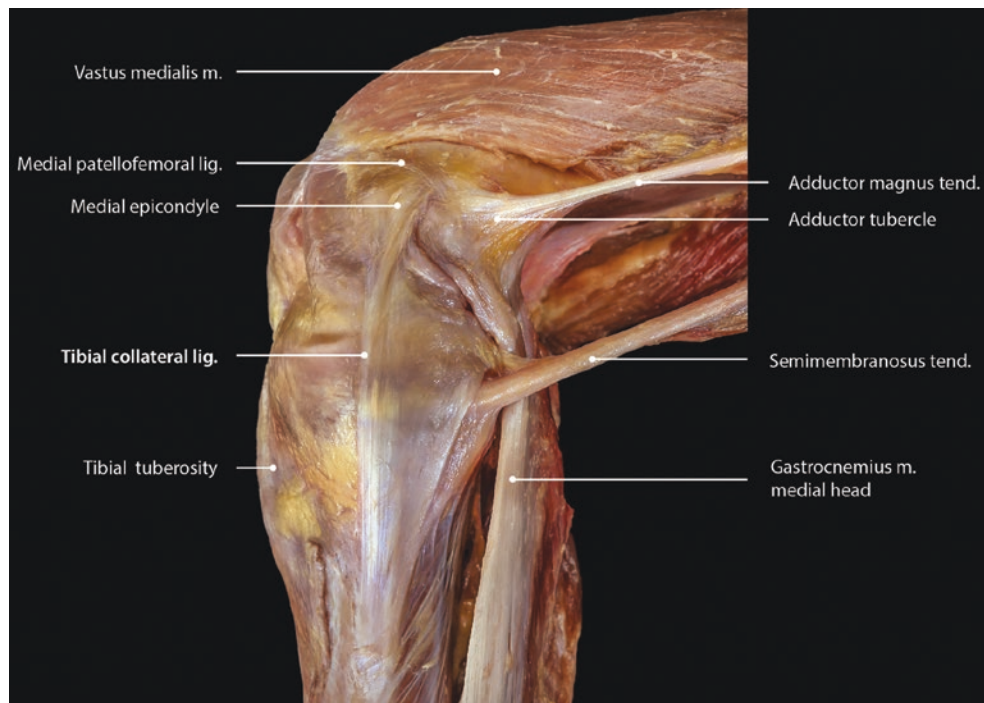


Fig. 6.10 Medial aspect of knee at 90° flexion. The deep fascia has been removed

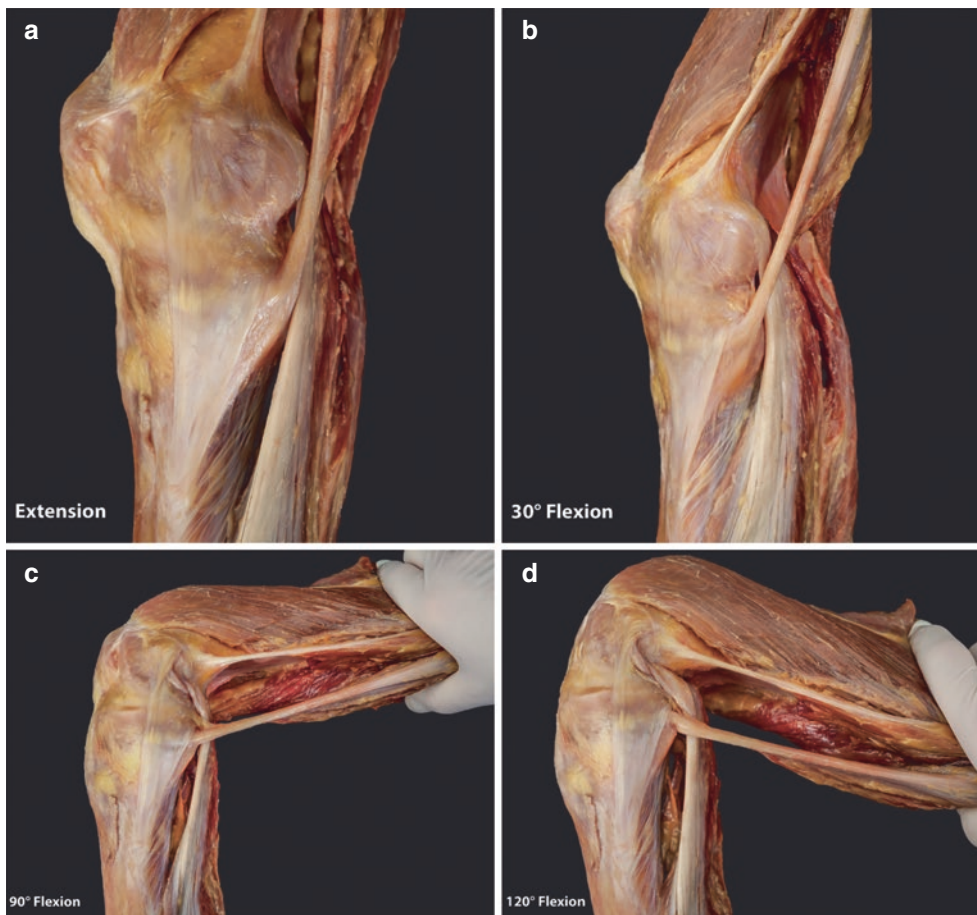


Fig. 6.11 Right knee, medial aspect. Note changes in tibial collateral ligament with increasing flexion ((a) extension, (b) 30° flexion, (c) 90° flexion, (d) 120° flexion)

6.5 Medial Capsule (see Fig. 6.12)

Terminology

“**Medial collateral ligament**” (MCL) is not an anatomical structure, but rather a **functional unit** that is made up of two anatomical structures: the **tibial collateral ligament (TCL)** and the **mid-third medial capsule**.

In 1948, Last introduced new terminology for the MCL in an article published in the *Journal of Bone and Joint Surgery* [6]. He described the medial collateral ligament as having a superficial and a deep part. This has led to the tibial collateral ligament being called the “superficial medial collateral ligament” and the mid-third medial capsule the “deep medial collateral ligament.” This is now orthopaedic lingo, even to the point that *Terminologia Anatomica II* [7] now accepts the sub-division of the terminology of the medial collateral ligament onto superficial and deep parts.

The **anterior third** of the medial capsule is thin to allow knee flexion. It blends with the retinaculum anteriorly. The **mid-third medial capsule (deep medial collateral ligament)** is thick and strong. It attaches to the femur slightly distal to the medial epicondyle as well as to the medial meniscus (see Figs. 1.35, 3.21, and 6.13). The **posterior third** of the medial capsule is thick. It blends with the trailing edge of the tibial collateral ligament.

The junction of the mid- and posterior thirds of the medial capsule has a thin portion. The surgeon should take advantage of this when making a posteromedial arthrotomy (*refer to Chap. 11*).

In its vertical orientation, the knee capsule can be divided into a menisco-femoral portion and a menisco-tibial portion (also called the coronary ligament) (*see Fig. 3.4*).

The mid-third medial capsule (deep MCL) is taught in extension. It becomes increasingly slack as the knee flexes (*see Fig. 6.14*).

The effect of tibial rotation on the mid-third medial capsule can be seen in Fig. 6.15.

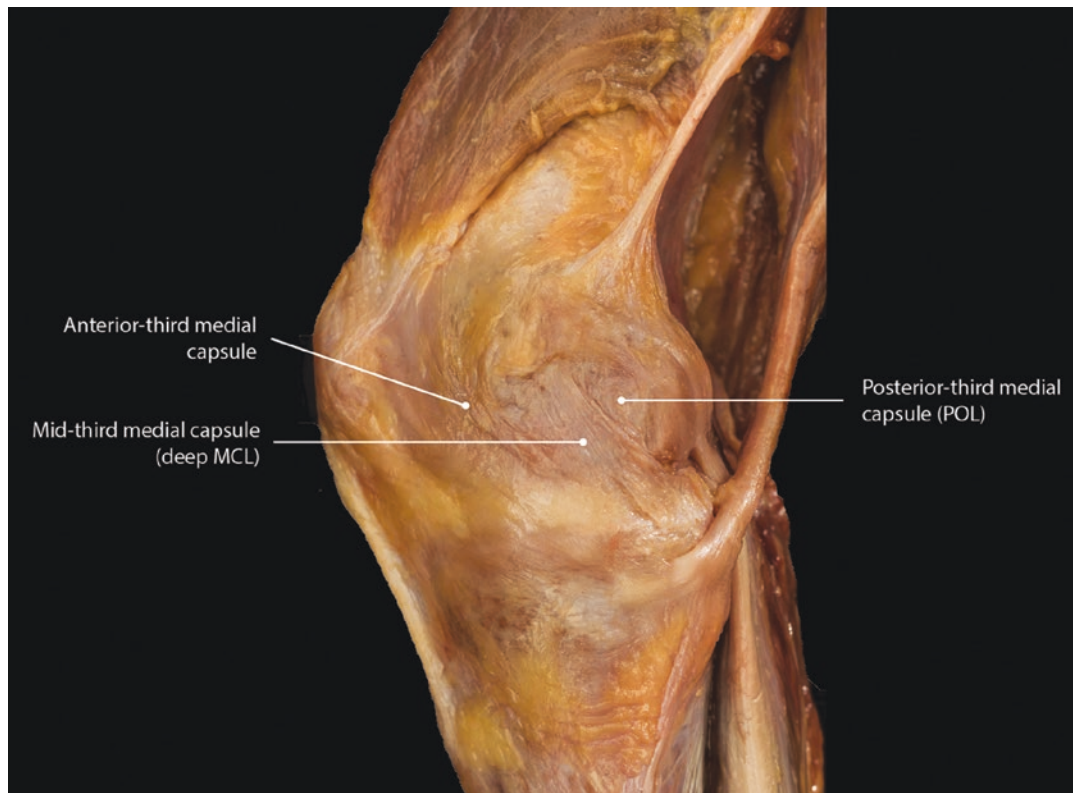


Fig. 6.12 The tibial collateral ligament has been removed to expose the medial capsule

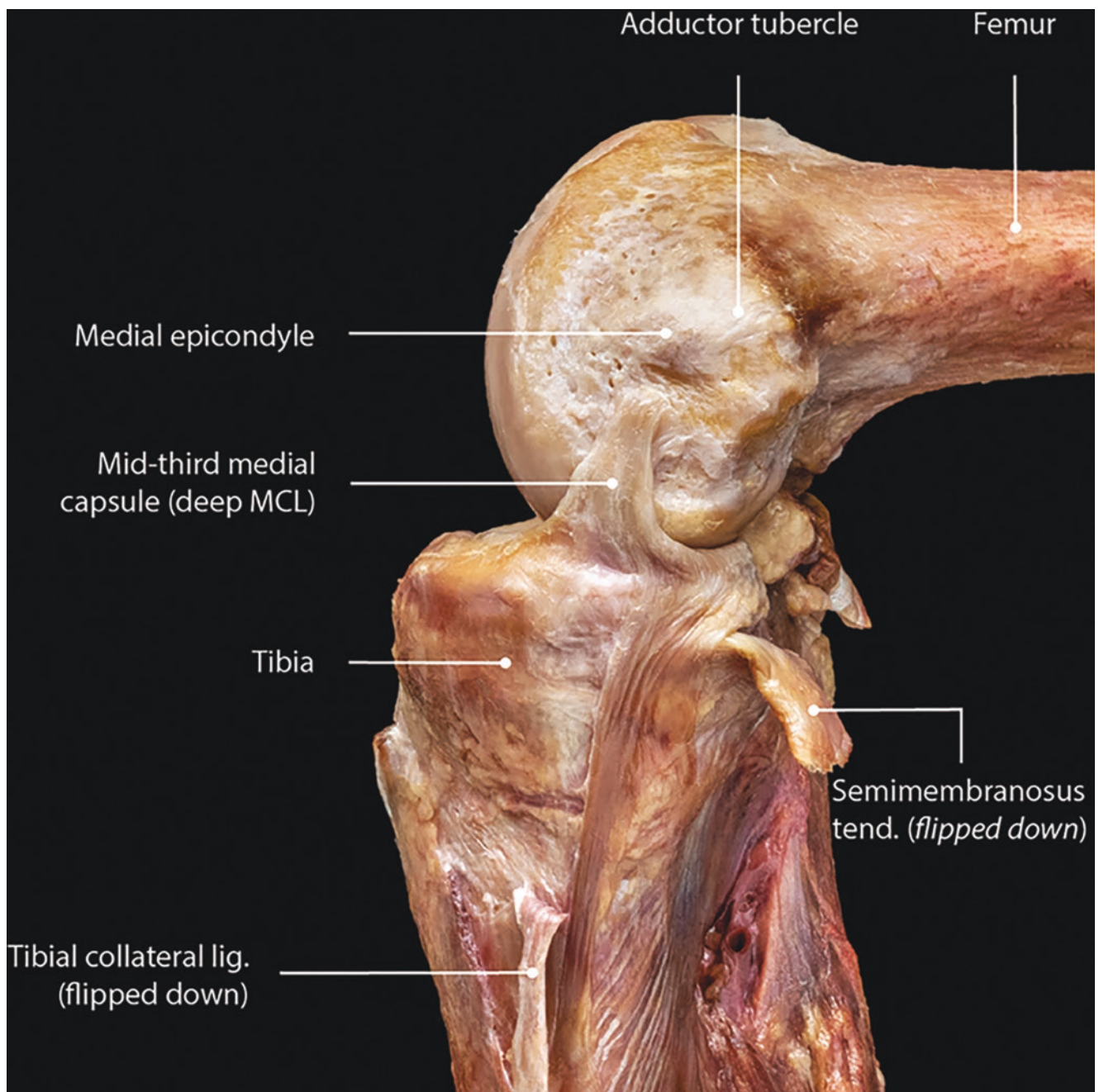


Fig. 6.13 Mid-third medial capsule (deep medial collateral ligament) after surrounding structures have been removed



Fig. 6.14 Right knee, medial aspect. Note the effect of flexion on mid-third medial capsule (deep MCL) ((a) extension, (b) 30° flexion, (c) 90° flexion, (d) 120° flexion)

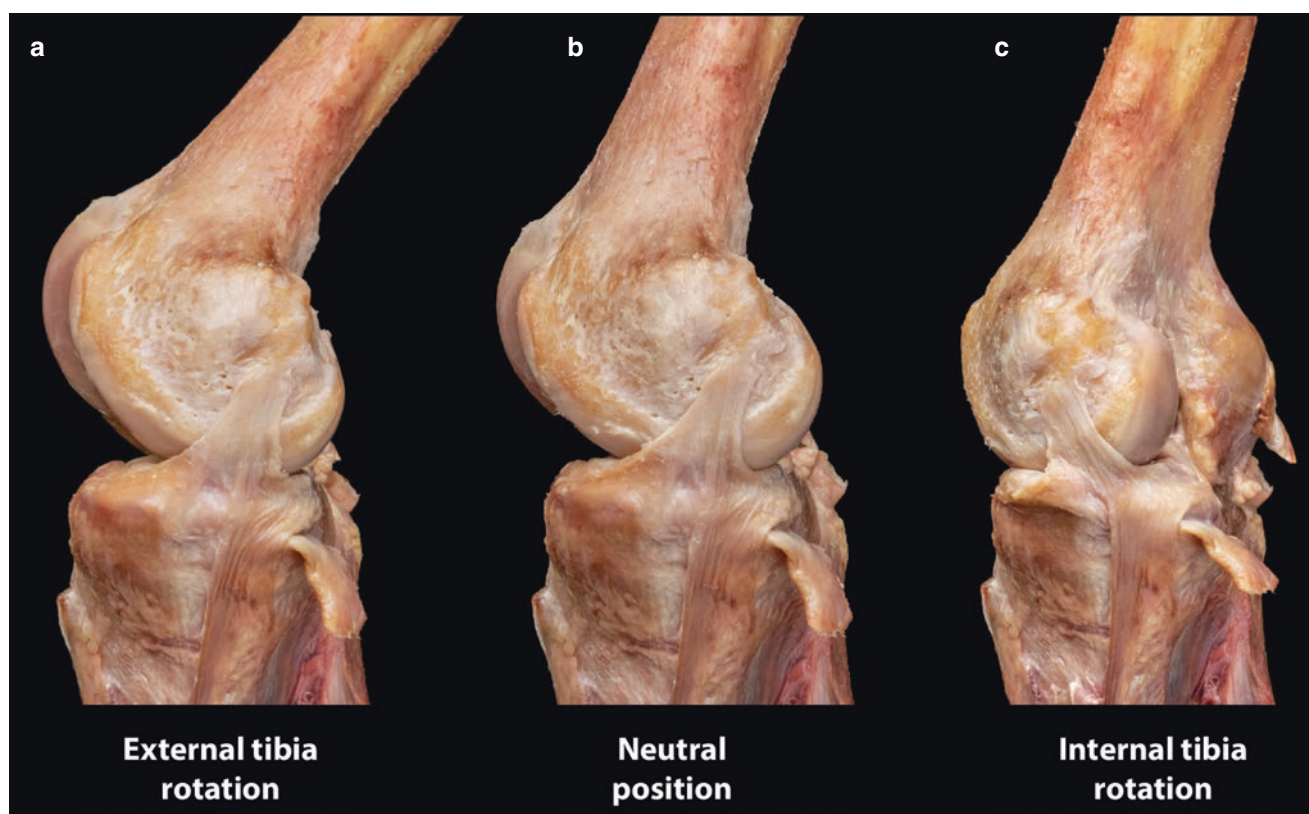


Fig. 6.15 Right knee, medial aspect. Note the effect of tibial rotation on mid-third medial capsule (deep MCL) ((a) external tibia rotation, (b) neutral position, (c) internal tibia rotation)

6.6 Pes Anserinus

The insertions of the tendons of the **sartorius**, **gracilis**, and **semitendinosus** collectively form the **pes anserinus**. The pes anserinus inserts onto the medial aspect of the proximal tibia. The upper border of the pes anserinus is located 6 cm (three fingerbreadths) distal to the medial joint line when the knee is at 90° flexion (see Fig. 6.16). The pes anserinus muscles are primarily flexors of the knee and secondarily internal rotators of the tibia.

The tendon of the **sartorius** muscle is broad, flat and has an aponeurotic form. It is continuous with the deep fascia of the leg (fascia cruris). The **gracilis** and **semitendinosus** tendons lie deep to the sartorius tendon expansion (see Fig. 6.17).

There is a bursa under the insertion of the pes anserinus to the tibia: the **pes anserinus bursa** (anserine bursa) (see Fig. 6.18).

The innervation of the pes anserinus is interesting. Three major nerves go to the lower extremities: the obturator, fem-

oral, and sciatic nerves. Each of the three muscles that compose the pes anserinus is innervated by one of these nerves. The **obturator nerve** goes to an adductor, the gracilis muscle. The sartorius muscle, which lies in the anterior compartment of the thigh in company with the quadriceps muscles, gets the **femoral nerve**. The semitendinosus muscle originates in the posterior thigh as a hamstring muscle and is innervated by the **sciatic nerve**. Though the three muscles originate from separate compartments, they all insert on the medial side of the upper tibia to flex the knee and internally rotate the tibia.

Exam Question

“What is the innervation of the pes anserinus?”

Answer:

- **Sartorius** – femoral nerve
- **Gracilis** – obturator nerve
- **Semitendinosus** – sciatic nerve

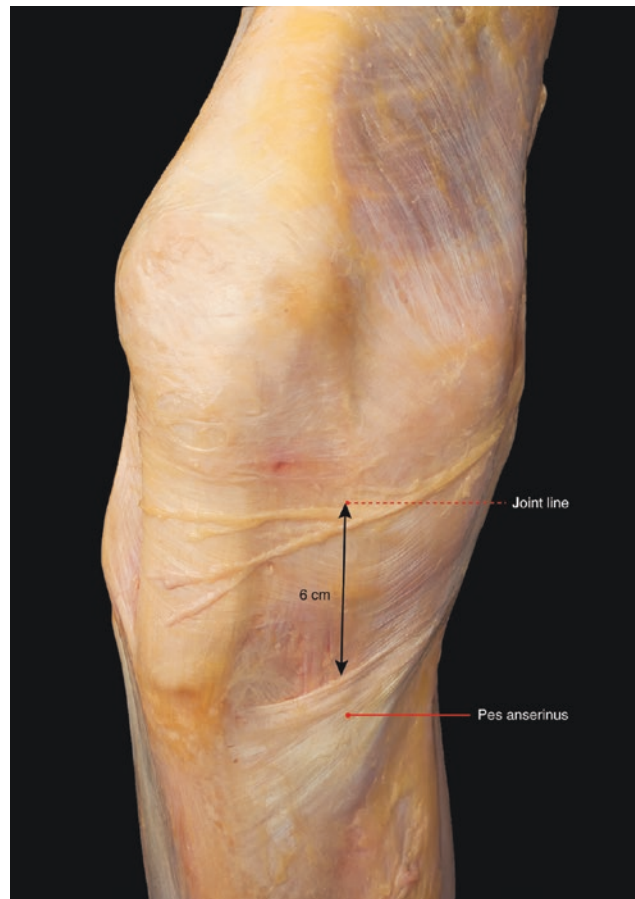


Fig. 6.16 The superior border of the pes anserinus is located 6 cm (3 fingerbreadths) distal to the joint line

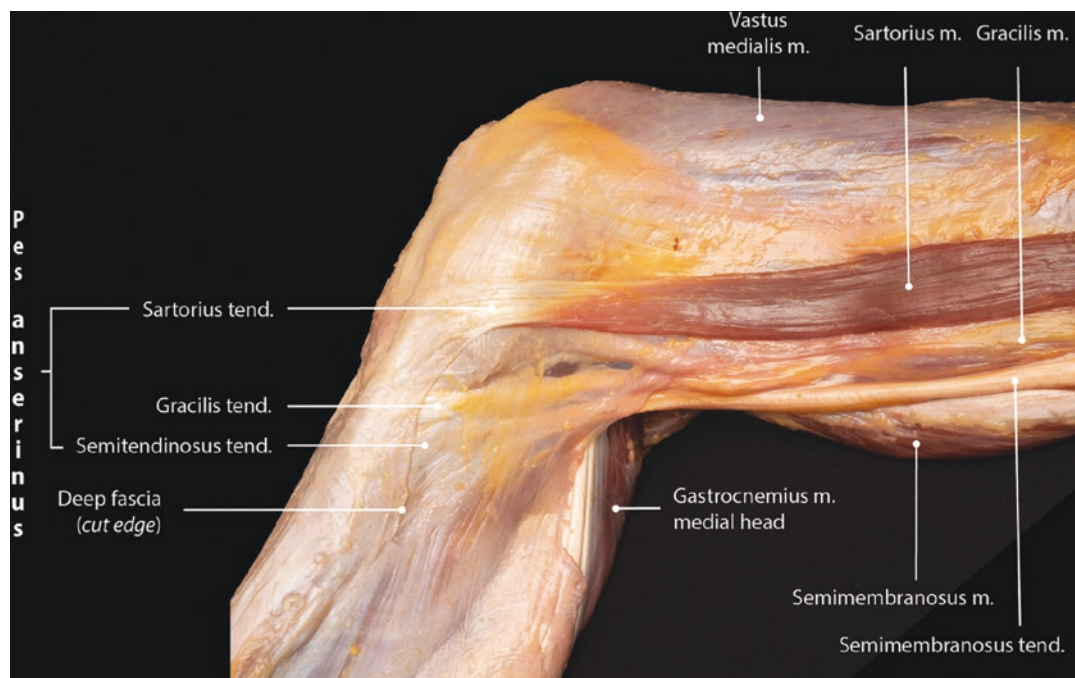
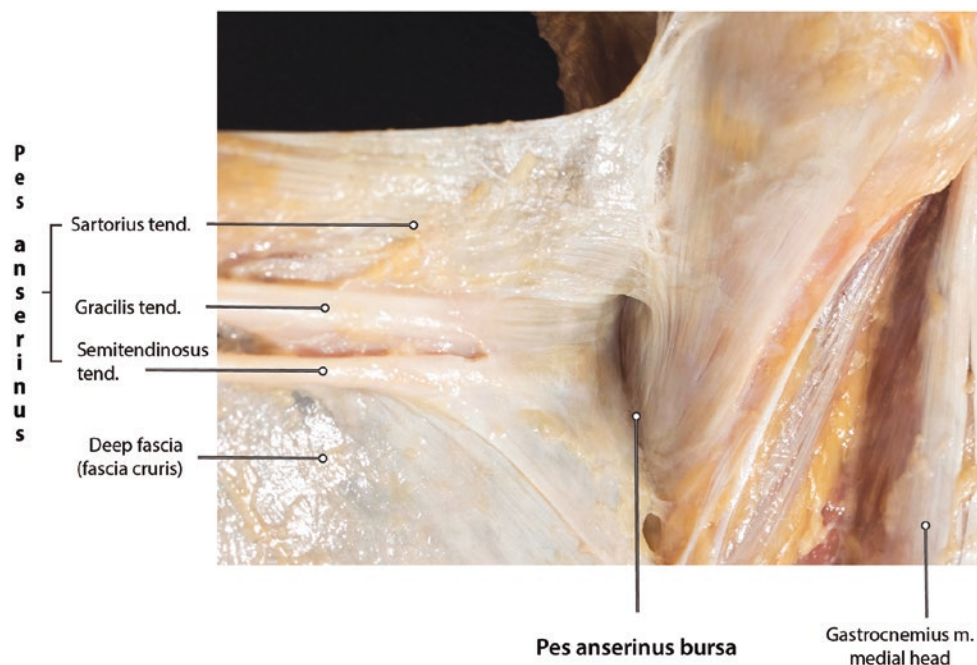


Fig. 6.17 Medial aspect of right knee. Most of the deep fascia has been removed to show the components of the pes anserinus. The tendon of the **sartorius** muscle is broad, flat and has an aponeurotic form. It is

continuous with the deep fascial layer (cut). Deep to it are of the **gracilis** and **semitendinosus** tendons

Fig. 6.18 Undersurface of pes anserinus showing **pes anserinus bursa** (anserine bursa). Note the continuation of the sartorius tendon aponeurosis distally as the fascia cruris



6.7 Insertions of Semimembranosus Tendon

The five insertions of the semimembranosus tendon to the posteromedial knee are (1) the **anterior (tibial) arm** (also known as *pars reflexa*) (see Fig. 6.19a). It courses anteriorly in a horizontal groove just below the medial tibial condyle and inserts beneath the tibial collateral ligament. (2) The **direct head**. It inserts to a groove on the posterior aspect of medial tuberosity of the tibia. (3) A large tendinous expansion continues upward and laterally as a thickening of the posterior capsule of the knee toward origin of the lateral head of the gastrocnemius. This forms the **oblique popliteal ligament** (OPL). (4) An expansion blends with the posteromedial capsule (also known as **posterior oblique ligament** or

POL). (5) A portion of the semimembranosus tendon continues posteriorly to expand onto the **popliteus fascia** covering the popliteus muscle (see Figs. 6.19 and 6.20).

Distal ramifications of the semimembranosus tendon fuse into the periosteum of the medial tibia. An insertion of the tendon to the posterior horn of the medial meniscus has been described, but we have not found a significant connection [8]. Other insertions have been described but they are not surgically important [9, 10].

The semimembranosus muscle is a flexor and internal rotator of the tibia. As the knee flexes the oblique popliteal ligament tenses the posterior capsule. All branches act as major stabilizing elements for the posteromedial aspect of the knee (see Fig. 6.19b).

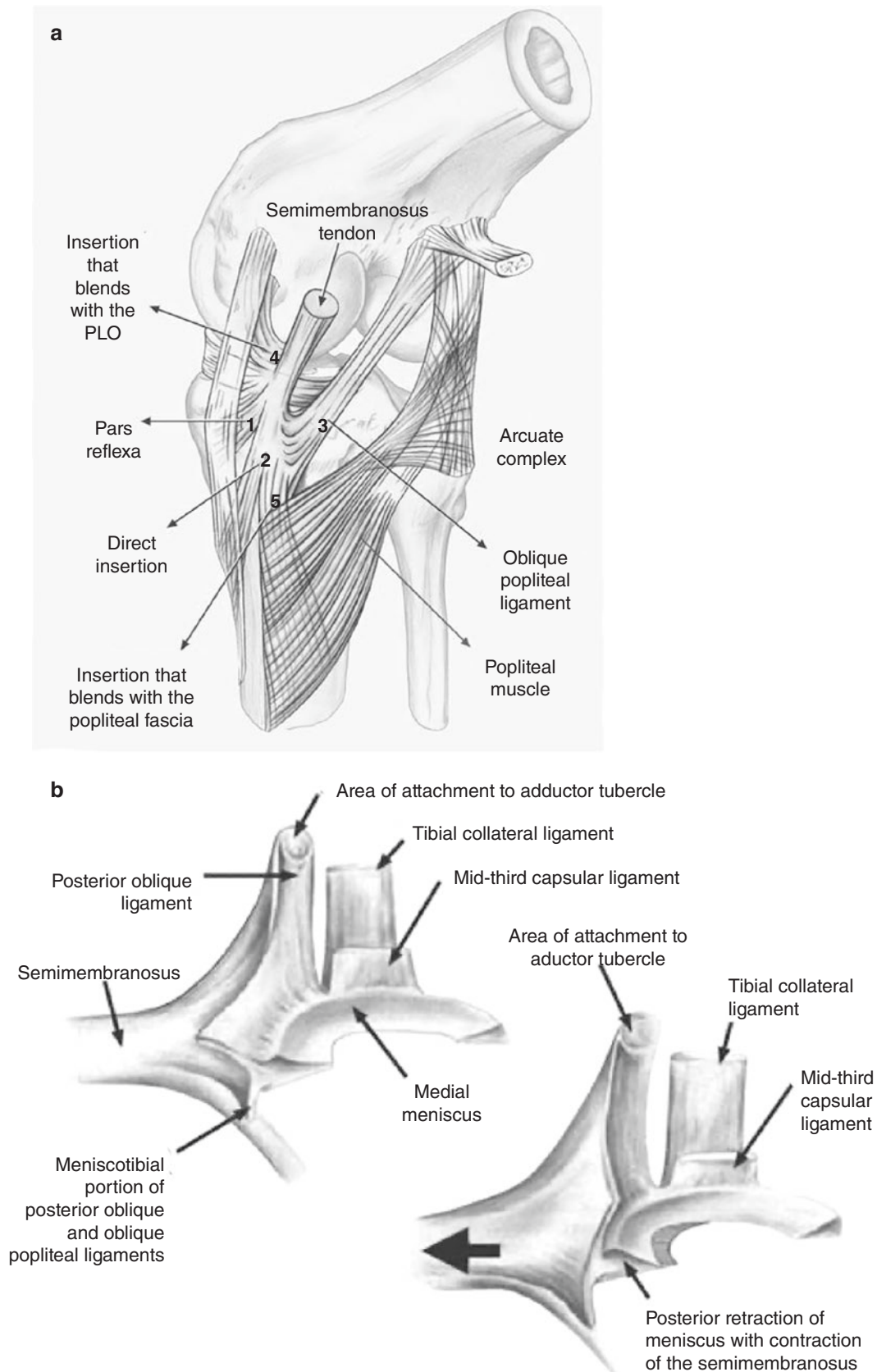


Fig. 6.19 Semimembranosus tendon insertions. (a) (1) Anterior arm “tibial arm” or “pars reflexa,” (2) direct insertion, (3) oblique popliteal ligament, (4) expansion to posterior oblique ligament (POL), and (5) popliteus fascia expansion. (b) Intracapsular orientation of the postero-

medial corner structures showing the proposed “dynamizing” action (arrow) of the semimembranosus. Note the relationship of the semimembranosus capsular expansion, the posterior oblique ligament, and the posteromedial meniscus (From Sims and Jacobson [16]; with permission)

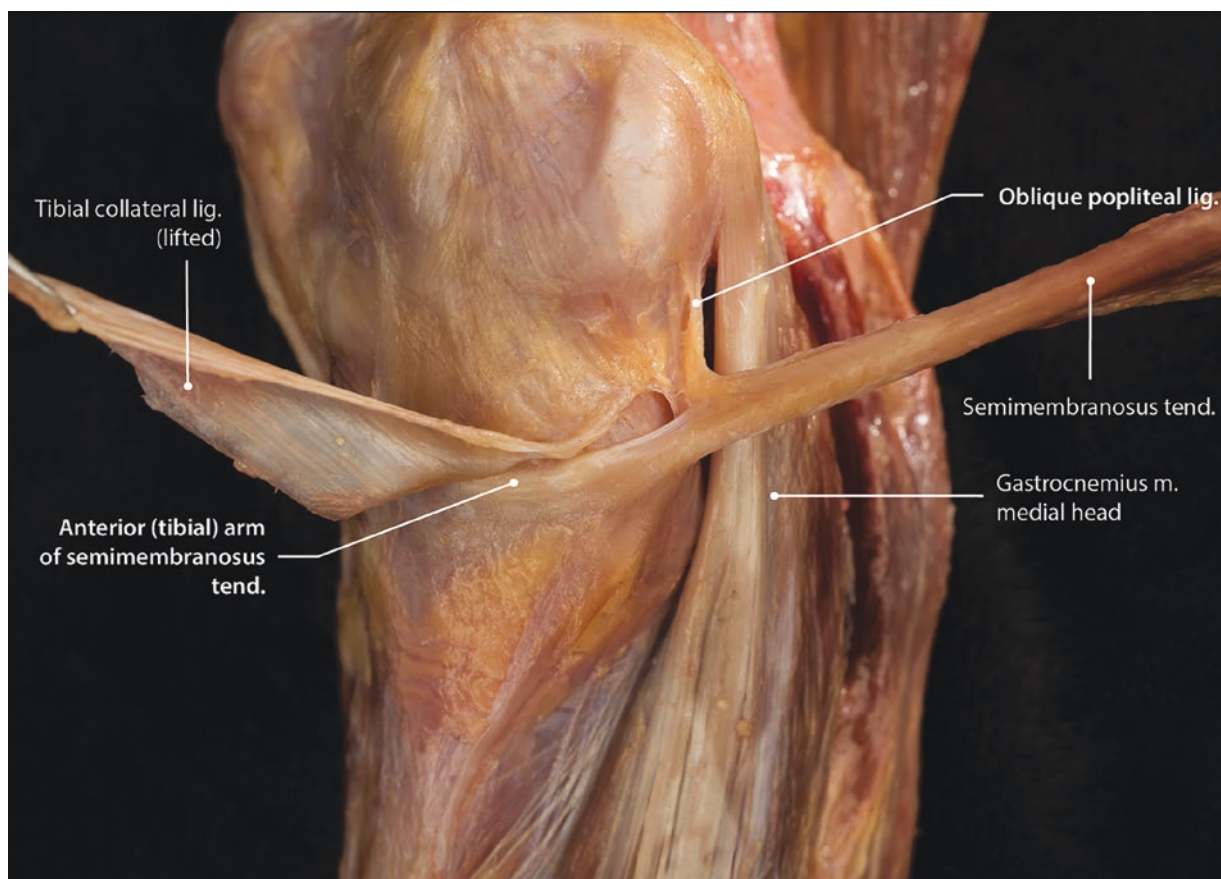


Fig. 6.20 Right knee, posteromedial aspect showing two insertions of semimembranosus tendon. The **anterior (tibial)** arm passes under the tibial collateral ligament (lifted). A large tendinous expansion of the

semimembranosus tendon continues upward and laterally as a thickening of the posterior capsule of the knee to form the **oblique popliteal ligament**

6.8 Posteromedial Capsule (Posterior Oblique Ligament) (POL)

Hughston and Eilers re-named the **posteromedial capsule** the **posterior oblique ligament (POL)** and divided it into three parts [11]. (1) They called the anterior part, which runs parallel to the tibial collateral ligament, the **superficial** arm. (2) The **central**, or tibial, arm is the largest and thickest part of the posteromedial capsule and has a thick attachment to the posterior third of the medial meniscus; it blends with the posterior fibers of the tibial collateral ligament. (3) The **capsular** arm is furthest posterior.

Warren et al. did not find this ligament [5, 12]. Neither did Robinson et al., who simply called the structures posterior to the tibial collateral ligament the “posteromedial joint capsule” [13, 14].

It is easy to confuse OPL with POL. We will not use the term POL but refer to it as the posteromedial capsule.

6.9 Medial Head of Gastrocnemius Muscle

The medial head of the gastrocnemius muscle originates from the upper surface of the medial femoral condyle, just distal and medial to the popliteal fossa. It covers the posteromedial capsule (*see* Figs. 1.35 and 8.3).

6.10 Popliteal Cyst

The popliteal cyst (Baker’s cyst), if present, is in the semimembranosus-gastrocnemius bursa under the medial head of gastrocnemius muscle at its origin from the femur. It was first described by William Marrant Baker in 1885 [15] (*see* Fig. 6.23).

In children, popliteal cysts usually do not communicate with the knee joints, and they tend to disappear with growth. In adults, popliteal cysts are usually secondary to fluid from

the knee joint that gets pushed into the semimembranosus-gastrocnemius bursa through an opening in the posterior capsule. This opening can be large and can be a one-way flap that prevents the fluid that has been pushed into the bursa from going back into the knee joint.

Exam Question

“What are the borders of the popliteal cyst?”

Answer:

- **Medial head of gastrocnemius muscle**
- **Posteromedial capsule**
- **Semimembranosus tendon**

6.11 Adductor Magnus Tendon

The adductor magnus muscle inserts in a broad aponeurosis into the linea aspera of the femur and continues as a tendon that inserts onto the adductor tubercle (*see* Fig. 6.10).

6.12 Posterior Medial (Deep) Structures

The deep anatomical structures on the posterior aspect of the medial side of the knee are complicated and important (*see* Fig. 6.21). With the knee at 90° flexion, the adductor magnus tendon is a good landmark. The descending genicular artery runs alongside the adductor magnus tendon and supplies the medial femoral condyle area. The **saphenous nerve** exits the anterior compartment near the musculotendinous junction of the sartorius muscle to become subcutaneous (*see* Fig. 6.22).

The deeper posteromedial structures, including the medial approach to the semimembranosus-gastrocnemius bursa, are shown in Fig. 6.23. Lifting the medial head of gastrocnemius muscle exposes the popliteal cyst (*see* Fig. 6.23).

The deep fascia of the medial leg (*see* Fig. 6.24) and its undersurface (*see* Fig. 6.25) is shown.

To visualize the course of the popliteal artery, the entire pes anserinus has been removed (*see* Figs. 6.26, 6.27, 6.28, and 6.29).

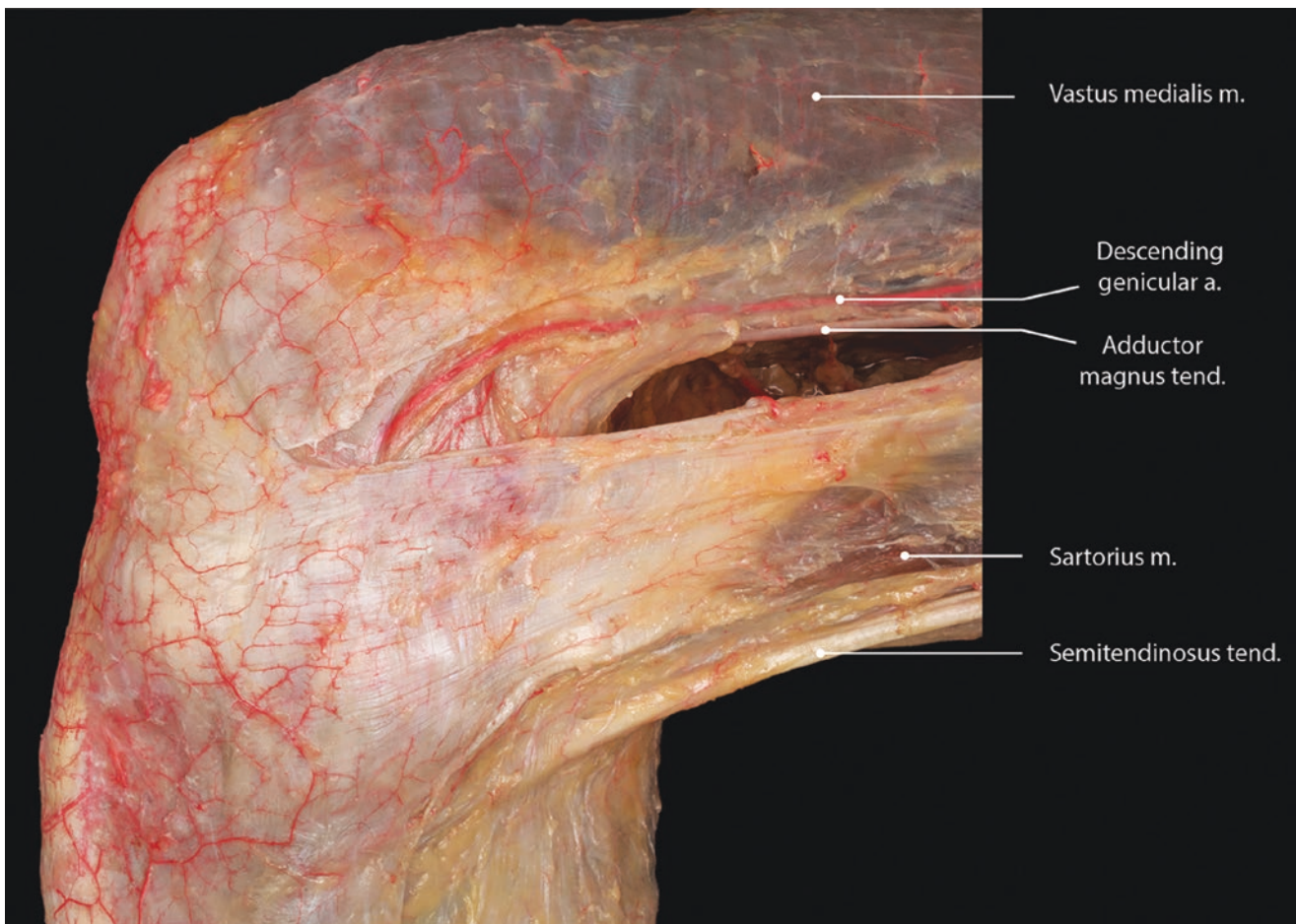


Fig. 6.21 The deep fascia has been split along the posterior border of the vastus medialis muscle. The descending genicular artery supplies the medial femoral condyle

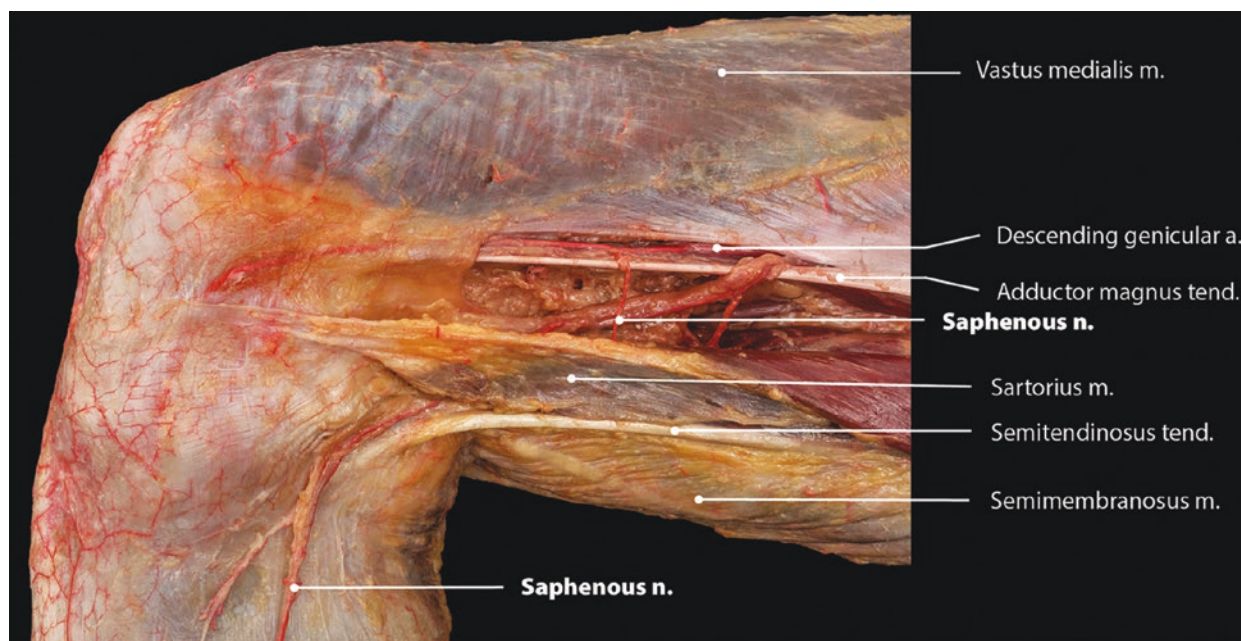


Fig. 6.22 The posterior deep fascia has been removed. The descending genicular artery supplies the medial femoral condyle. Note the saphenous nerve exiting the anterior compartment near the musculotendinous junction of the sartorius muscle to become subcutaneous

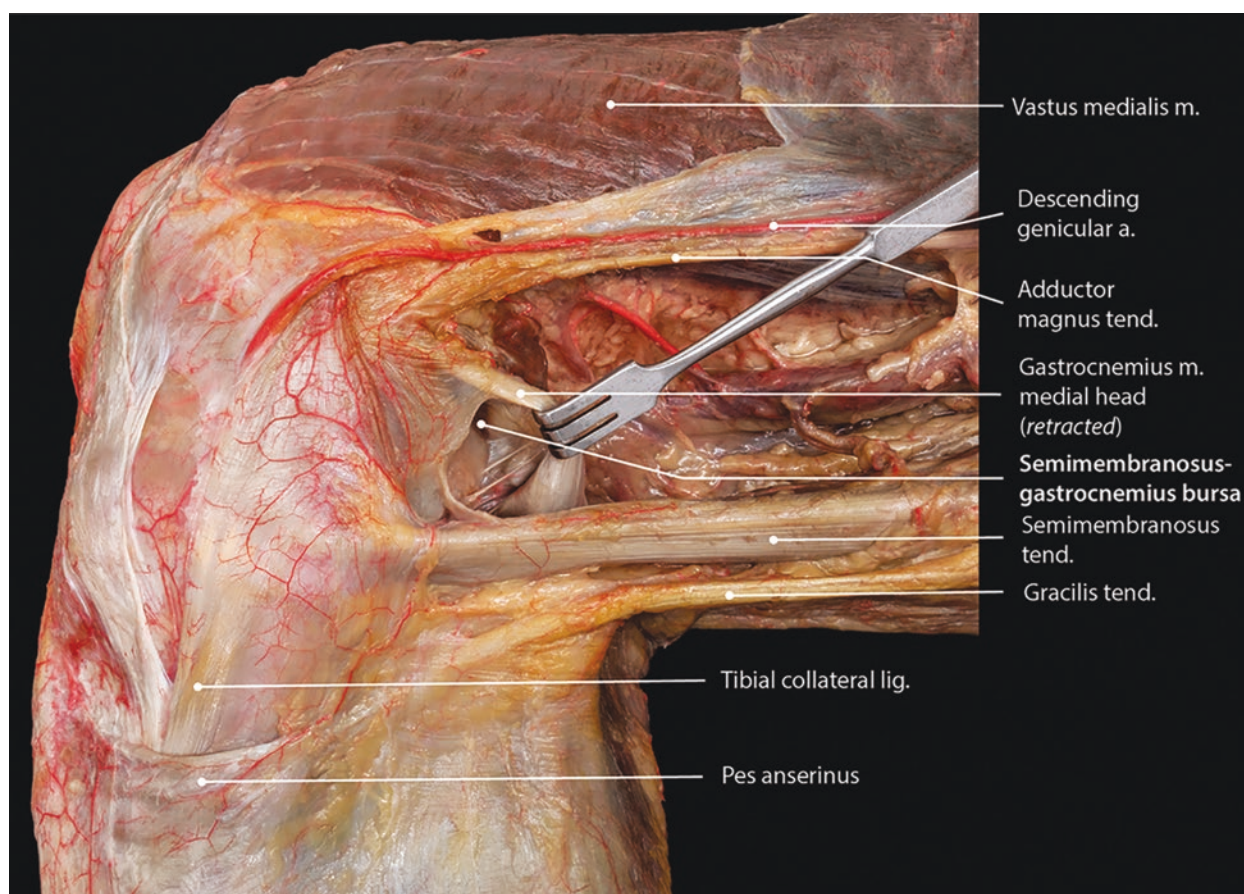


Fig. 6.23 The sartorius muscle and tendon have been removed, and the medial head of gastrocnemius muscle has been retracted to show the semimembranosus-gastrocnemius bursa. This would be the location of a popliteal cyst

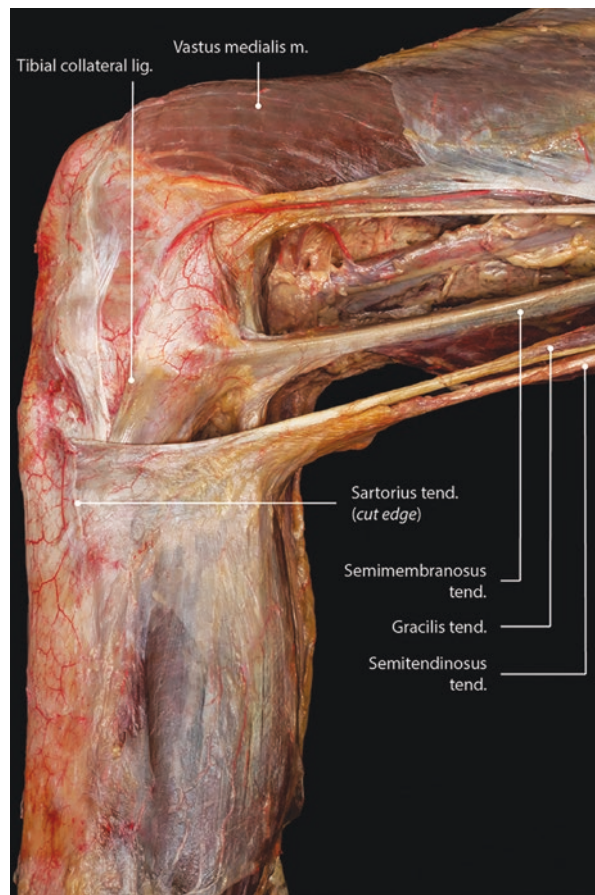


Fig. 6.24 The sartorius muscle and its broad, flat tendon have been removed. The gracilis and semitendinosus tendons insert on the tibia as the remaining components of the pes anserinus

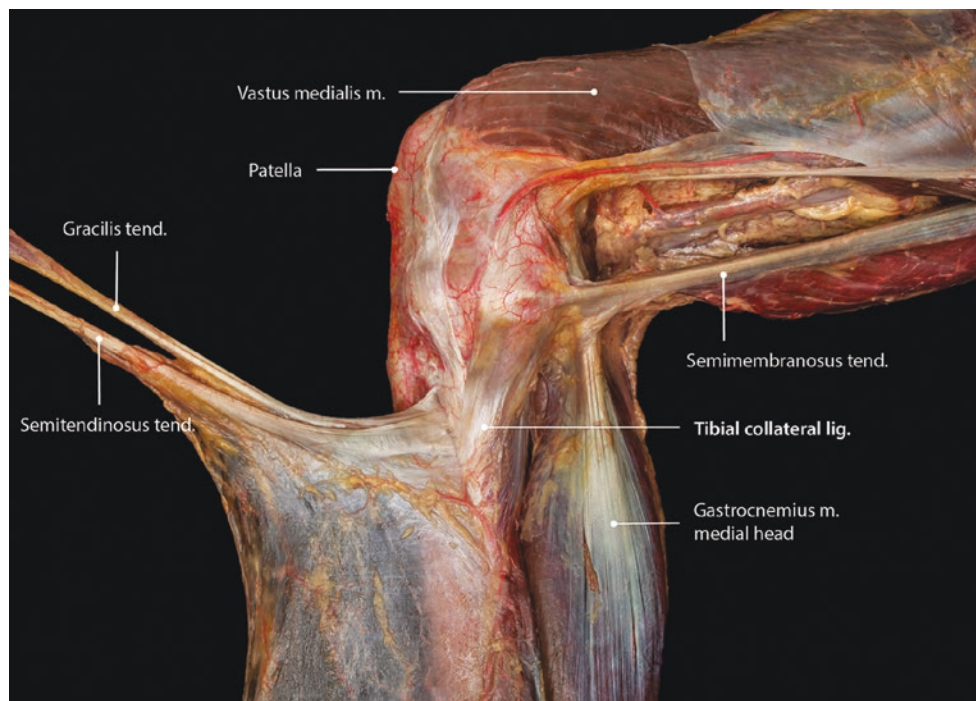


Fig. 6.25 The gracilis and semitendinosus tendons and the distal deep fascia have been lifted to expose their undersurface. Note the tibial collateral ligament attaching the tibia further distally

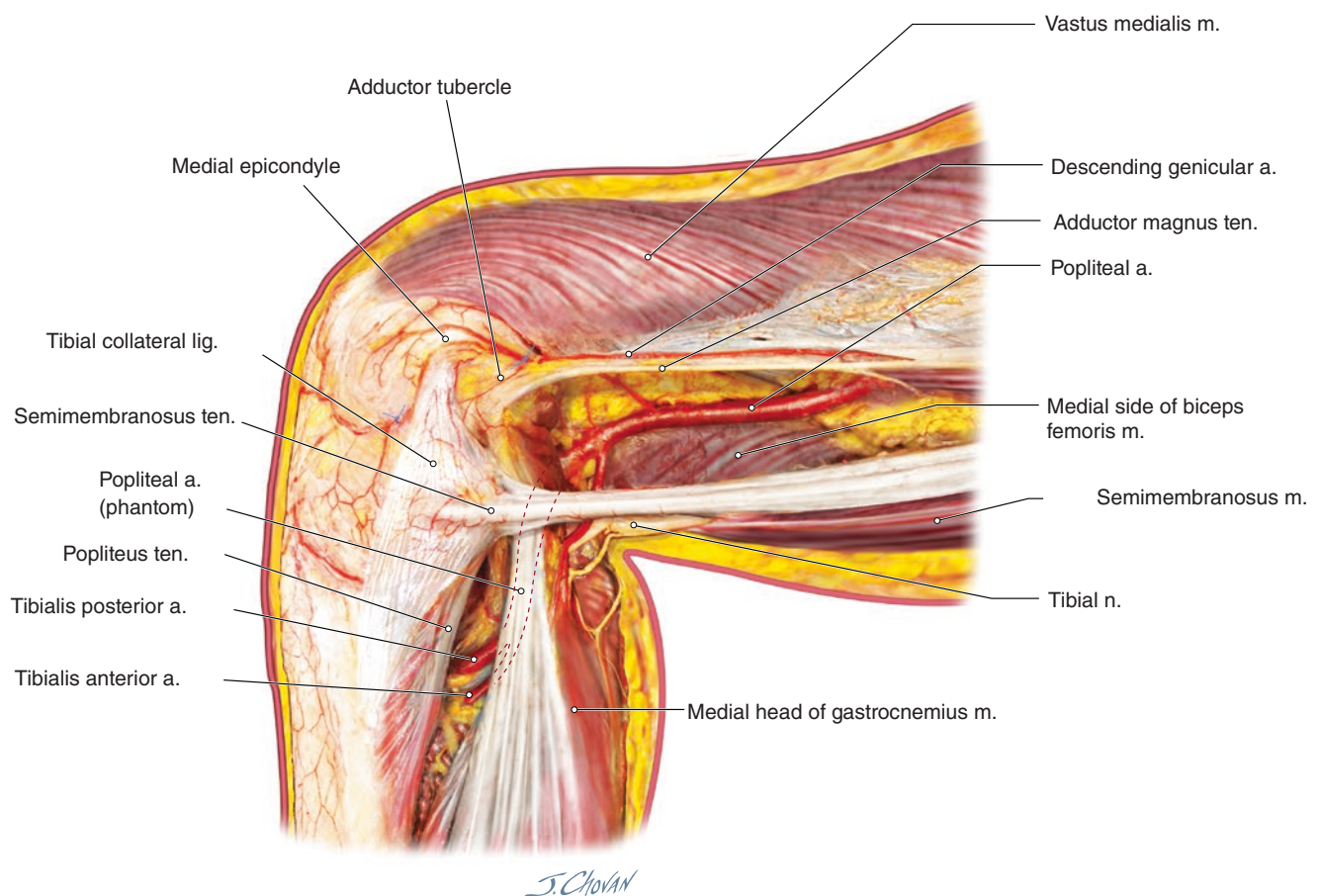


Fig. 6.26 The deep fascia and the pes anserinus have been removed from the medial aspect of the knee. Note the course of the popliteal artery

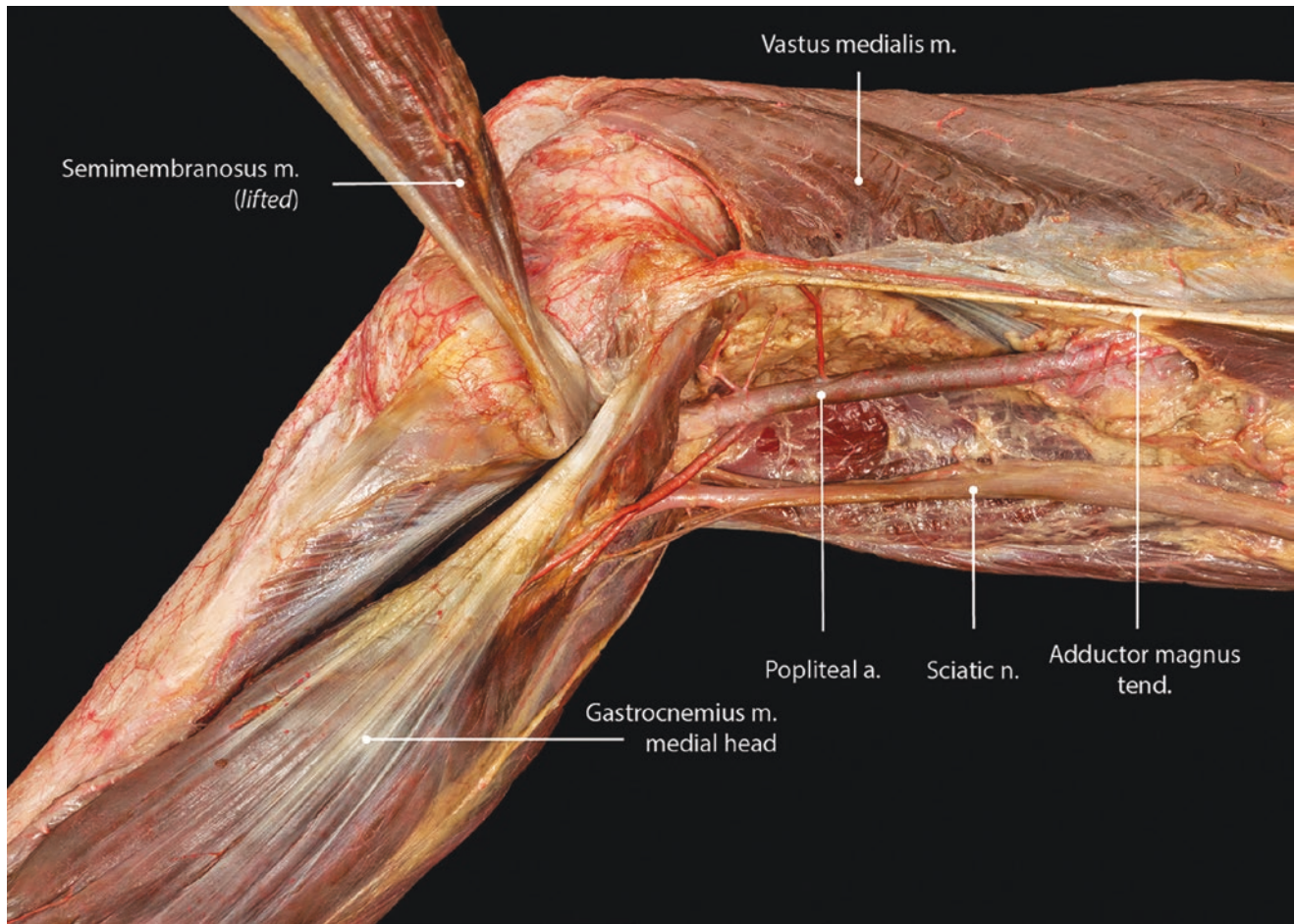


Fig. 6.27 The semimembranosus muscle has been lifted to reveal the popliteal artery and sciatic nerve and their branches

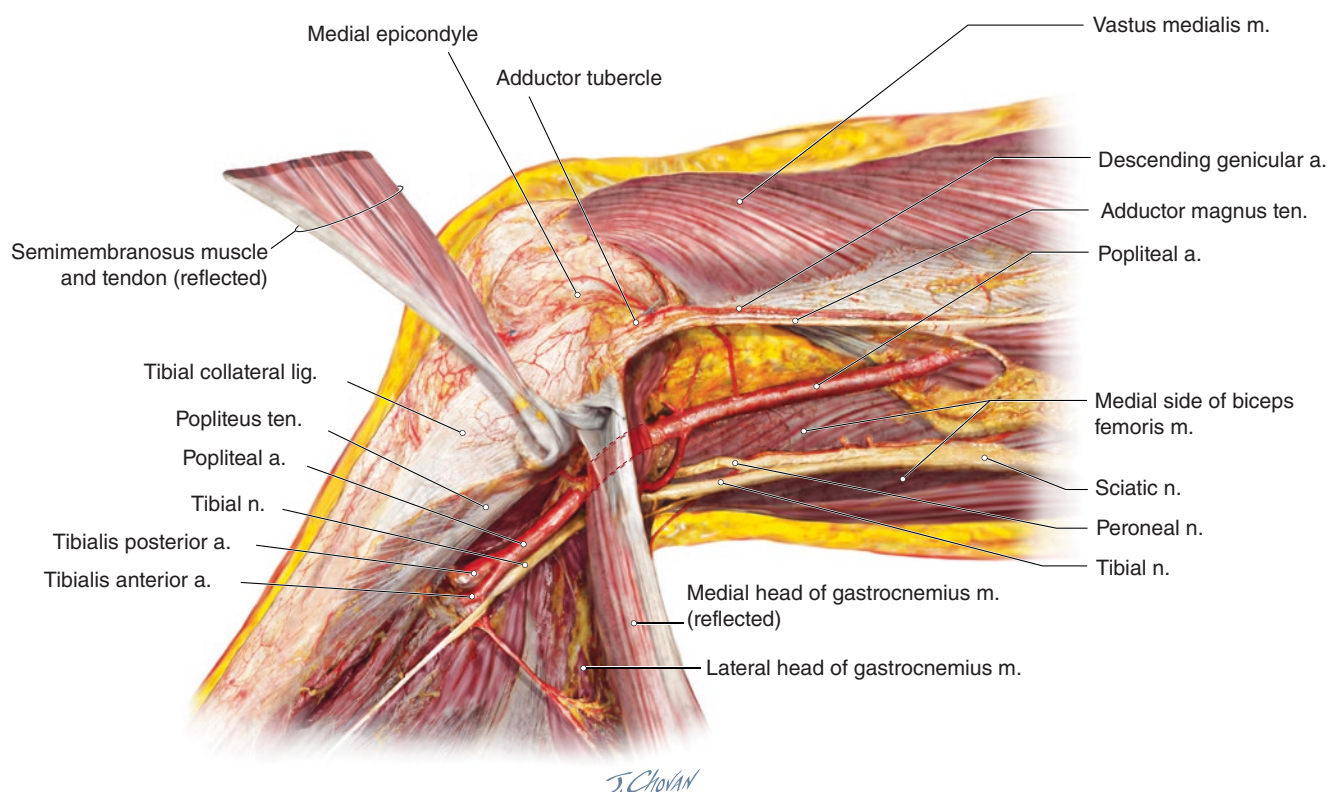


Fig. 6.28 The semimembranosus and medial gastrocnemius muscles have been lifted to show the continuation of the popliteal artery and sciatic nerve

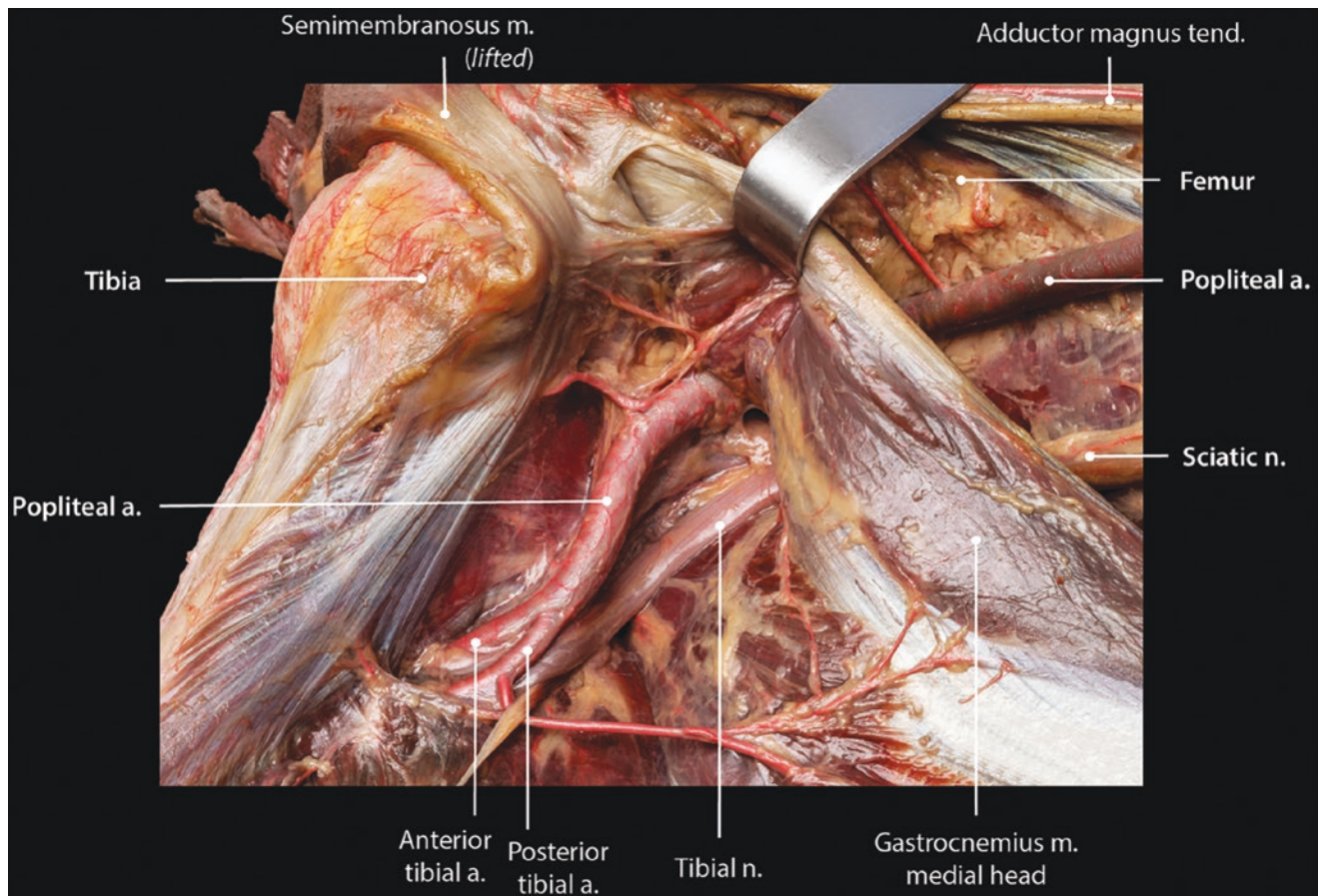


Fig. 6.29 Deep dissection of the posteromedial knee showing the **popliteal artery** and **sciatic nerve**

6.13 Vasculature

The femoral artery gives off the **descending genicular artery** (highest genicular artery) [*a. genus suprema; anastomotica magna artery*] in the lower thigh just before it passes into the adductor canal. It immediately divides into a saphenous branch and musculo-articular branches. The muscular branch continues within the vastus medialis muscle in front of the tendon of the adductor magnus. The **articular branch** passes under the medial patellofemoral ligament to supply the medial femoral

condyle and to anastomose around the knee joint (*see* Fig. 6.30).

The **medial superior genicular artery** passes under the tendon of the adductor magnus. It branches out to supply the vastus medialis muscle and knee joint and to anastomose with the arterial network of the knee (*see* Fig. 6.31).

The **medial inferior genicular artery** passes below the medial tibial condyle, beneath the medial head of gastrocnemius and tibial collateral ligament. It ascends to the anterior and medial side of the knee to supply the upper tibia, knee joint and to anastomose with other genicular arteries (*see* Fig. 6.32).

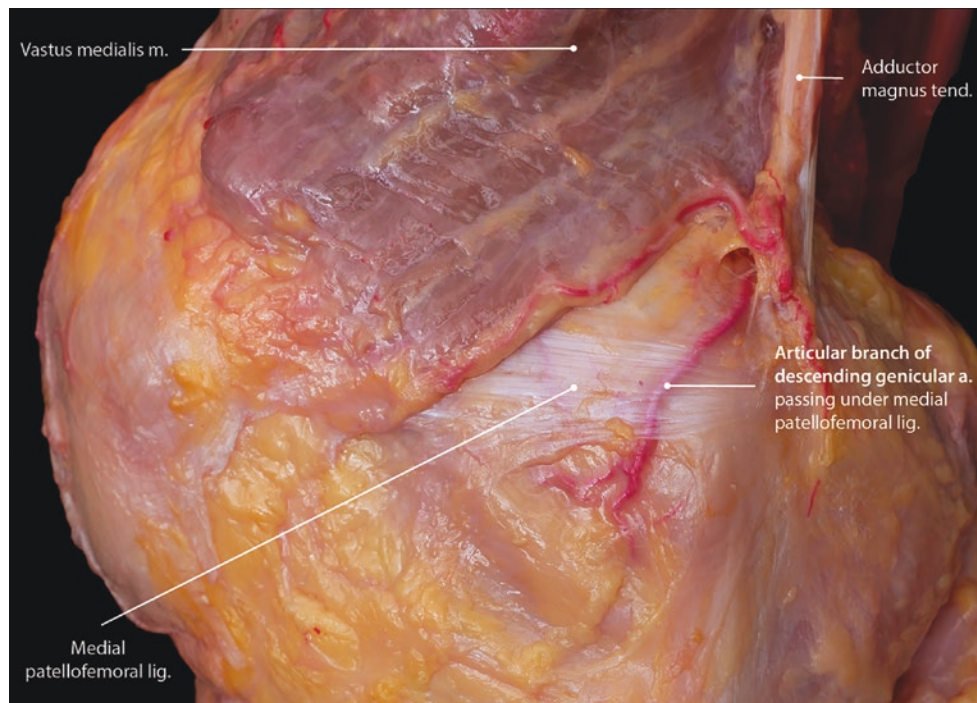


Fig. 6.30 The **articular branch** of the **descending genicular artery** passes under the medial patellofemoral ligament (MPFL) to supply the medial femoral condyle and to anastomose around the knee joint

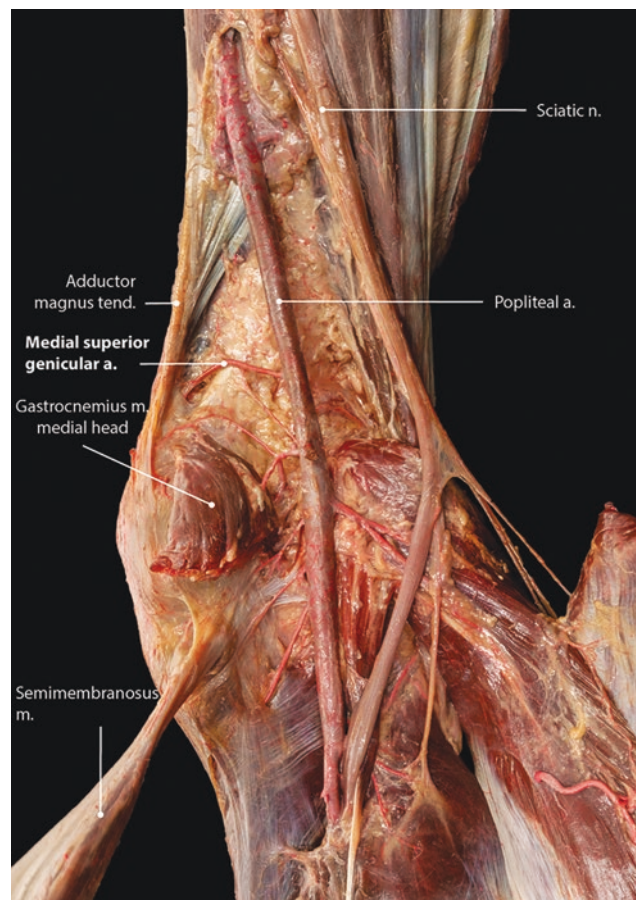


Fig. 6.31 The **medial superior genicular artery** passes under the tendon of the adductor magnus. It branches out to supply the vastus medialis muscle and knee joint and to anastomose with the arterial network of the knee

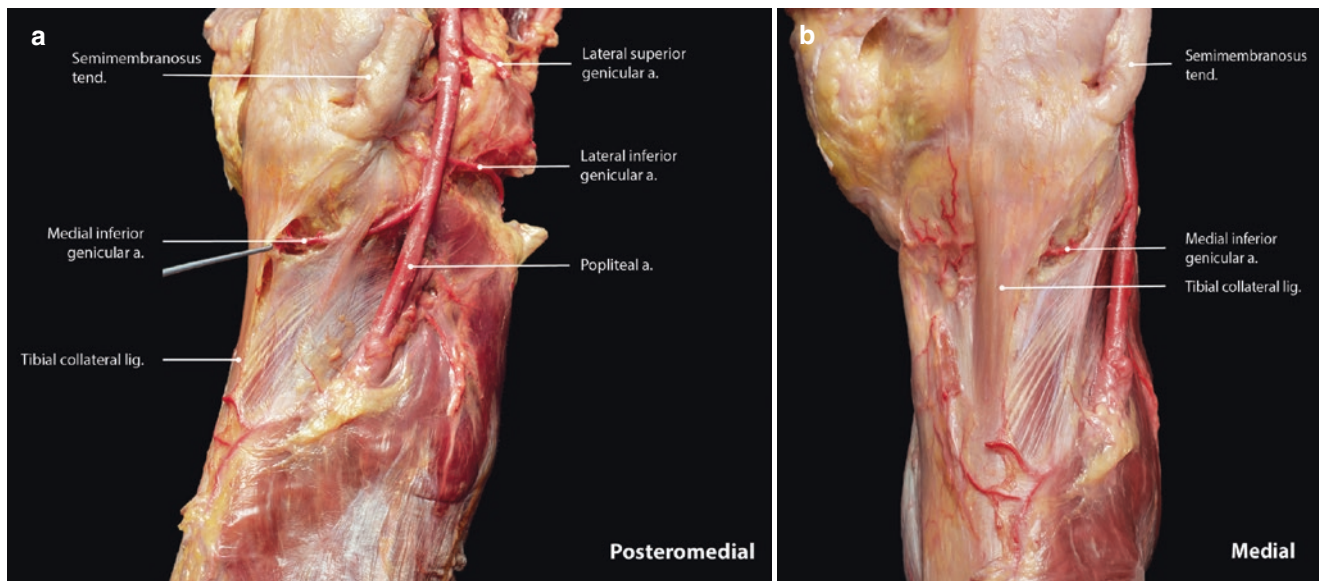


Fig. 6.32 (a) The medial inferior genicular artery ascends to the anterior and medial side of the knee to supply the upper tibia, knee joint and to anastomose with other genicular arteries. (b) The **medial inferior**

genicular artery passes below the medial tibial condyle, beneath the medial head of gastrocnemius and tibial collateral ligament

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Lateral Knee Anatomy

7

Robert Śmigielski and Bertram Zarins

7.1 Fascia Lata

The deep fascia of the thigh is the **fascia lata**. If the skin and subcutaneous fat are lifted away from the deep fascial layer, patches of deep subcutaneous fat and superficial nerves and blood vessels tend to adhere to the deep fascia (see Fig. 7.1). The deep fascia of the leg is the **fascia cruris** (see Fig. 7.2).

Three palpable bony landmarks on the lateral knee form a triangle. They are the **fibular head**, **Gerdy's tubercle**, and **tibial tuberosity**. Gerdy's tubercle is a facet on the anterolateral upper tibia just distal to the knee joint. It is the attachment site of the deep fibers of the iliotibial tract. Gerdy's tubercle is slightly proximal and anterior to a line connecting the tibial tuberosity and the fibular head (see Figs. 7.3 and 12.1).

The lateral fibers of the fascia lata are thick and strong. They are called the **iliotibial tract (ITT)** or, interchangeably, the **iliotibial band (ITB)**. Superficial anterior fibers of the ITT continue across the front of the patella. Posterior fibers of the ITT continue to Gerdy's tubercle (see Fig. 7.4).

Terminology

Gray's Anatomy does not distinguish between the ITB and ITT but calls the structure the "iliotibial band" (*tractus iliotibialis*) [1].



Fig. 7.1 Right knee, lateral aspect. The skin and superficial subcutaneous fat have been removed to expose the deep subcutaneous fat

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Fig. 7.2 Right thigh, knee, and leg (lateral aspect) showing the deep fascia

The ITT is thick and can be dissected into layers. Deep fibers of the ITT connect to the lateral epicondyle with the “condylar strap” [2] (see Fig. 7.5).

The iliotibial tract is a continuation of the aponeurotic tendon of the tensor fascia lata muscle [3]. This makes it “dynamic.” However, there is little, if any, excursion. Distally the aponeurosis of the vastus lateralis muscle attaches to ilio-tibial tract and helps to tense the ITT as knee extends and as the ITB moves forward. This contributes to lateral knee stability, especially in extension.

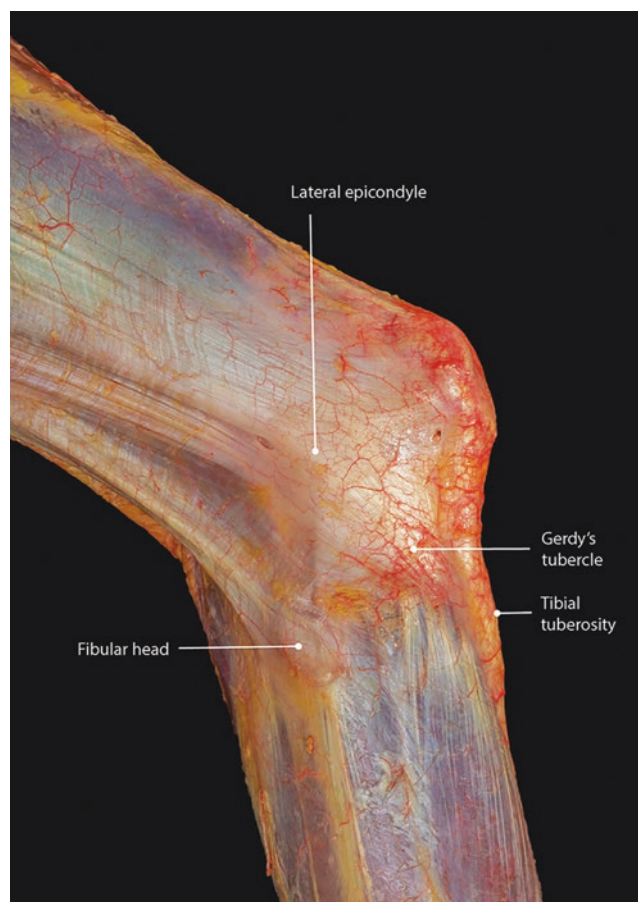


Fig. 7.3 Right knee, lateral aspect, demonstrating the bony landmarks

The ITT moves forward in extension and backward in flexion but is tense in both positions. With flexion, the ITT, popliteus tendon, and fibular collateral ligament cross each other, enhancing lateral stability. The ITT and biceps tendon remain parallel to each other in flexion and extension.

The deep fibers of the lateral intermuscular septum connect distally to the femur. They have been called the “Kaplan fibers.” (Fig. 7.6).

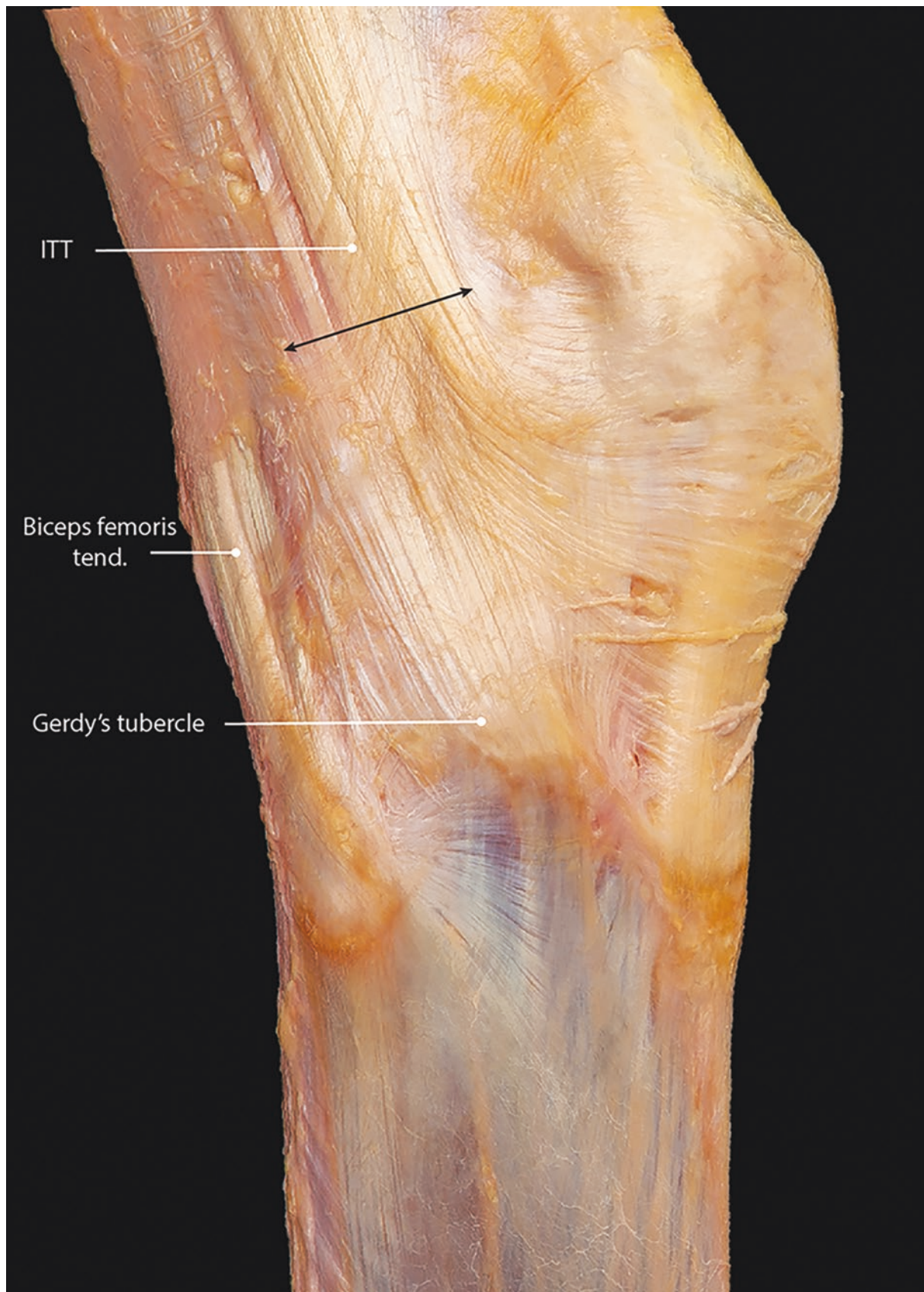


Fig. 7.4 Right knee, lateral aspect in extension. The thick lateral fibers are called the iliotibial tract (ITT) or, interchangeably, the iliotibial band (ITB). Superficial anterior fibers of the ITT do not attach to the

patella but cross its anterior surface. Posterior fibers of the ITT continue to Gerdy's tubercle. Note the width of the ITT (arrow)

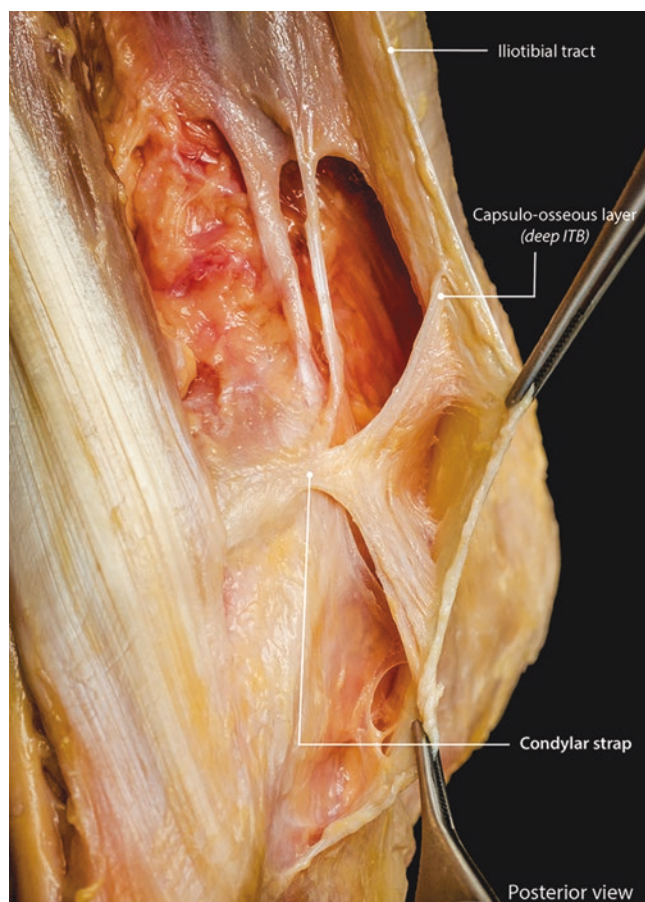


Fig. 7.5 Right knee, distal lateral aspect. The iliotibial tract is thick and can be split into layers. Deep fibers of the ITT connect to the lateral epicondyle with the “condylar strap”

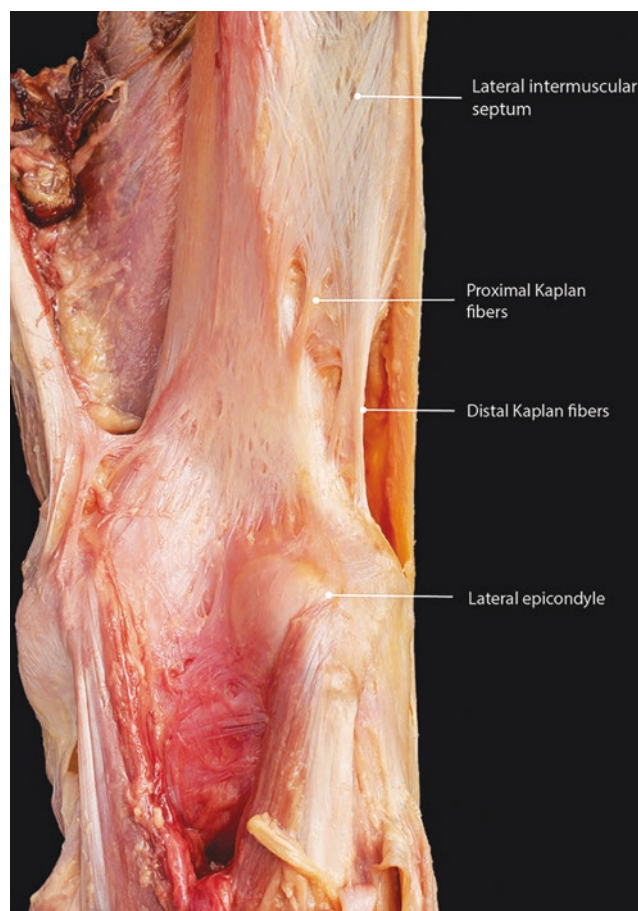


Fig. 7.6 Right knee, posterior aspect. The lateral intermuscular septum connects distally to the femur with “Kaplan fibers”

7.2 Lateral Patellar Retinaculum (see also Chap. 4)

The lateral patellar retinaculum is a composite of several fascial layers that intermix and blend. The most superficial

layer is an extension of the iliotibial tract (see Fig. 4.22). Deep to it are thick transverse fibers that form the lateral patellofemoral and lateral patellotibial ligaments (see Fig. 7.7). The deepest layer is the joint capsule. The layers blend into one that attaches to the lateral border of the patella.

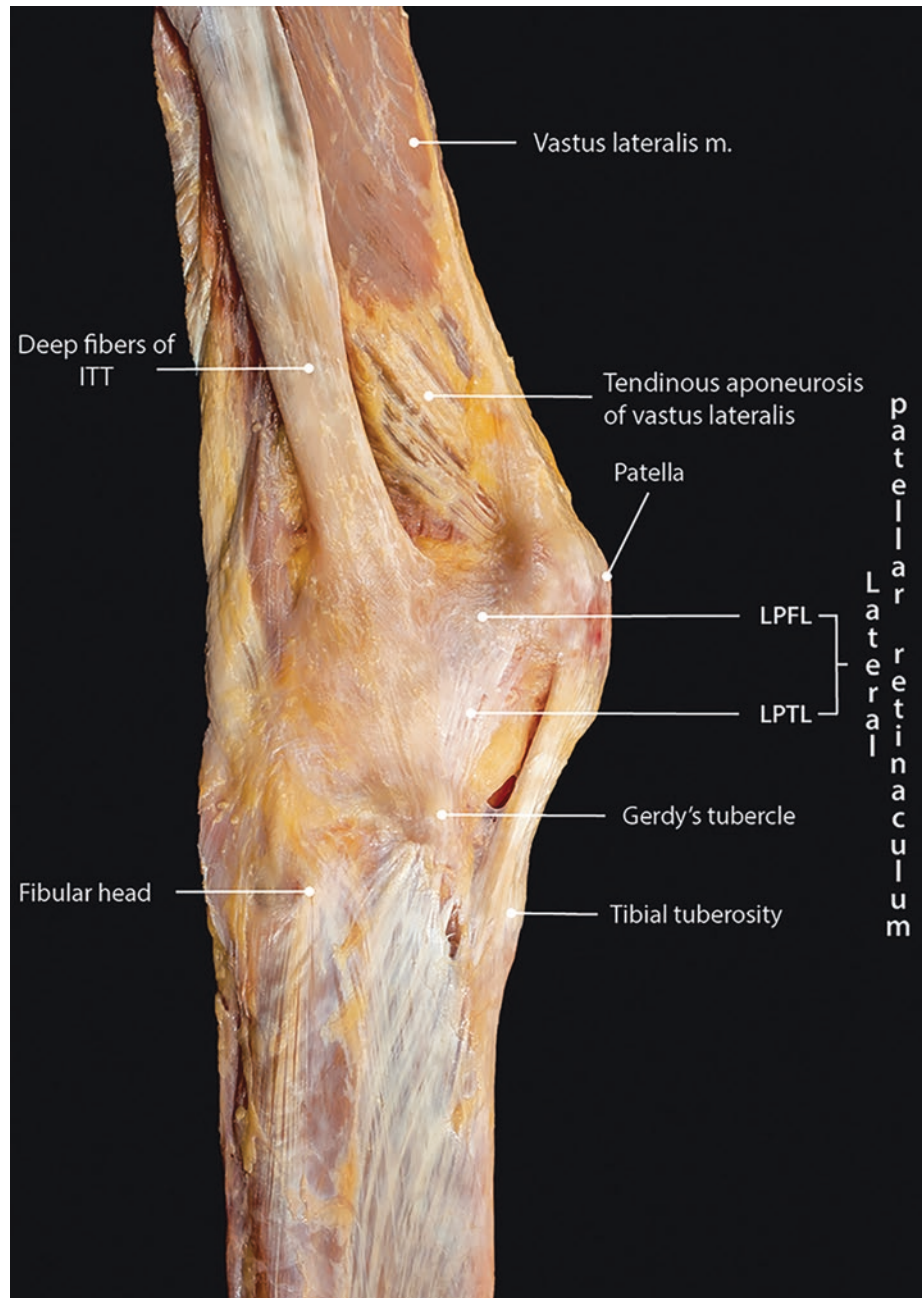


Fig. 7.7 Right knee in extension, lateral aspect. The fascia lata has been removed except for the deep fibers of the iliotibial tract. The lateral patellofemoral ligament (LPFL) and lateral patellotibial ligament (LPTL)

compose the middle layer of the lateral patellar retinaculum. The tendinous aponeurosis of the vastus lateralis muscle inserts into the lateral border of the patella, blending with the quadriceps femoris tendon

7.3 Anterolateral Ligament

The **anterolateral ligament (ALL)** is a longitudinal oblique thickening of the anterolateral capsule. The ALL was first described by Segond in 1879 [4]. The ALL attaches proximally to the femur about 9 mm proximal to the lateral epicondyle. It attaches distally to the proximal tibia midway

between Gerdy's tubercle and the fibular head [5]. Deep posterior fibers of iliotibial tract (ITT) can be confused with the underlying anterolateral ligament (*see* Figs. 7.8, 7.9, 7.10, 7.11, and 7.12).

The ALL is thought to restrain anterior tibial translation and internal rotation [2, 6, 7] but its role in anterior cruciate ligament injuries is unclear.

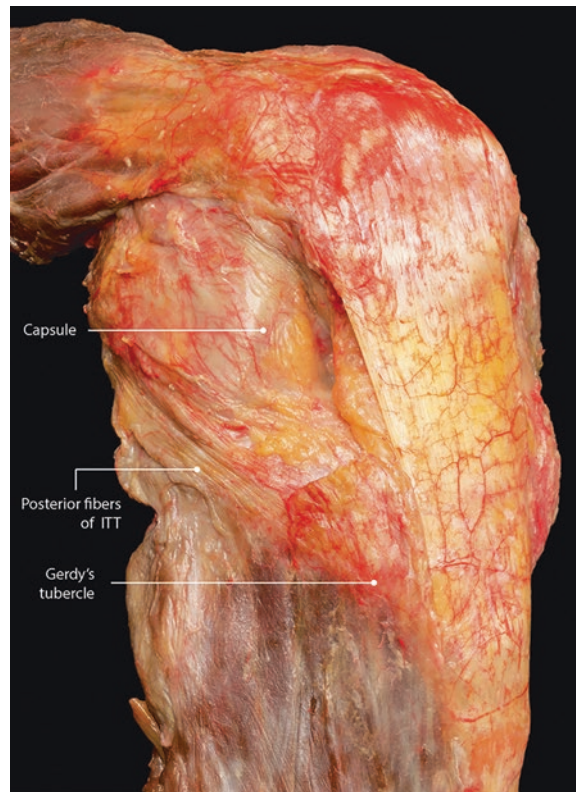


Fig. 7.8 Right knee, anterolateral aspect, with fascia lata removed except for the deep posterior fibers of iliotibial tract (ITT). These can be confused with the anterolateral ligament

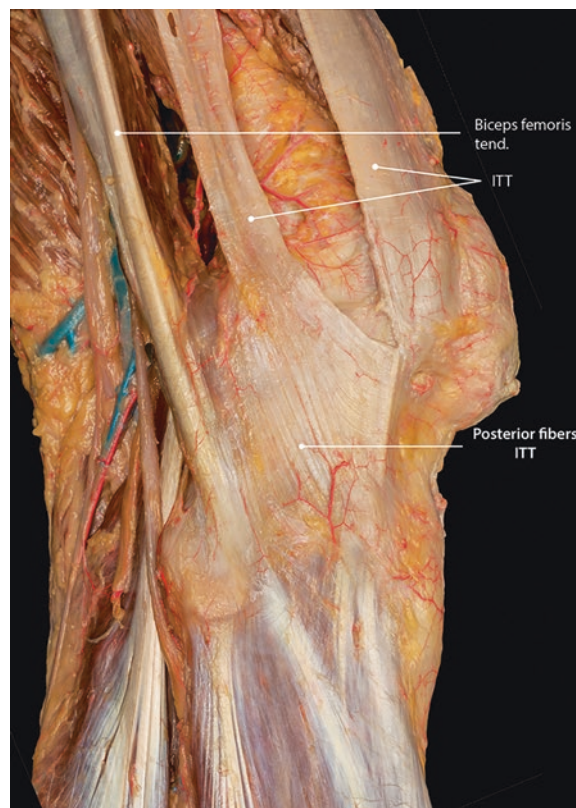


Fig. 7.9 Right knee, lateral aspect. The iliotibial tract (ITT) has been split and the biceps femoris tendon isolated

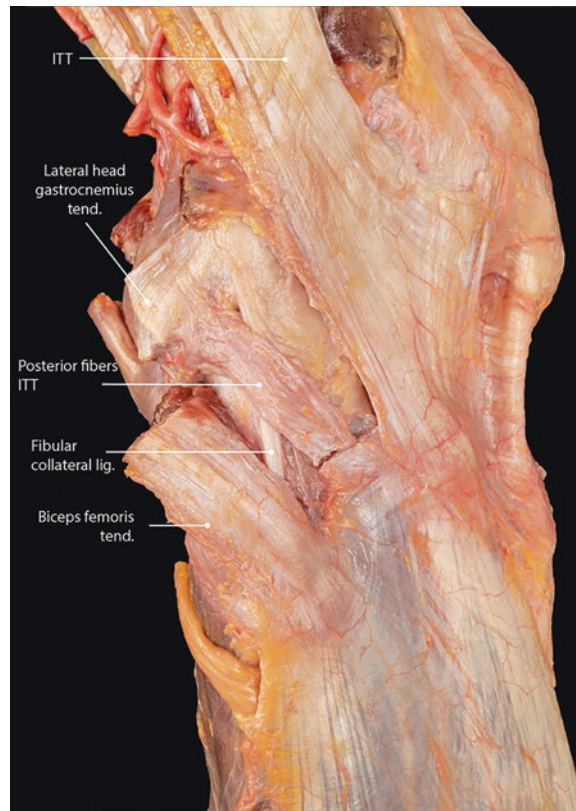


Fig. 7.10 Right knee, lateral aspect. Note the posterior fibers of the iliotibial tract (ITT)

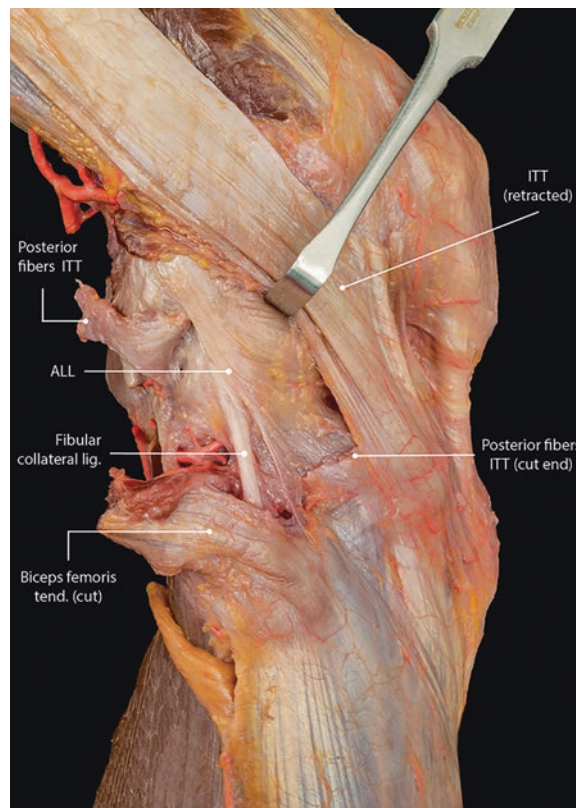


Fig. 7.11 Right knee, lateral aspect. The posterior fibers of the iliotibial tract (ITT) have been lifted to show the anterolateral ligament (ALL). Iliotibial tract (ITT)



Fig. 7.12 Lateral aspect right knee. The anterolateral ligament (ALL) is lifted with an instrument

7.4 Vastus Lateralis Muscle

The **vastus lateralis muscle** (*vastus externus*) thickens into a tendon that blends with the vastus medialis tendon to form the middle layer of the quadriceps tendon. It continues to insert into the lateral border of the patella and gives an expansion the lateral capsule (*see* Fig. 7.13). The posterior border of the muscle is the lateral intermuscular septum.



Fig. 7.13 Right knee, lateral aspect, showing vastus lateralis muscle

7.5 Fibular (Lateral) Collateral Ligament

The **fibular collateral ligament (FCL)** (*ligamentum col-laterale fibulare; external lateral or long external lateral ligament*) attaches proximally to the lateral epicondyle of the femur and distally to styloid process of the fibular head (*see* Fig. 7.14).

The FCL is separated from the posterolateral capsule. This is unlike the mid-third medial capsule (deep medial collateral ligament), which is intimately associated with the capsule.

In the coronal plane, the FCL is a posterior structure, in contrast to the medial collateral ligament, which is a midline structure.

The FCL provides stability to lateral side of knee in extension. It relaxes in flexion to permit rotation (*see* Fig. 7.15).

In extension, the fibular collateral ligament is chief static stabilizer of the lateral knee. In flexion, the iliotibial tract is the chief static stabilizer, and the biceps tendon and popliteus muscle/tendon are the chief dynamic stabilizers.

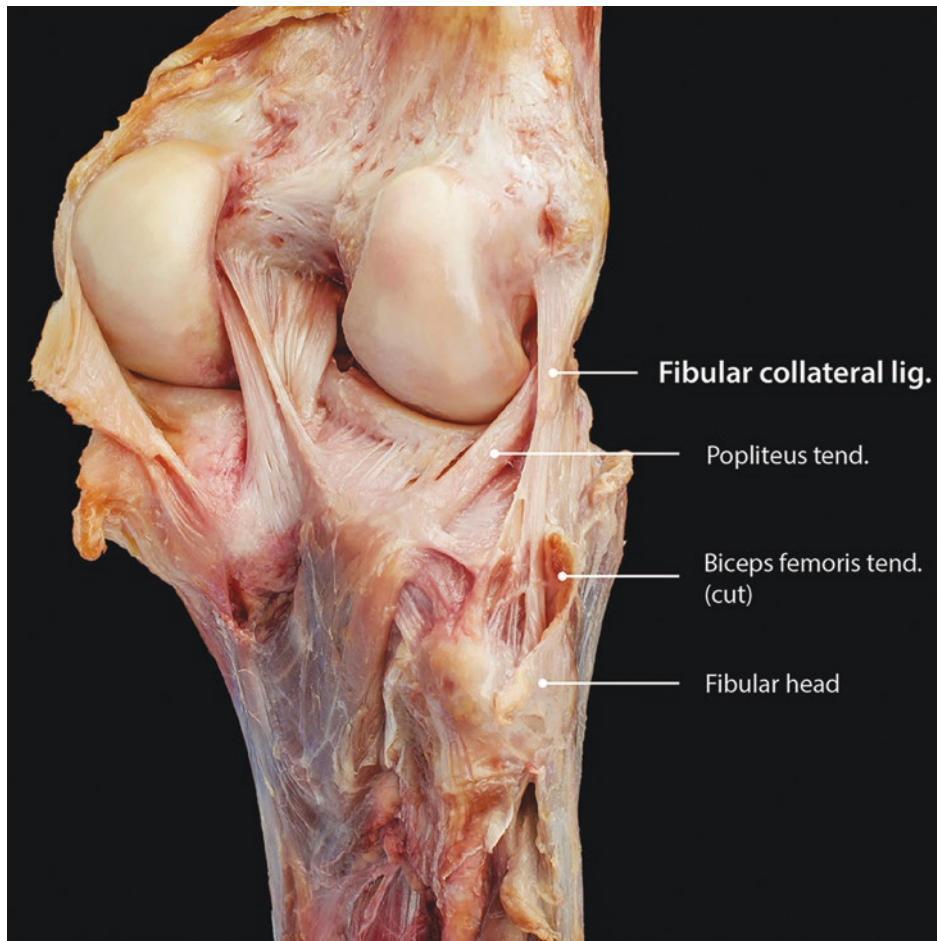


Fig. 7.14 Right knee, posterolateral aspect



Fig. 7.15 Right knee, lateral aspect. (a) Extension; (b) full flexion. The fibular collateral ligament relaxes in flexion to permit rotation

7.6 Popliteus Muscle

The popliteus tendon originates in a depression slightly distal to the lateral femoral epicondyle (*see* Fig. 1.17). The relationship between the origin of the popliteus tendon and the attachment of the fibular collateral ligament changes as the knee flexes (*see* Fig. 7.16). This is important when operating

on the knee (*see* Fig. 12.19). There is a fibrous connection between the fibular head and the popliteus muscle, the popliteofibular ligament. The popliteus muscle inserts to the posterior tibia above the soleal (popliteal) line (*see* Fig. 7.17). (By orthopaedic convention, muscle and tendon origins are proximal and insertions are distal, regardless of being a tendon or muscle.)

Fig. 7.16 Right knee, lateral aspect. (a) Extension; (b) 45° flexion. The popliteus tendon originates from the femur slightly distal to the lateral epicondyle. Note how the relationship between fibular collateral ligament attachment site and the popliteus tendon origin site changes with knee flexion (*)

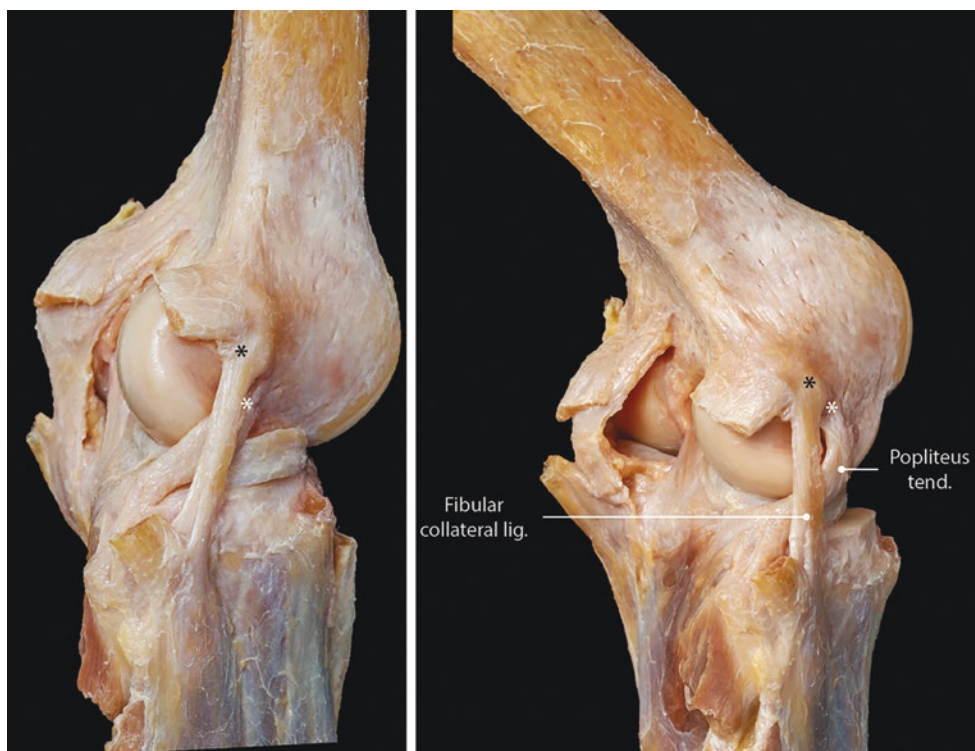
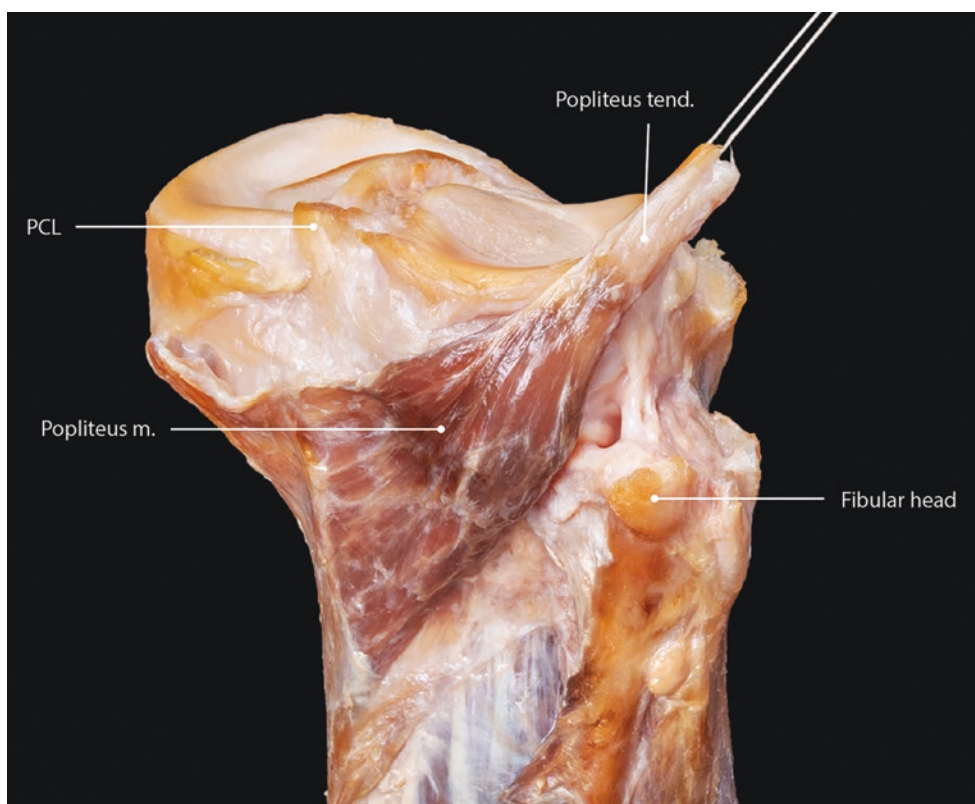


Fig. 7.17 Right knee, posterior aspect. The popliteus muscle inserts onto the posterior tibia above the popliteal line



7.7 Biceps Femoris Muscle

The lateral hamstring tendon is the **biceps femoris** (see Fig. 7.18). It has two origins: the **long head**, which originates from the ischial tuberosity, and the **short head**, which takes origin from the linea aspera of the femur. Both the long and short heads of the biceps femoris muscle form a common tendon which inserts onto fibular head (see Figs. 7.19, 7.20, and 7.21). The biceps femoris is a strong flexor of knee as well as a strong external rotator of tibia.

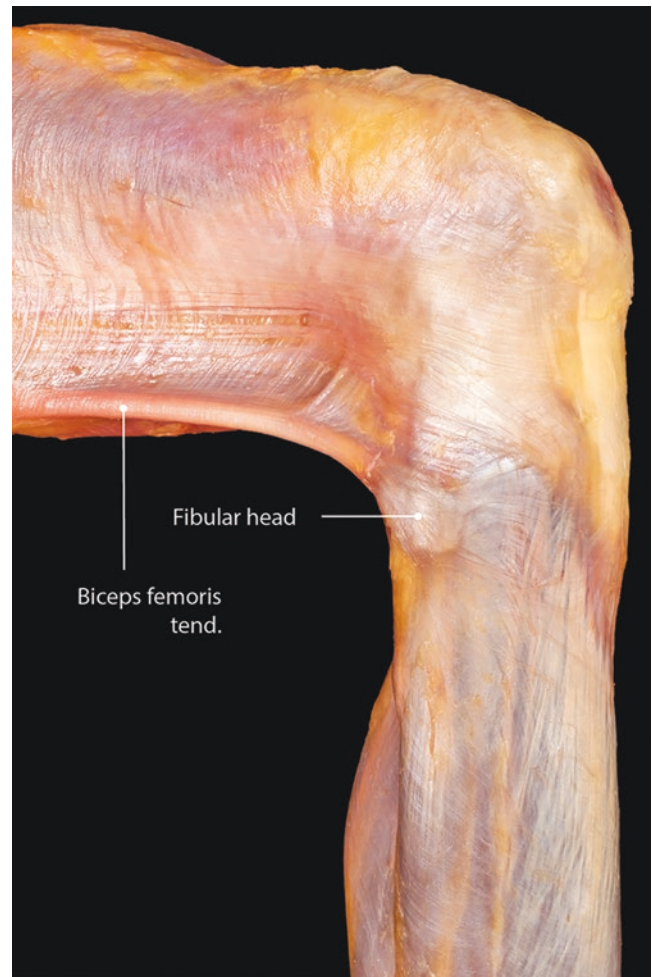


Fig. 7.18 Right knee, lateral aspect at 90° flexion showing the insertion of the lateral hamstring tendon (biceps femoris) into the fibular head

Fig. 7.19 Right knee, posterolateral aspect. The fascia lata has been split just posterior to the lateral intermuscular septum

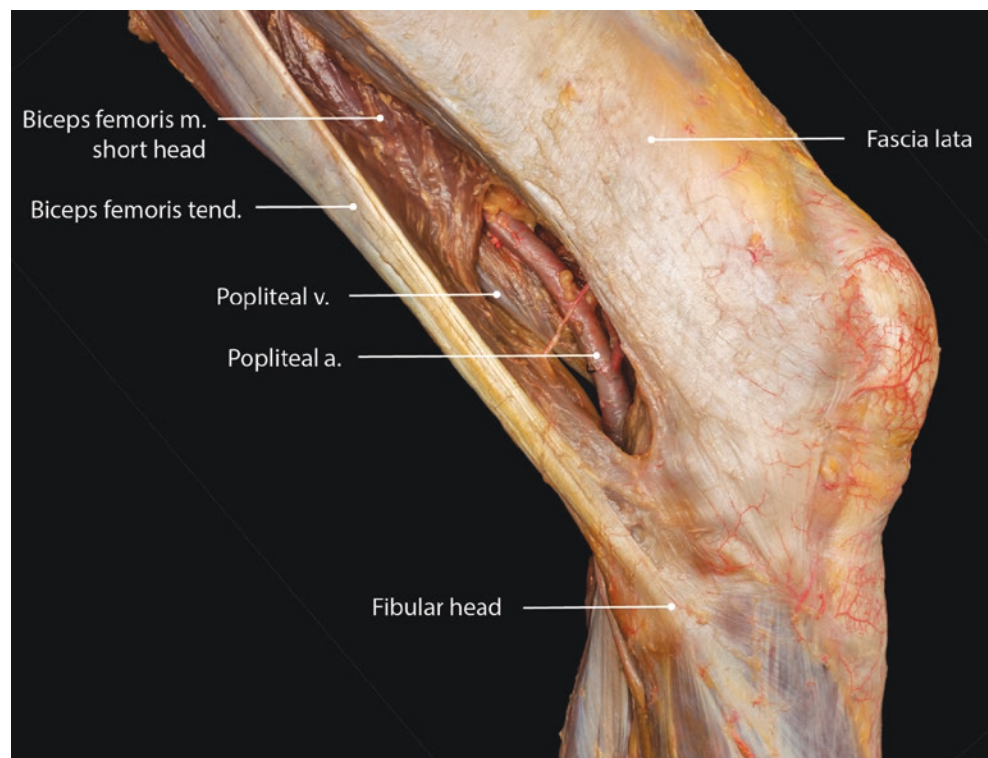


Fig. 7.20 Right knee, lateral aspect. The biceps femoris tendon has been retracted inferiorly

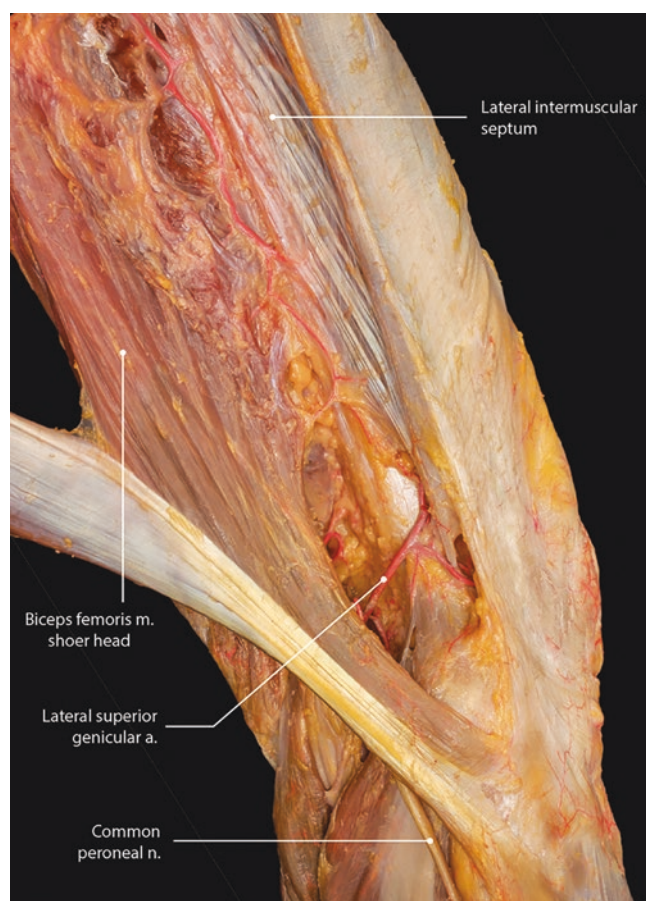
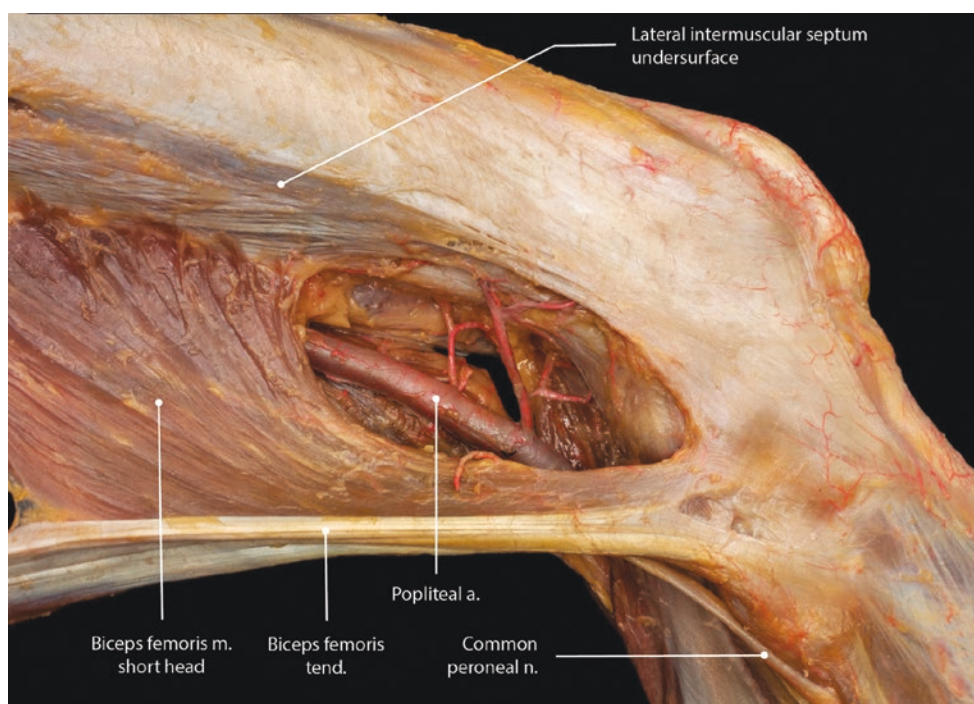


Fig. 7.21 Right knee, posterolateral aspect. Note the superficial branch of the lateral superior genicular artery piecing the lateral intermuscular septum distally

7.8 Common Peroneal Nerve

The **common peroneal nerve** [*common fibular nerve*; *n. peroneus communis*; *external popliteal nerve*; *peroneal nerve*] is one the two terminal branches of the sciatic nerve (see Fig. 7.22). The common peroneal nerve hugs the medial border of the biceps tendon. It gives off several branches in the popliteal fossa. The nerve then winds around the fibular neck (see Fig. 7.23). At this point, the common peroneal nerve trifurcates into 3 main branches under the deep fascia: (1) the **articular trunk**, which consists of the recurrent articular branch to the proximal tibiofibular joint and a motor branch to the tibialis anterior muscle; (2) the **deep peroneal nerve** [*deep fibular nerve*; *n. peroneus profundus*; *anterior tibial nerve*] which innervates the muscles in the anterior compartment. There are two branches (upper or proximal and lower or distal) from the deep peroneal nerve. All of these structures are in the anterior compartment and lie under the fascia cruris. The tibialis anterior muscle is thereby innervated by both the articular trunk and the deep peroneal nerve, and (3) the **superficial peroneal nerve** [*superficial peroneal nerve*; *n. peroneus superficialis*], which innervates the muscles of the lateral compartment (see Fig. 7.24).

The cutaneous branches of the peroneal nerve are the lateral sural cutaneous nerve [*n. cutaneus surae lateralis*; *lateral cutaneous branch*], which gives sensation to the upper two thirds of the lateral leg (see Fig. 7.25), and the **sural communicating nerve**, which joins a branch from the tibial nerve to form the **sural nerve** [*n. suralis*; *short saphenous nerve*]. The sural nerve may also be found as a continuation of the lateral sural cutaneous nerve or as another anatomical variant [8].

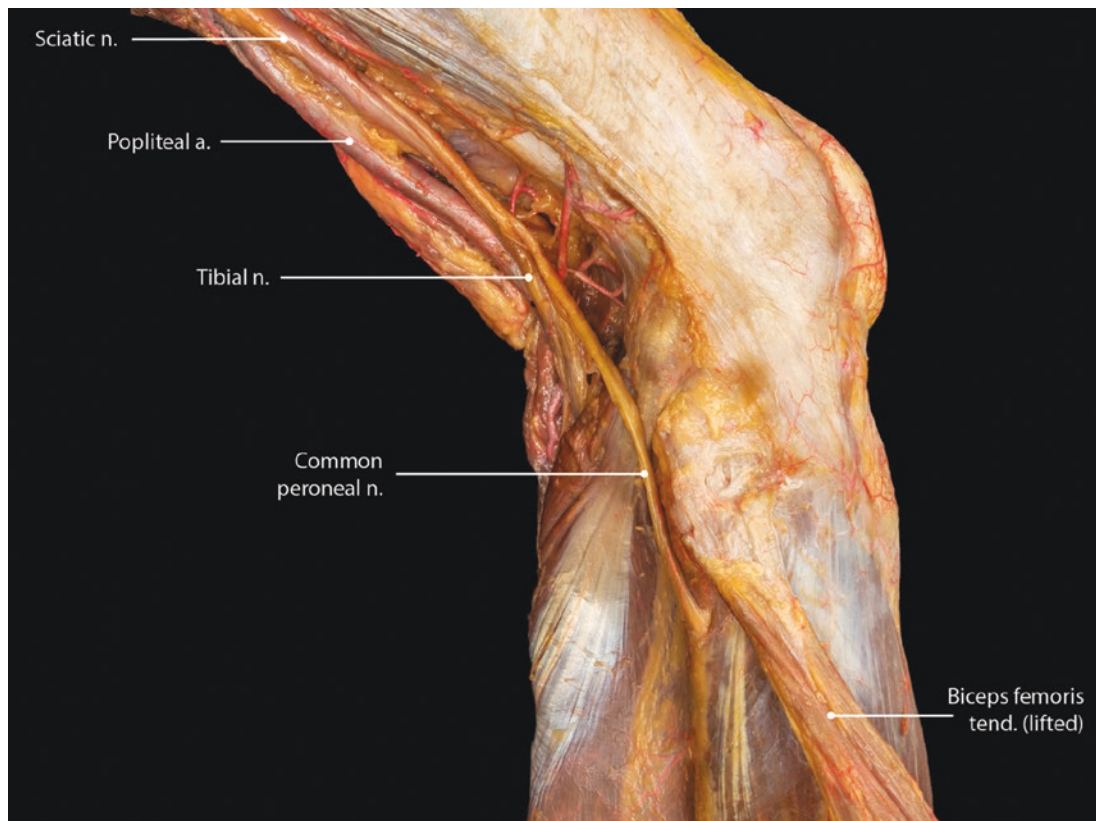


Fig. 7.22 Right knee, posterolateral aspect. The sciatic nerve splits into the common peroneal nerve and the tibial nerve

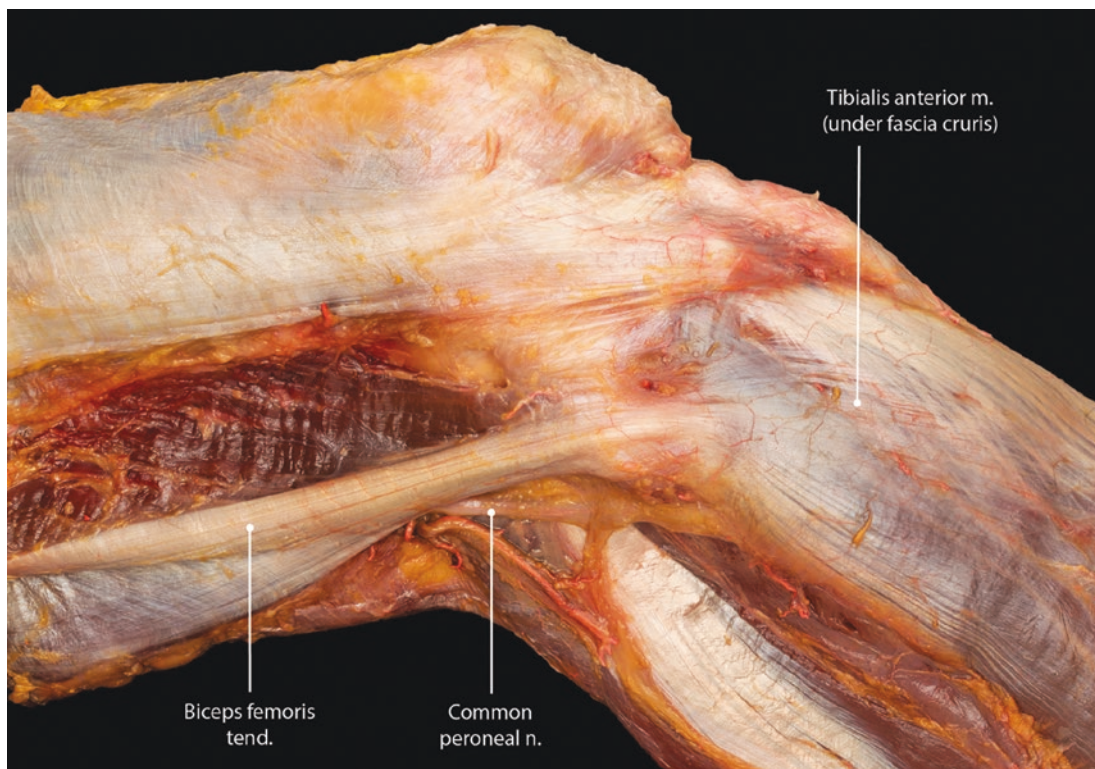


Fig. 7.23 Right knee, lateral aspect. The peroneal nerve hugs the medial border of the biceps femoris tendon. The nerve then winds around the fibular neck

Fig. 7.24 Branches of the **common peroneal nerve**: (1) the **articular trunk**, which consists of the recurrent articular branch to the proximal tibiofibular joint and a motor branch to the tibialis anterior muscle; (2) the **deep peroneal nerve**; and (3) the **superficial peroneal nerve**

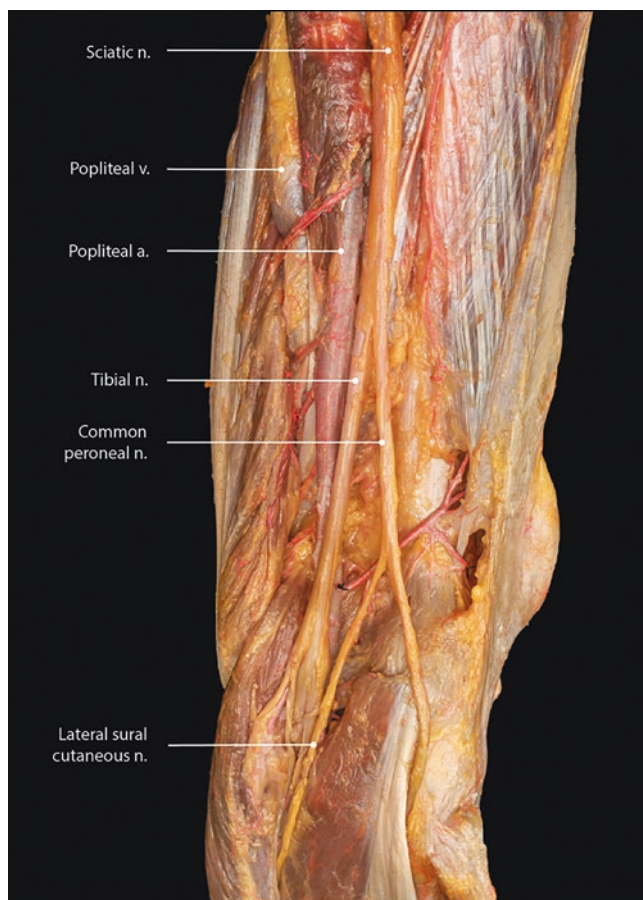
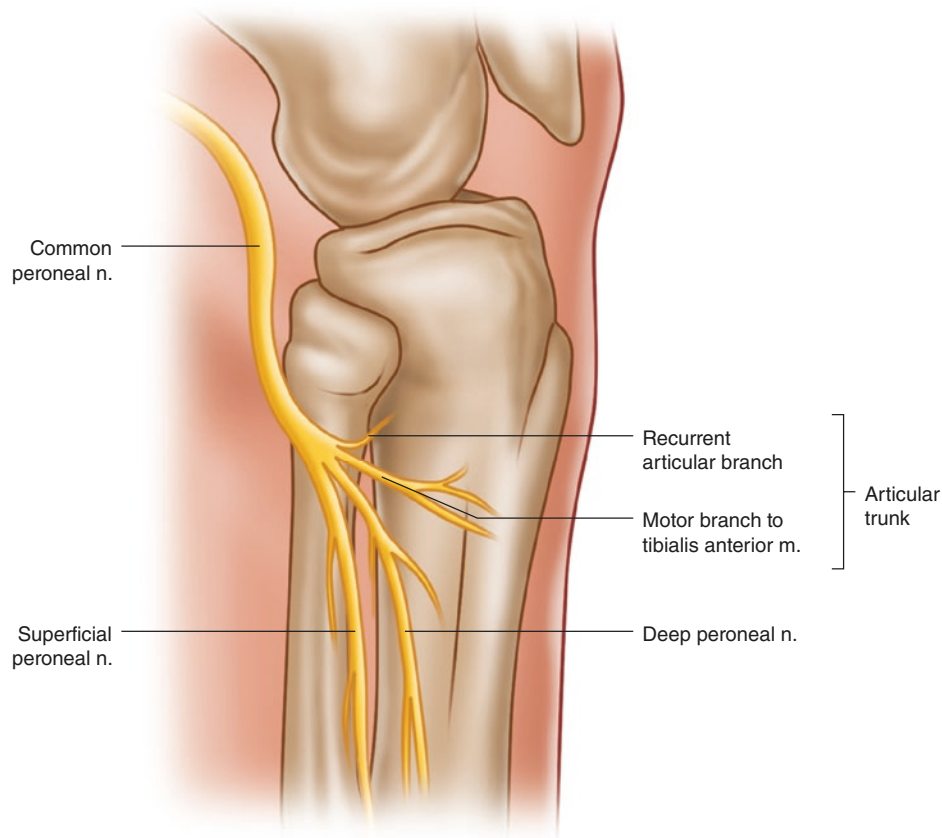


Fig. 7.25 Right knee, posterior aspect

7.9 Proximal Tibiofibular Joint

The **proximal tibiofibular joint** is the articulation between the head of the fibula and the lateral tibial condyle (*see* Fig. 1.30).

7.10 Lateral Intermuscular Septum

The **lateral intermuscular septum** divides the anterior thigh (containing the quadriceps and sartorius muscles) from the posterior thigh (with the hamstring muscles) (*see* Fig. 12.4). The lateral intermuscular septum attaches to the lateral lip of the linea aspera and the lateral supracondylar line of the femur medially and to the posterior edge of the iliotibial tract laterally.

7.11 Lateral Head of Gastrocnemius Muscle

The **lateral head of gastrocnemius muscle** originates from the lateral surface of the lateral femoral condyle and the adjacent shaft of the femur. It forms the upper outer border of the diamond-shaped popliteal fossa (*see* Fig. 8.3).

7.12 Lateral Genicular Arteries

The popliteal artery sends off five genicular arteries: lateral superior, lateral inferior, medial superior, medial inferior, and middle genicular (*see* Fig. 1.43).

The **lateral superior genicular artery** goes from the popliteal artery laterally across the posterior femur. It branches anteriorly through the lateral intermuscular septum, dividing into superficial and deep branches. The superficial branch continues to the superior lateral patella (*see* Fig. 7.26). The deep branch supplies the lower femur and knee joint and joins the anastomotic vascular arch of the knee.

The lateral superior genicular artery is important surgically because it pierces the lateral intermuscular septum to enter the anterior thigh compartment close to where the septum attaches to the lateral femoral condyle. This has been called the “over-

the-top” location in anterior cruciate ligament surgery [9]. If the artery is disrupted in front of the septum, it retracts into the posterior compartment and bleeds uncontrollably. Since it is bleeding into the posterior compartment, it is not seen during surgery. Even if recognized it would be very difficult to get to the source of the hemorrhage.

The **lateral inferior genicular artery** goes above the fibular head to the front of the knee. It joins the anterior tibial recurrent artery to go to the infrapatellar fat pad. The lateral inferior genicular artery is important because it runs along the periphery of the lateral meniscus at the level of the joint line. It is a large vessel and should be securely tied off if it is cut (not electrocoagulated), such as when performing a lateral arthrotomy (*see* Figs. 7.27 and 7.28).

The relationships of the neurovascular to other deep structures are shown in Fig. 7.29.

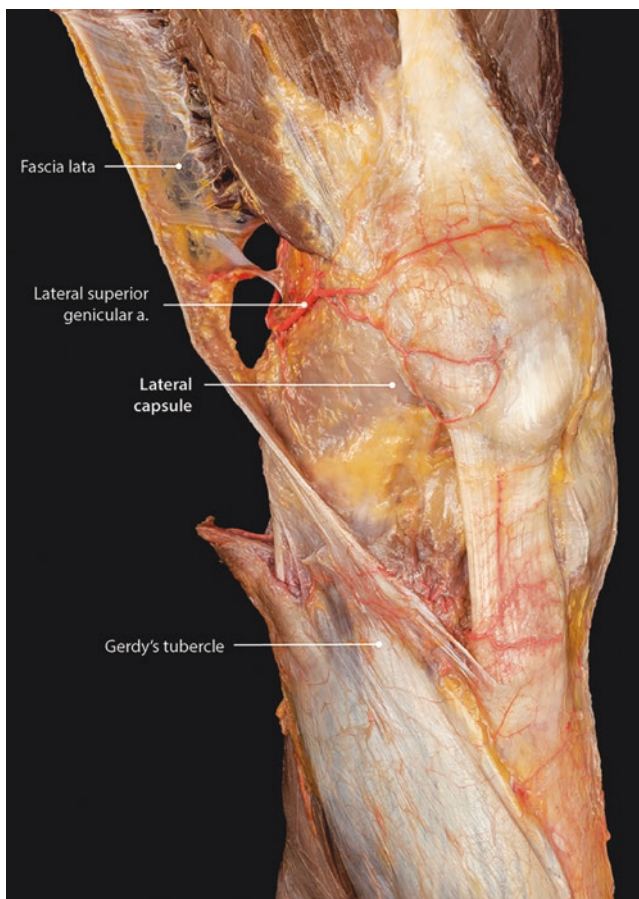


Fig. 7.26 Right knee, anterolateral aspect. The fascia lata has been lifted to expose the lateral capsule. Note the superficial branch of the lateral superior genicular artery going to the superior lateral patella

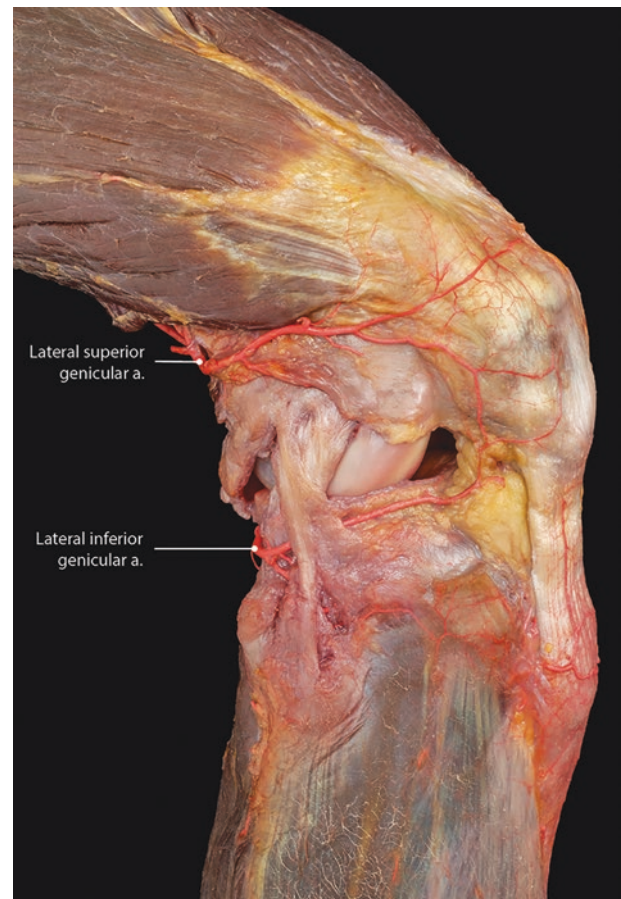


Fig. 7.27 Right knee, lateral aspect at 45° flexion showing the lateral superior and inferior genicular arteries

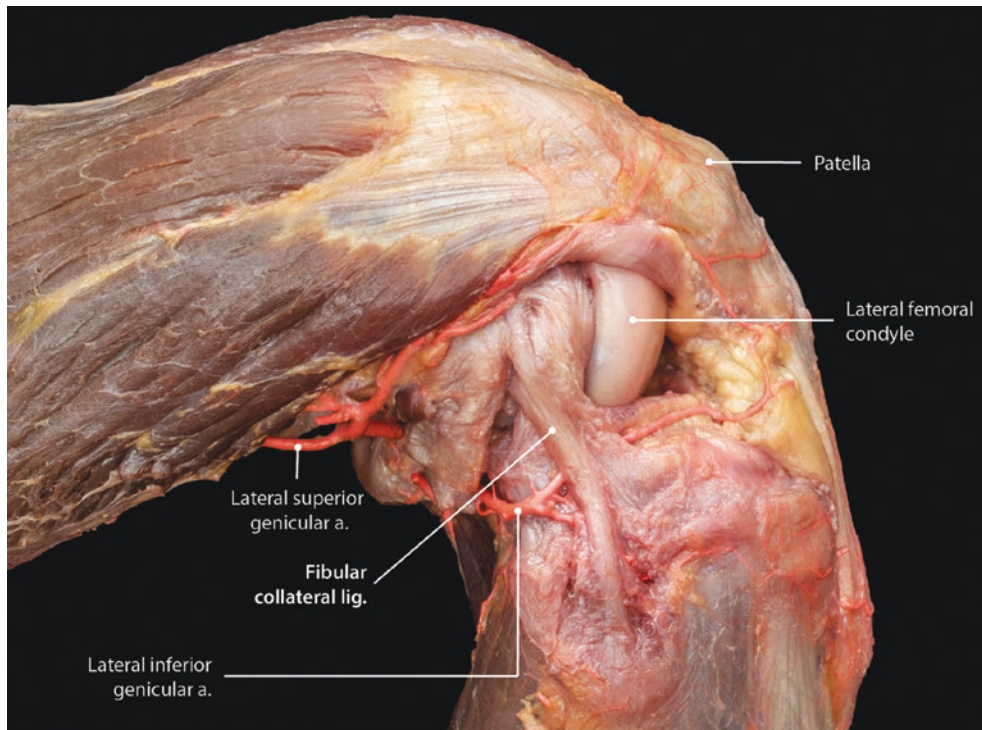


Fig. 7.28 Right knee, lateral view at about 110° flexion. Note that the fibular collateral ligament is lax

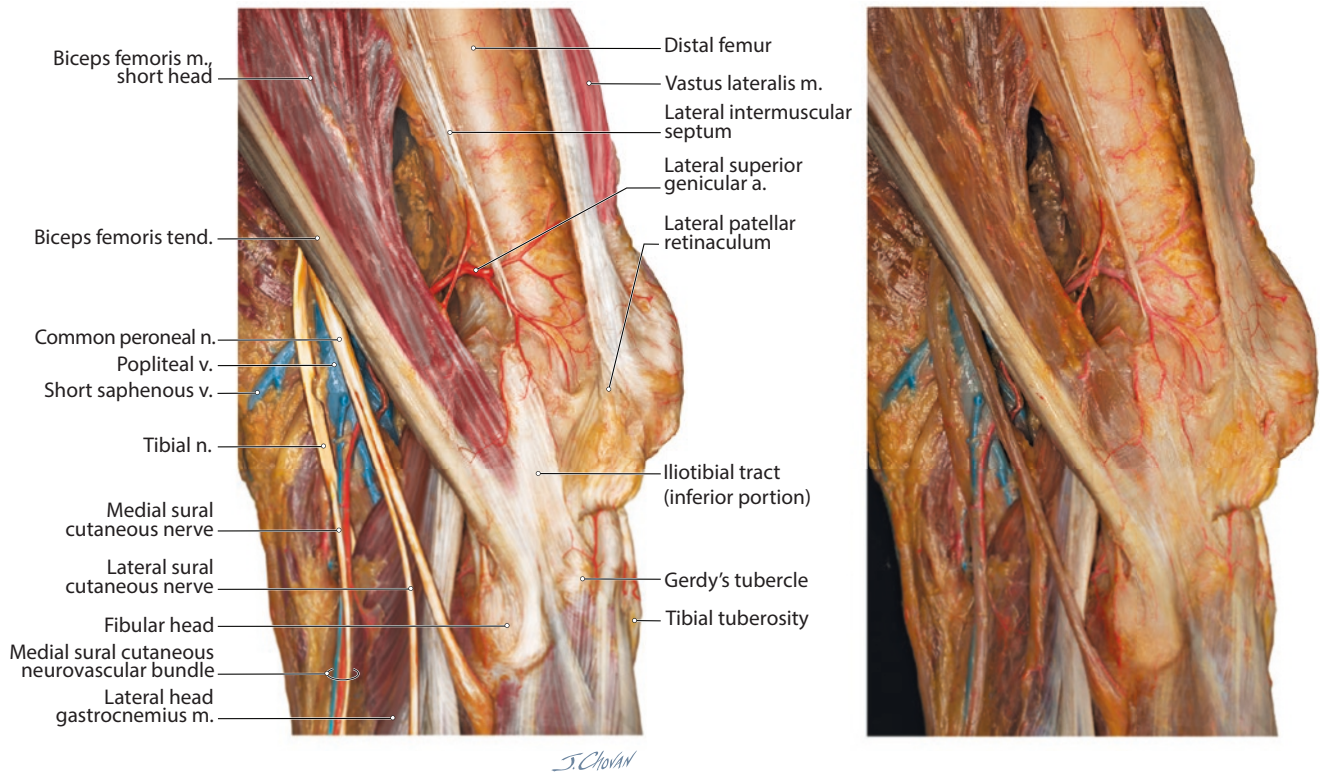


Fig. 7.29 Right knee, lateral aspect, summary

7.13 Short Fibular Collateral and Fabellofibular Ligaments

A **short fibular collateral ligament** adjacent to the posterolateral capsule behind the fibular collateral ligament is occasionally present. When a fabella is present, it attaches to the fabella and is called the **fabellofibular ligament**. The presence and thickness of these ligaments are inversely correlated with the presence and thickness of an arcuate ligament. They reinforce the posterior capsule and contribute to lateral stability [10–12] (*refer to Chap. 8*).

7.14 Fabella

The **fabella** [from Latin, “little bean”] is a sesamoid bone in the lateral head of the gastrocnemius muscle behind the lateral femoral condyle. It can be seen on X-ray in about 20% of knees. Cadaver studies have demonstrated a bony fabella in 74% and cartilaginous fabella in 26% of knees [13].

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Posterior Knee Anatomy

8

Robert Śmigielski, Bertram Zarins,
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8.1 Layers

The skin in the popliteal fossa is thin and smooth and is fairly firmly attached to the underlying deep fascia to prevent wrinkling when the knee flexes. Below the skin lies subcutaneous fat. The popliteal fossa has two layers of subcutaneous fat, superficial and deep. The **stratum membranosum** separates the superficial subcutaneous fat from the deep subcutaneous fat (see Fig. 1.1b) (refer to Chap. 1). Below the subcutaneous fat is the **deep fascia** (see Fig. 13.5). The deep fascia of the posterior thigh (*fascia lata*) is thin. It becomes thicker in the popliteal area where it has transverse bands. Below the knee, the deep fascia continues as the *fascia cruris* (see Fig. 8.1).

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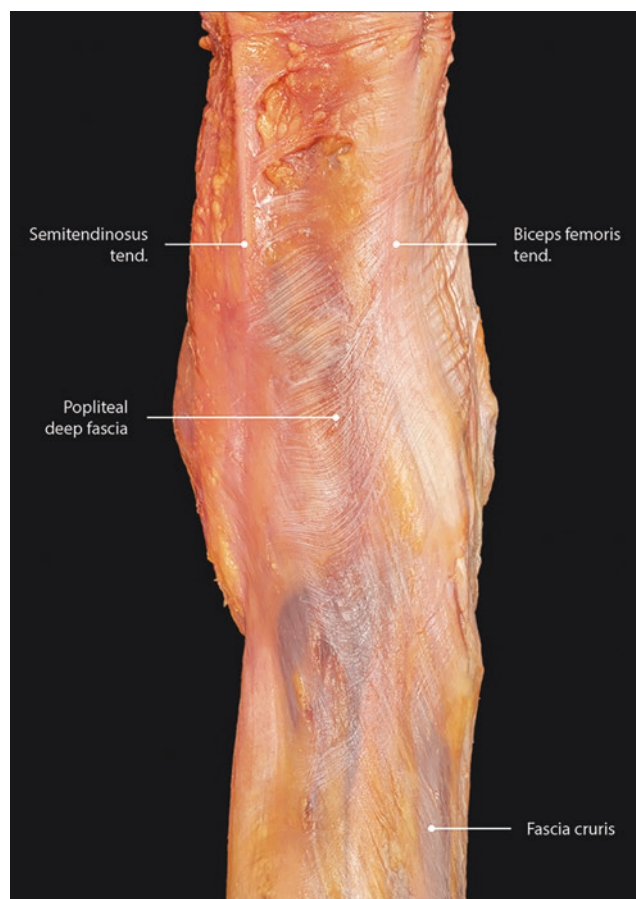


Fig. 8.1 Right knee. The skin and subcutaneous fat have been removed to expose the posterior deep fascia

8.2 Popliteal Fossa

Removing the deep fascia in the back of the knee reveals the **popliteal fossa**. It is filled with adipose tissue (*see* Fig. 8.2).

The popliteal fossa is diamond shaped. It is bounded proximally by the semimembranosus and semitendinosus

tendons medially and the biceps femoris tendon laterally. The distal borders are the converging heads of medial and lateral gastrocnemius muscle (*see* Fig. 8.3). Deep to the origin of the medial head of gastrocnemius muscle is the **semimembranosus-gastrocnemius bursa**. This is the typical location of a popliteal cyst (*see* Fig. 6.23).

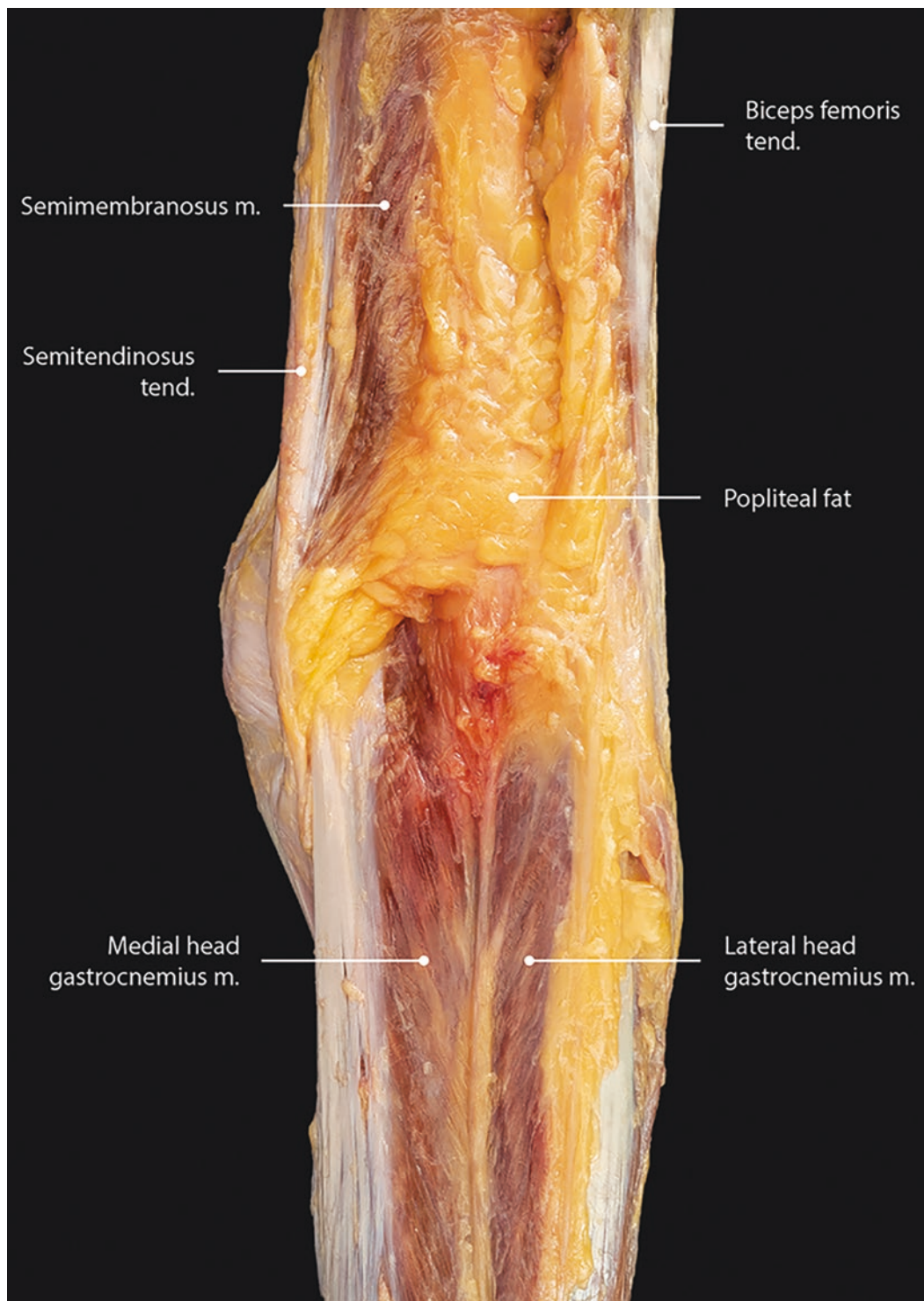


Fig. 8.2 Right knee, posterior aspect. The deep fascia has been removed. The popliteal fossa is filled with adipose tissue

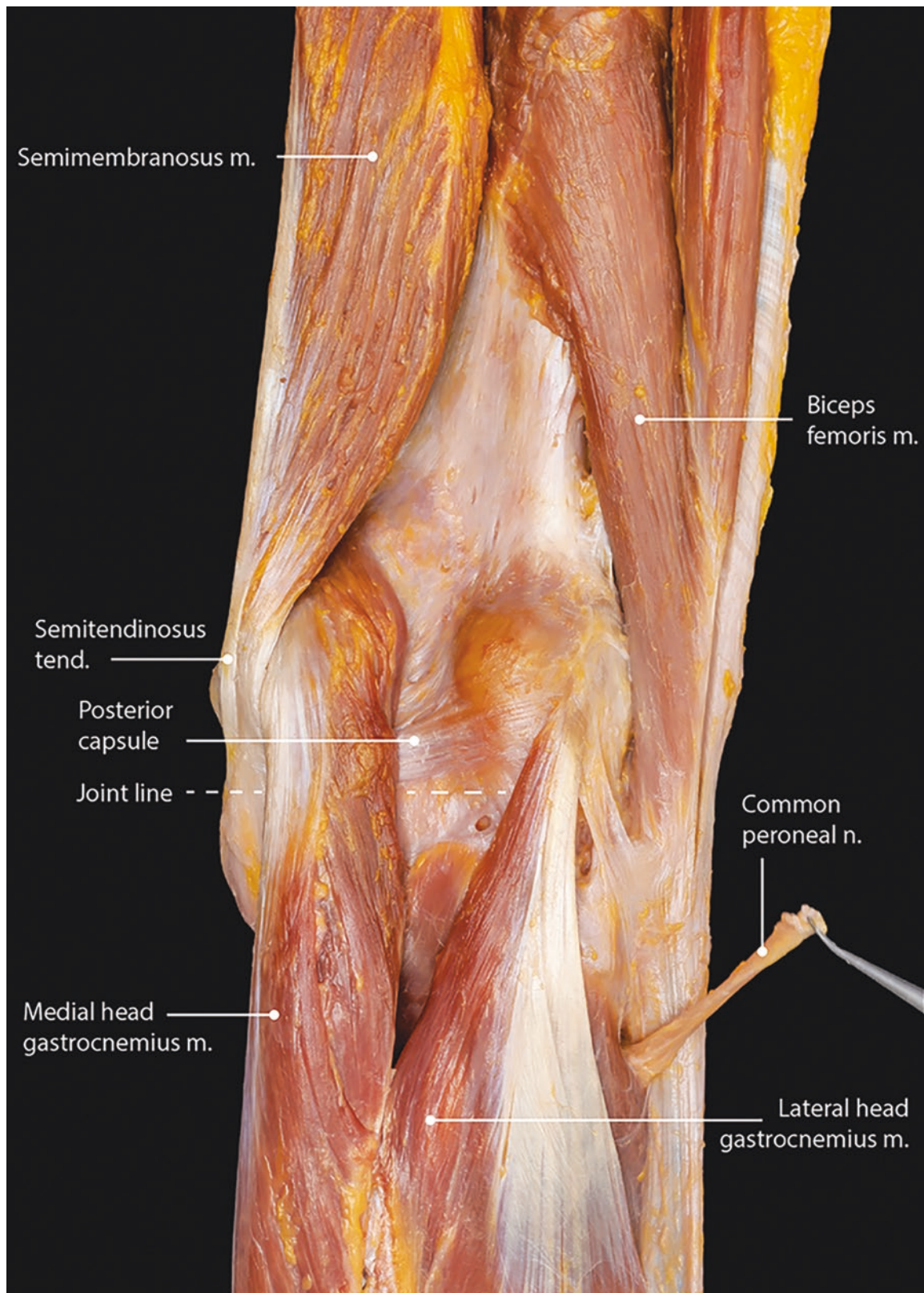


Fig. 8.3 Right knee, posterior aspect. The contents of the popliteal fossa have been removed up to posterior capsule. The popliteal fossa is diamond shaped. It is bounded by the semimembranosus and semiten-

dinosus tendons medially and the biceps femoris tendon laterally. The converging heads of medial and lateral gastrocnemius muscle form the distal boundaries

8.3 Nerves

The **sciatic nerve** (*n. ischiadicus*; *great sciatic nerve*) is derived from the **sacral plexus** [L4-L5 and S1, S2, S3]. Just before reaching the popliteal fossa, the sciatic nerve splits into two main branches: the **tibial nerve** and the **common peroneal nerve** (see Fig. 8.4).

The **tibial nerve** (*n. tibialis*; *internal popliteal nerve*) continues in the deep posterior compartment of the leg. Branches from the tibial nerve (*rami articulares*) enter the posterior knee capsule (see Fig. 8.5) [1]. The tibial nerve also gives off muscular branches. It gives off the medial sural

cutaneous nerve (*n. cutaneous surae medialis*; *n. communicates tibialis*) which descends between the two heads of the gastrocnemius muscle to unite with a similar branch coming from the common peroneal nerve.

The **common peroneal nerve** (*common fibular nerve*; *n. peroneus communis*; *external popliteal nerve*; *peroneal nerve*; *lateral popliteal nerve*) hugs the biceps femoris tendon above the knee and then winds around the neck of the fibula. It gives off the lateral sural cutaneous nerve (*n. cutaneous surae lateralis*; *lateral cutaneous branch*), which sends a peroneal anastomotic branch (*n. communicans fibularis*) to join its medial counterpart to form the sural nerve.

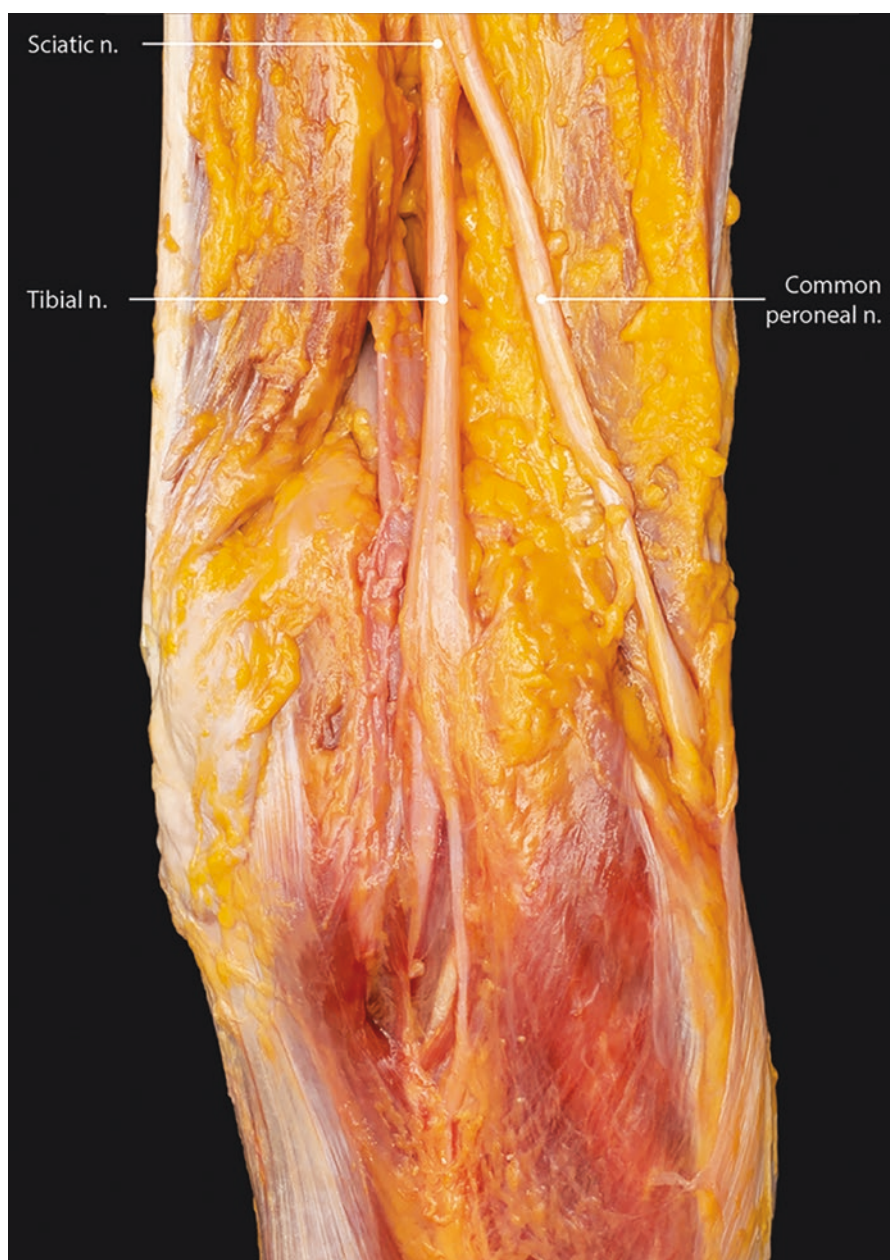


Fig. 8.4 Right knee, posterior. Just before reaching the popliteal fossa, the sciatic nerve splits into two main branches: the **tibial nerve** and the **common peroneal nerve**

Occasionally, the peroneal anastomotic branch continues as a separate branch down to the heel. Between the neck of the fibula and the peroneus longus, the common peroneal nerve divides into superficial and deep peroneal nerves. The **deep peroneal nerve** (deep fibular nerve; *n. peroneus profundus*; *anterior tibial nerve*) travels down the anterior compartment of the leg. The **superficial peroneal nerve** (*superficial fibular nerve*; *peroneus superficialis*) continues in the lateral compartment (see Figs. 8.6, 8.7, and 8.8).

In the midline of the upper calf, just deep to the fascia cruris within the superficial posterior compartment, is the

sural nerve (*n. suralis*; *short saphenous nerve*) [1]. The medial and lateral sural cutaneous nerves unite in the upper leg to form the sural nerve. The small saphenous vein is a midline guide to the underlying medial sural cutaneous nerve. Sometimes the medial and lateral sural cutaneous nerves have already united in the upper calf to form the sural nerve. The superficial nerves are guides to the tibial and common peroneal nerves if traced proximally. Locating these structures is the principle behind Henry's exposure to the back of the knee [2] (*refer to Chap. 13*).

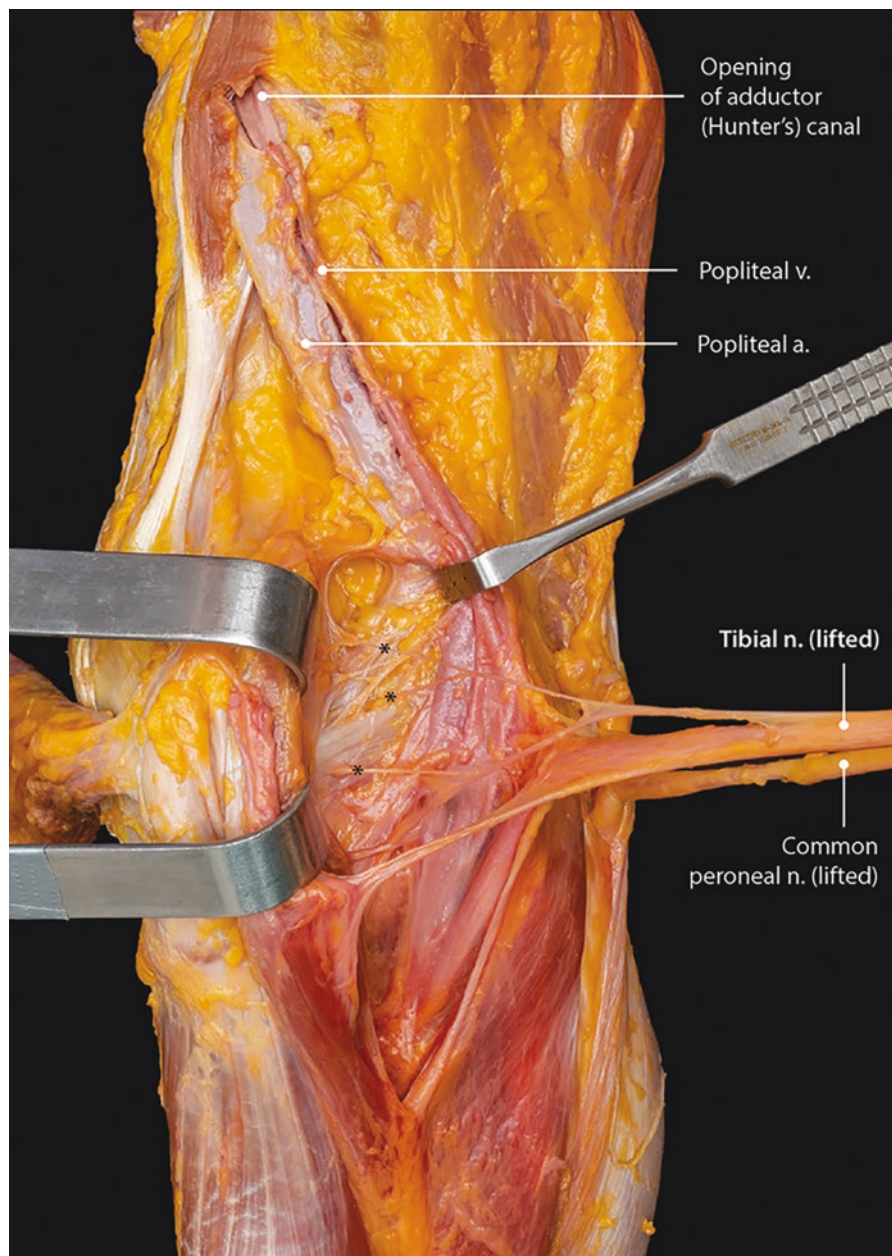


Fig. 8.5 Right knee, posterior. The popliteal artery and vein have been retracted laterally and the tibial and common peroneal nerves have been lifted. Note the branches from the tibial nerve entering the posterior capsule (*)

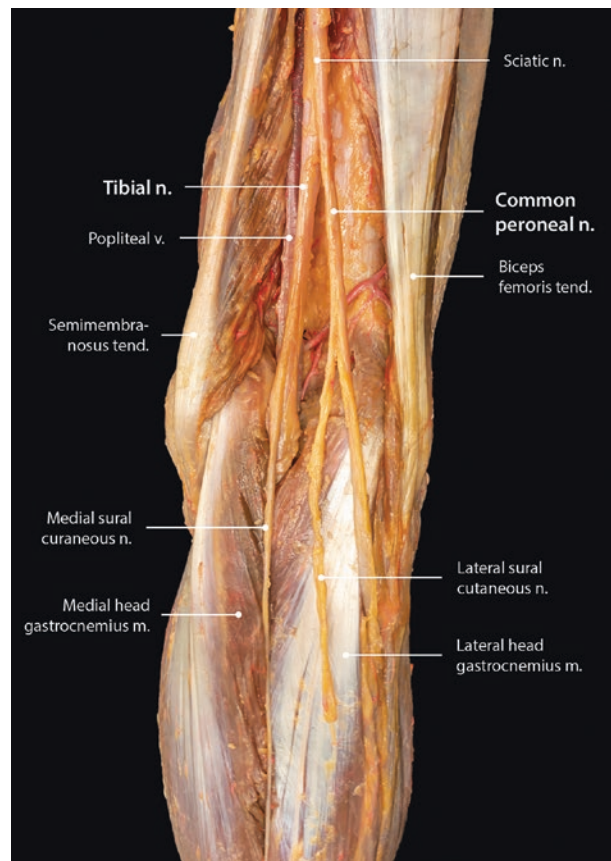


Fig. 8.6 The **tibial nerve** gives off the medial sural cutaneous nerve. It continues down the leg in the deep posterior compartment. The **common peroneal nerve** gives off the lateral sural cutaneous nerve, which

sends a peroneal anastomotic branch (not visualized) to join the medial sural cutaneous nerve to form the sural nerve

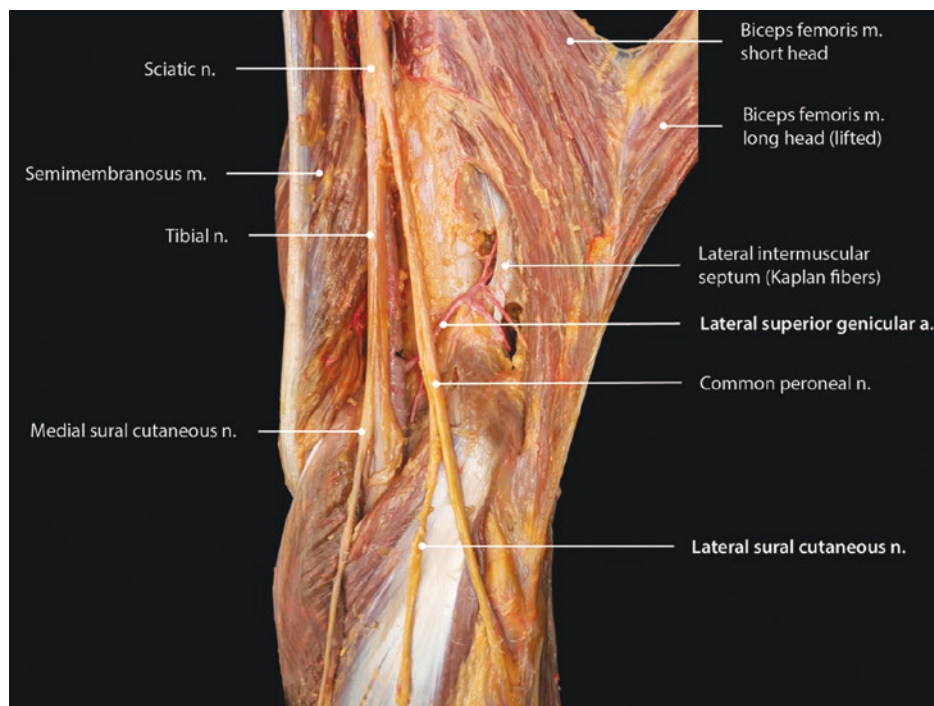


Fig. 8.7 Right knee popliteal fossa. Note the lateral superior genicular artery passing through the lateral intermuscular septum to enter the anterior thigh compartment

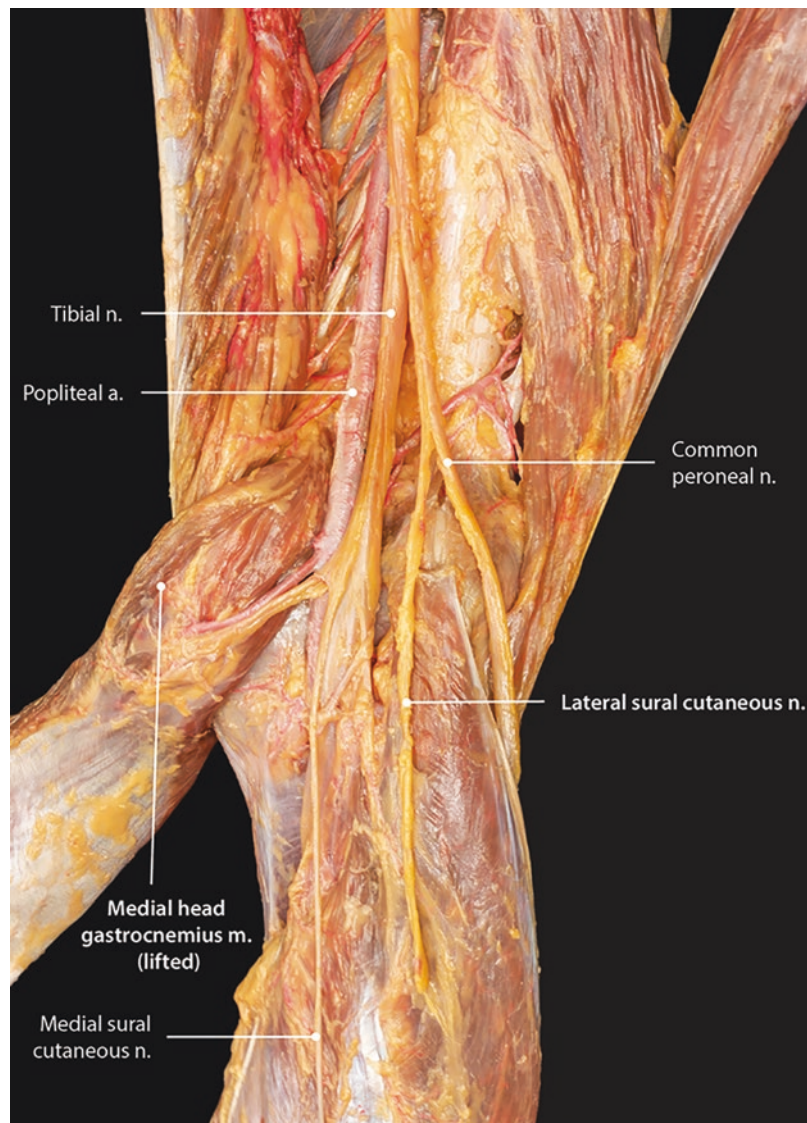


Fig. 8.8 Right knee, posterior. The medial head of gastrocnemius muscle has been lifted, and the popliteal vein has been removed. Note the neurovascular bundle entering the medial head of gastrocnemius muscle

8.4 Veins

The **popliteal vein** (*v. poplitea*) is formed by the junction of the anterior and posterior tibial veins at the lower border of the popliteus muscle. The popliteal vein hugs the popliteal artery. In the lower leg, the vein is medial to the artery, but it crosses over to lie lateral to the artery above the knee joint (see Fig. 8.9).

Just below the skin lying on the fascia cruris in the midline of the upper leg is the **small saphenous vein** (*v. saphena*

parva; *external or short saphenous vein*). It is deep to the stratum membranosum, within the deep subcutaneous fat, and superficial to the deep fascia. The vein pierces the deep fascia to go deep to join the popliteal vein (see Fig. 8.10). The small saphenous vein joins the popliteal vein in the popliteal fossa (see Fig. 8.11). The small saphenous vein often communicates with the great saphenous vein superficially (Fig. 8.12).

The relations of the popliteal vein to other structures are shown in Figs. 8.13, 8.14, 8.15, and 8.16.

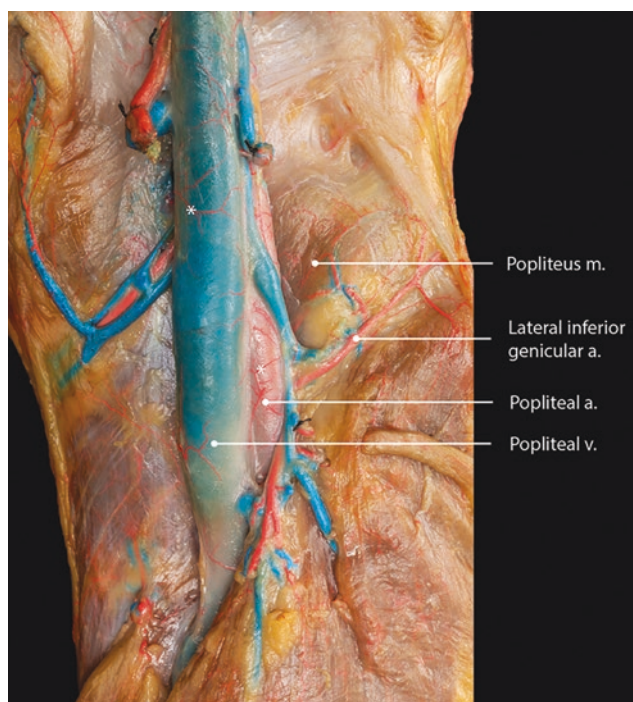


Fig. 8.9 Right knee, popliteal fossa. The popliteal vein covers and wraps around the popliteal artery. Vascular branches to the muscles have been ligated. The venous and arterial systems have been injected

postmortem with gelatin (veins blue, arteries red) and barium sulfate. Note vasa vasorum to popliteal vein (*)

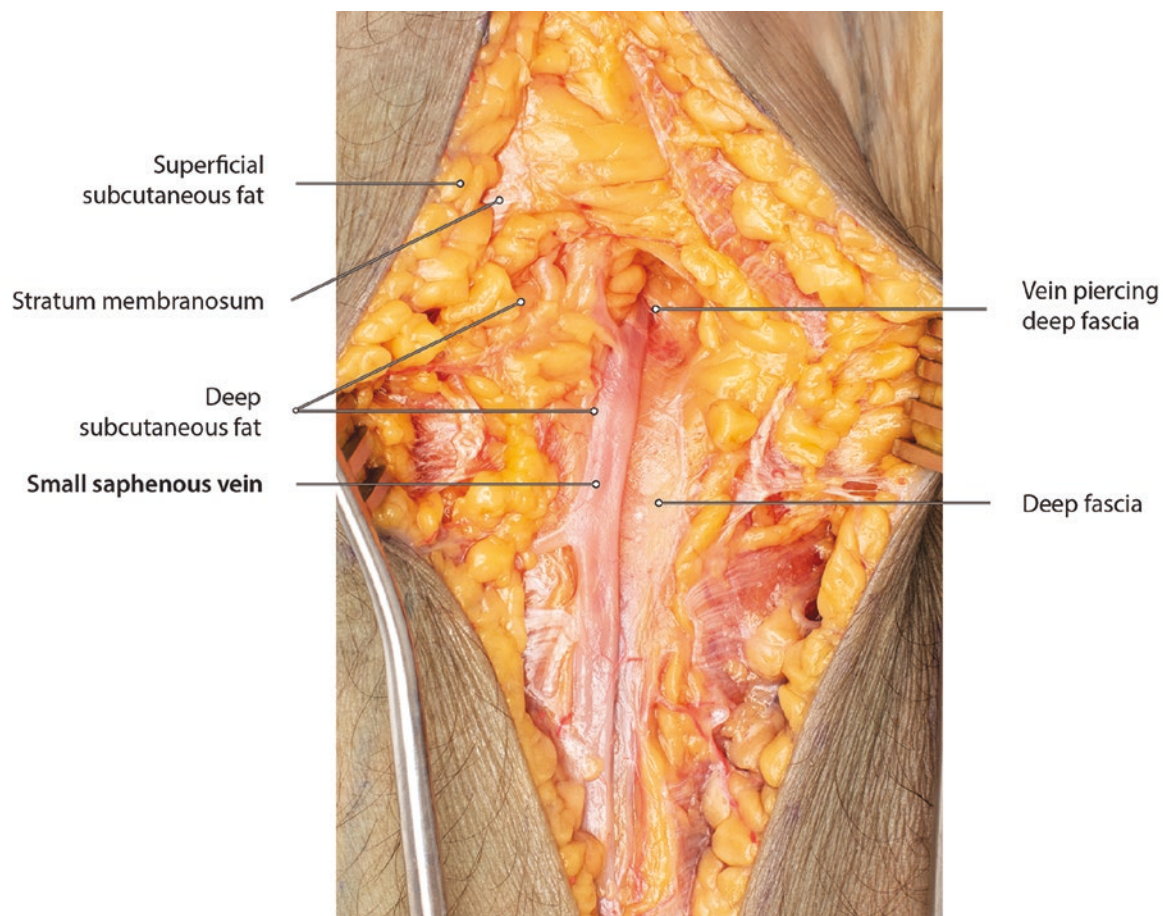


Fig. 8.10 Right knee, posterior. Just below the skin in the midline of the upper leg is the **small saphenous vein**. It is deep to the stratum membranosum, within the deep subcutaneous fat, and superficial to the deep fascia. The vein pierces the deep fascia to go deep to join the popliteal vein

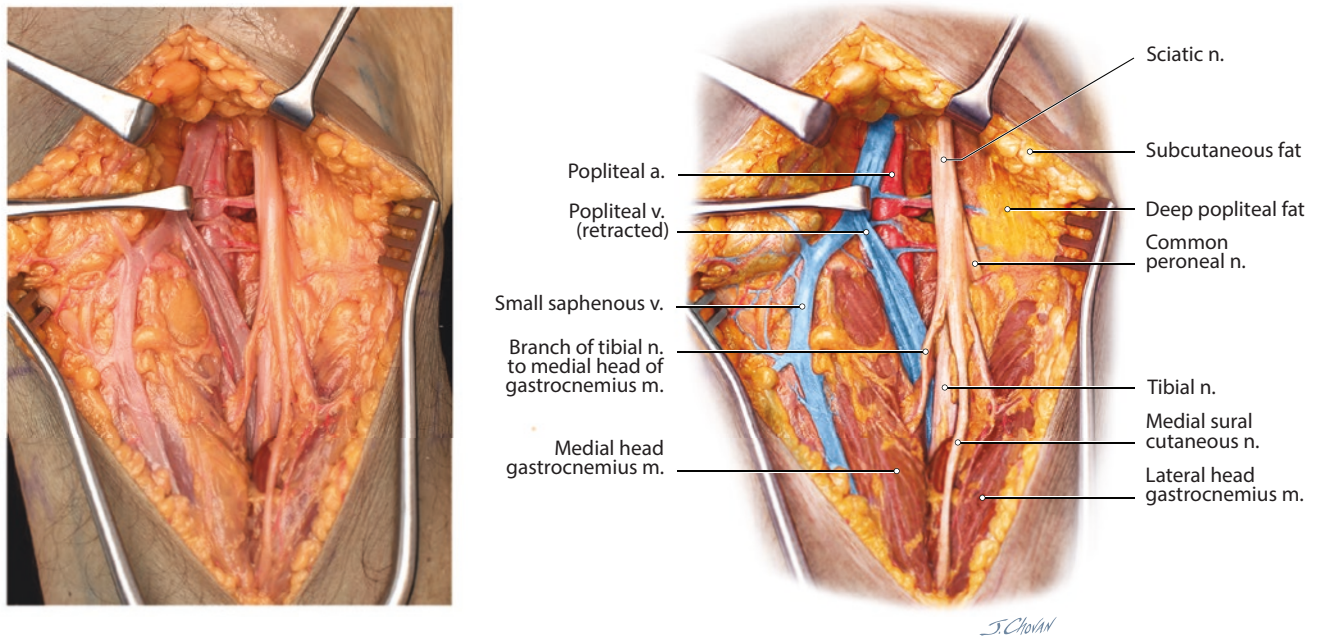


Fig. 8.11 The small saphenous vein joins the popliteal vein in the popliteal fossa

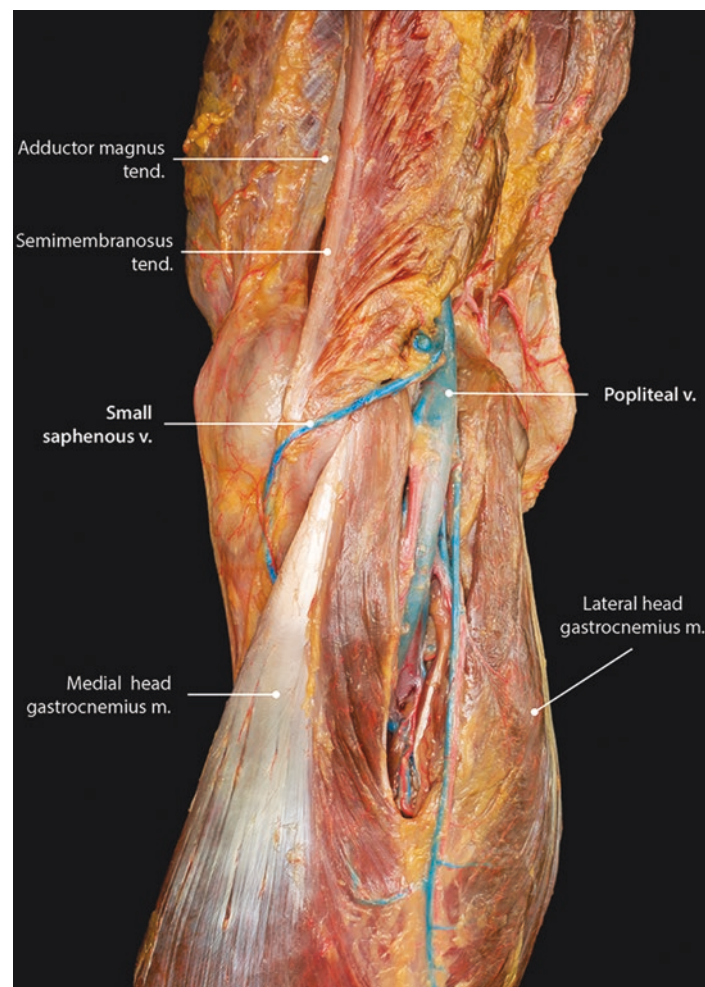


Fig. 8.12 Right knee, posterior. The veins (blue) and arteries (red) have been injected postmortem

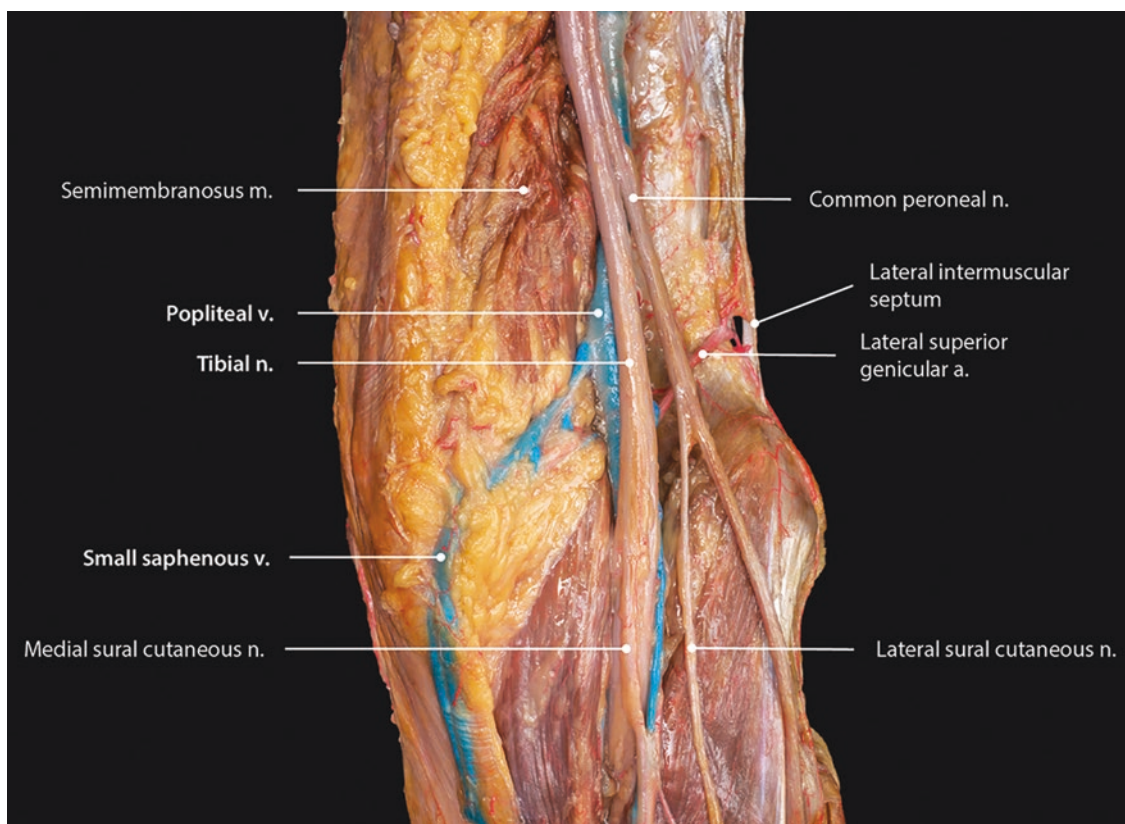


Fig. 8.13 Right knee, popliteal fossa showing neurovascular structures

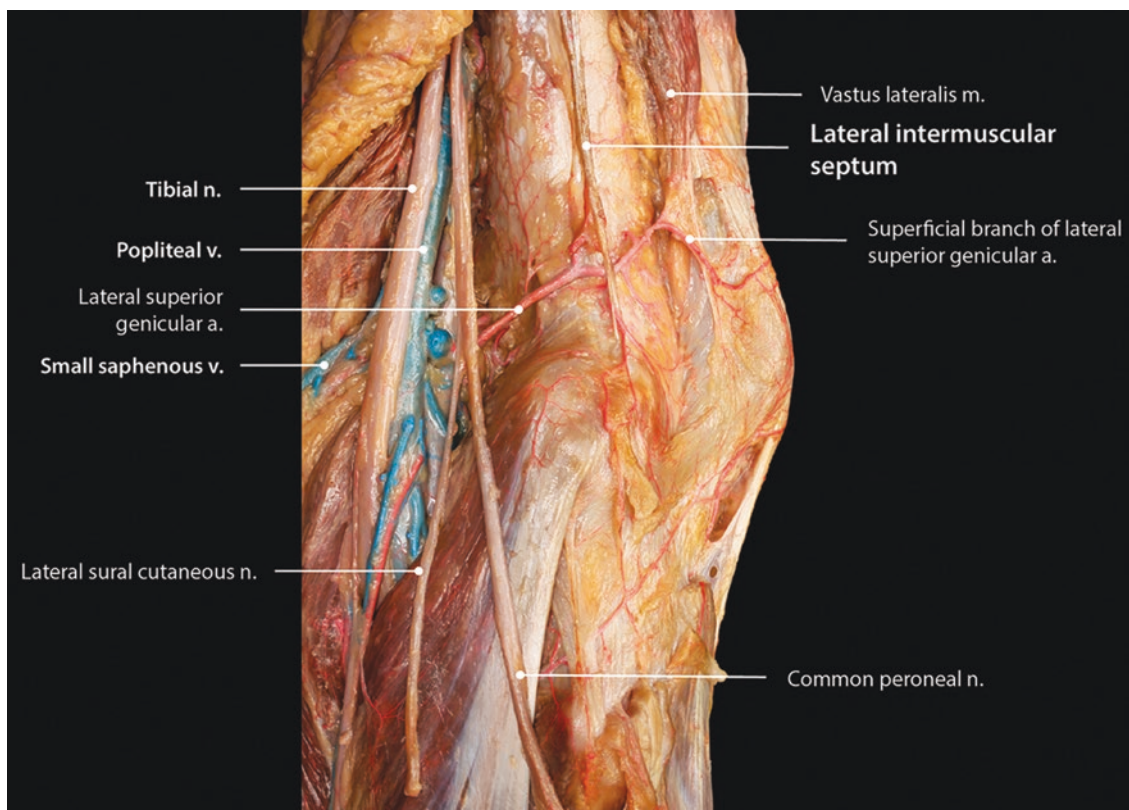


Fig. 8.14 Right knee, posterolateral. Note the lateral intermuscular septum, which separates the anterior from the posterior thigh compartments

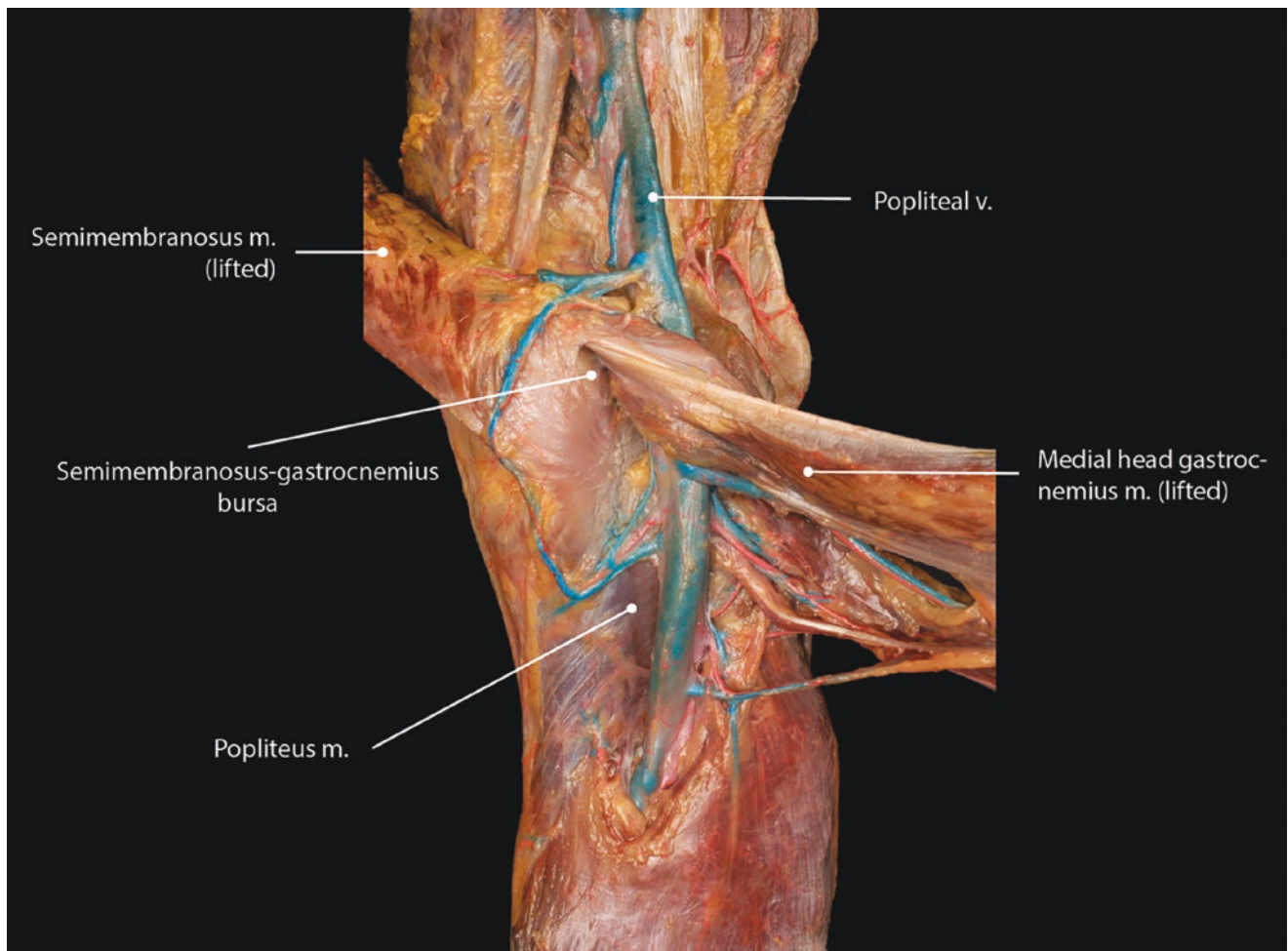


Fig. 8.15 Right knee, posteromedial. Deep exposure showing course of popliteal vein

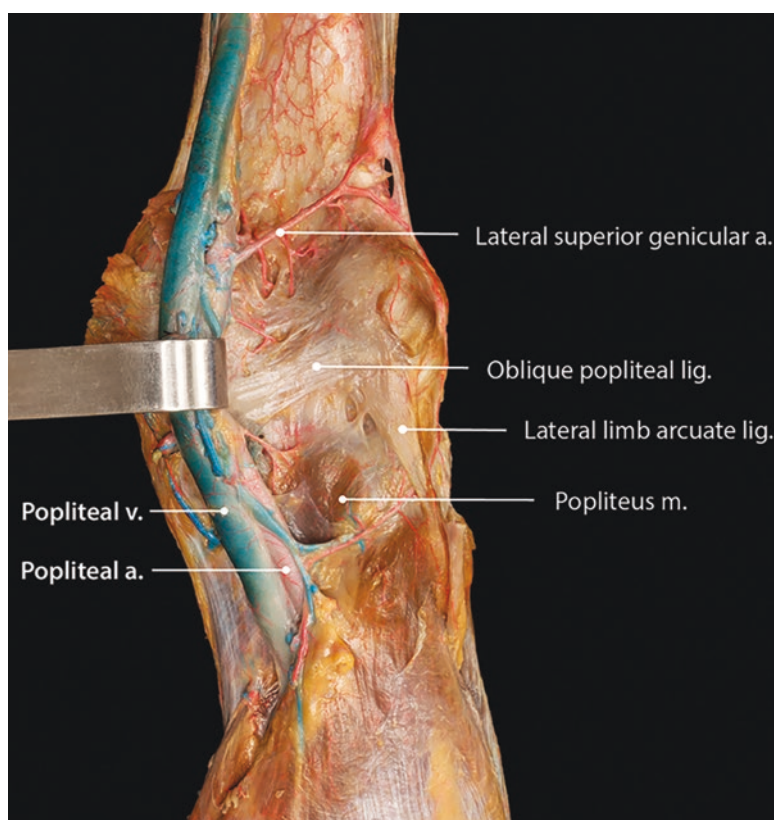


Fig. 8.16 Right knee, popliteal fossa. The popliteal vein and artery are retracted medially

8.5 Arteries

The **popliteal artery** (*a. poplitea*) is a continuation of the femoral artery. It passes through the popliteal fossa close to the posterior capsule (see Figs. 8.17 and 8.18). In the popliteal fossa, the popliteal artery gives off five major branches: superior medial, superior lateral, inferior medial, inferior lateral, and middle genicular arteries (see Figs. 8.19 and 8.20). They participate in an intricate anastomotic network that maintains circulation to the lower leg when the knee is fully flexed.

Precautions

Variants of the popliteal artery are not uncommon. When performing a surgical exposure of the posterior knee, the possibility of encountering an anatomic variant must be considered. There are 3 different patterns (see Fig. 1.48) (refer to Chap. 1).

The **lateral superior genicular artery** passes above the lateral femoral condyle, beneath the biceps femoris and divides into a superficial and deep branch (see Figs. 8.14 and 8.24). The superficial branch passes through the distal lateral intermuscular septum (see Fig. 7.21) and supplies the vastus

lateralis. It anastomoses with the descending branch of the lateral femoral circumflex and lateral inferior genicular arteries (see Fig. 7.29).

The medial superior genicular artery goes above the medial head of the gastrocnemius and passes beneath the tendon of the adductor magnus into the anterior thigh compartment (see Fig. 8.25).

The middle genicular artery (*a. genus media*; *azygos articular artery*) pierces the oblique popliteal ligament and supplies the ligaments and synovium inside the knee joint (see Fig. 8.25).

The **medial inferior genicular artery** passes along the upper margin of the popliteus muscle and then below the medial tibial condyle and beneath the tibial collateral ligament (see Fig. 8.26).

A separate branch comes from the popliteal artery to supply the medial meniscus (see Fig. 8.22).

The **lateral inferior genicular artery** goes above the fibular head to the front of the knee (see Figs. 8.23, 8.24, 8.26, and 8.28).

At the lower border of the popliteus muscle, the popliteal artery divides into the **anterior** and **posterior tibial arteries** (see Fig. 8.23).

The neurovascular structures of the posterior knee are shown in Figs. 8.17, 8.18, 8.19, 8.20, 8.21, 8.22, 8.23, 8.24, 8.25, 8.26, 8.27, and 8.28.

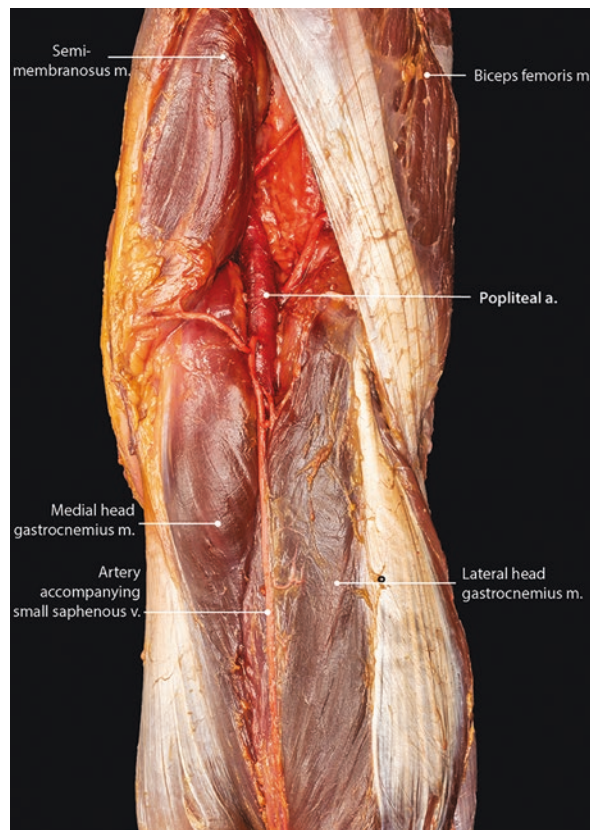


Fig. 8.17 Right knee, popliteal fossa. The **popliteal artery** is a continuation of the femoral artery. It passes through the popliteal fossa close to the posterior capsule

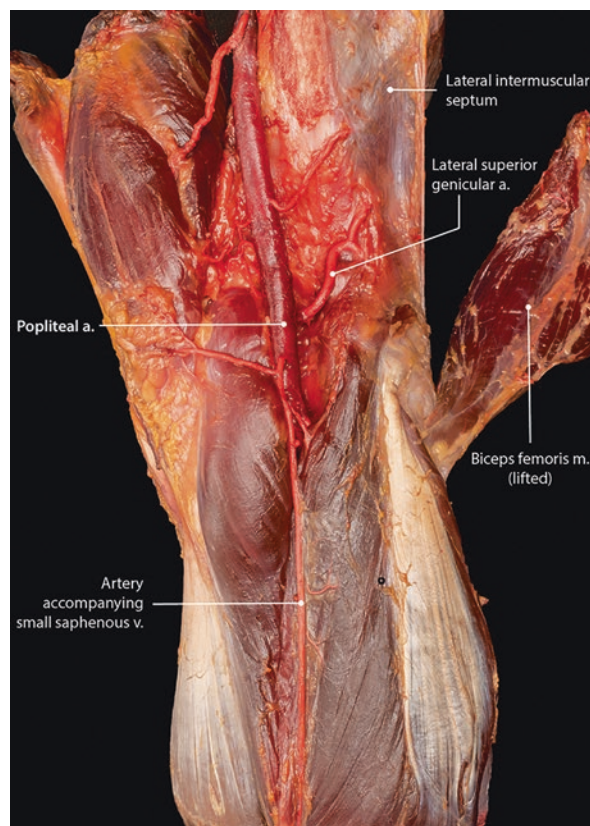


Fig. 8.18 Right knee, popliteal fossa. The semimembranosus and biceps femoris muscles have been lifted

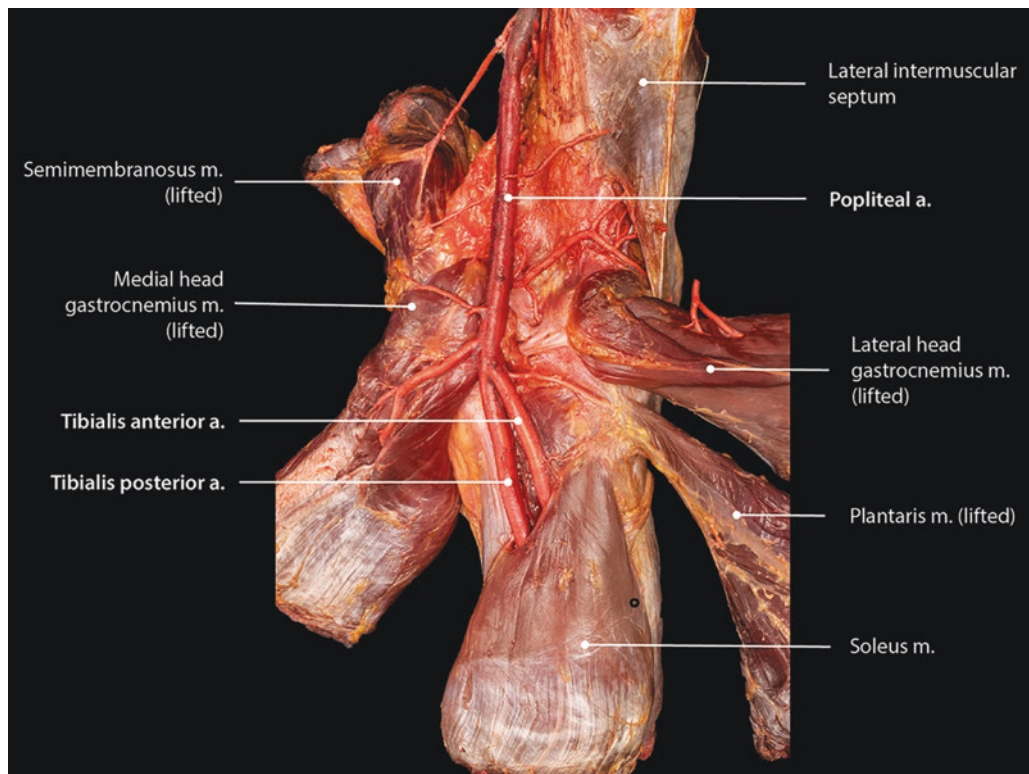


Fig. 8.19 Right knee, popliteal fossa, with the muscles lifted. This knee has a high division of the popliteal artery

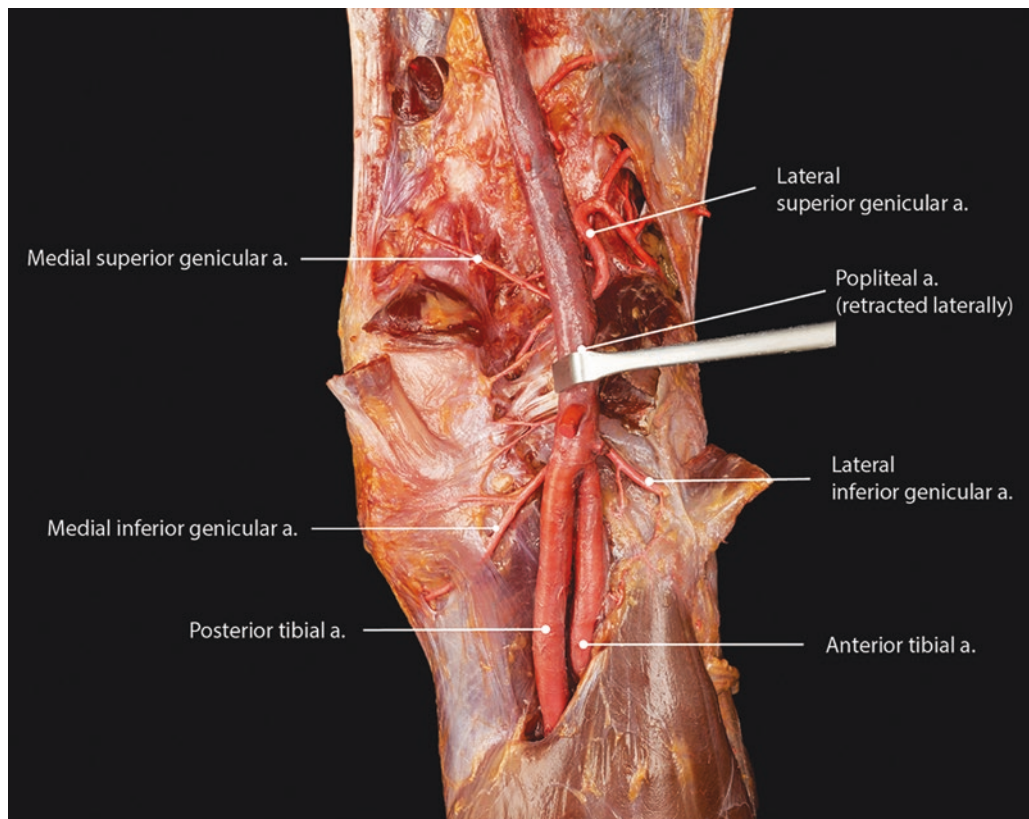


Fig. 8.20 Right knee, posterior aspect, with popliteal artery retracted laterally

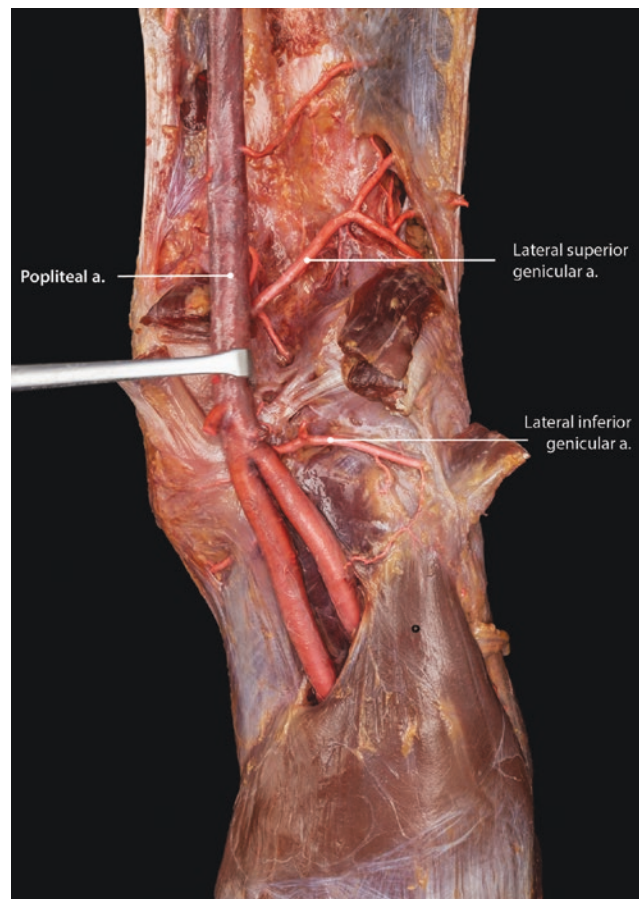


Fig. 8.21 Right knee, posterior aspect, with popliteal artery retracted medially

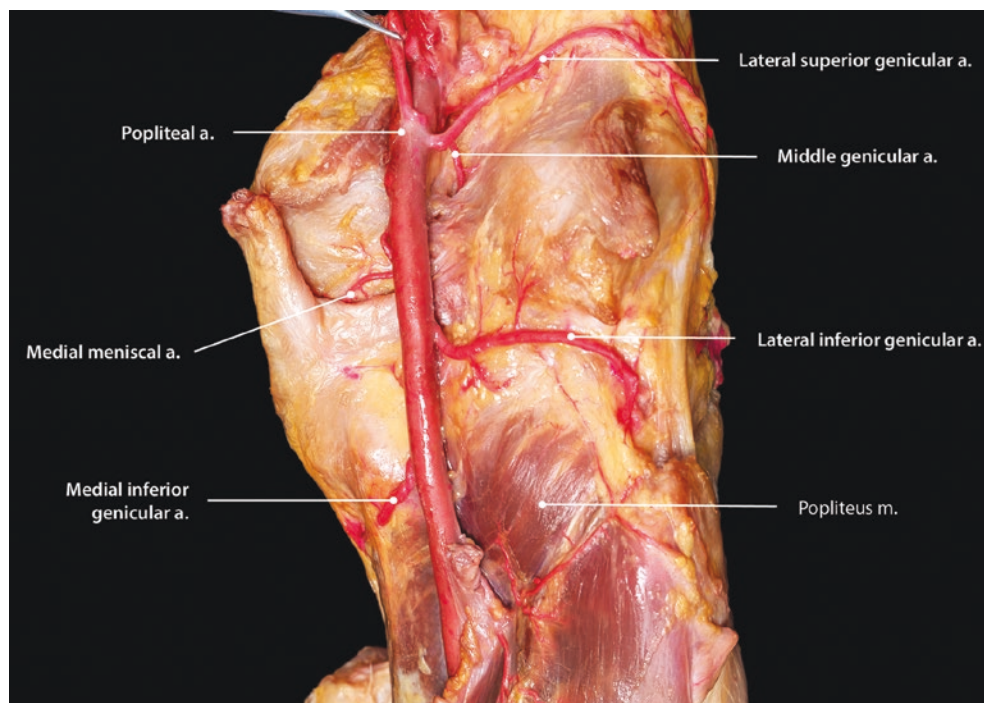


Fig. 8.22 Right knee, popliteal fossa. The popliteal artery passes through the popliteal fossa close to the posterior capsule. It gives off five major branches: superior medial, superior lateral, inferior medial,

inferior lateral, and middle genicular arteries. Note the artery to the medial meniscus (*From Chahla et al. [8]; with permission*)

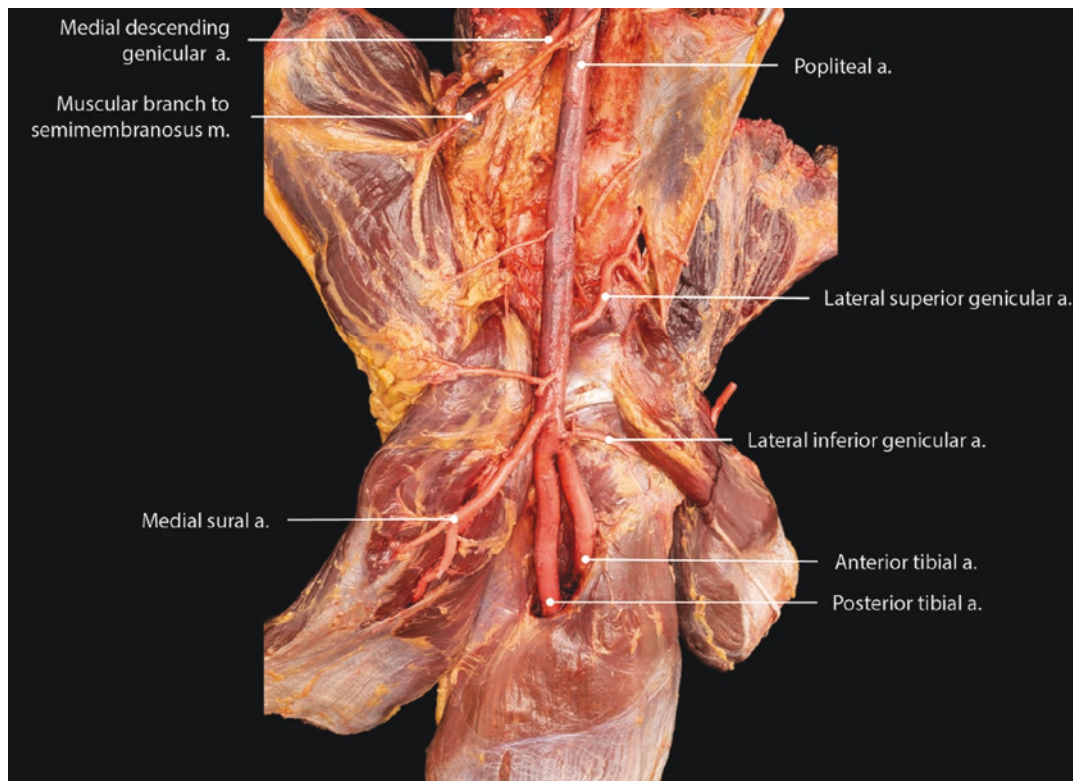


Fig. 8.23 Right knee, posterior aspect showing popliteal artery with branches. This knee has a high division of the popliteal artery

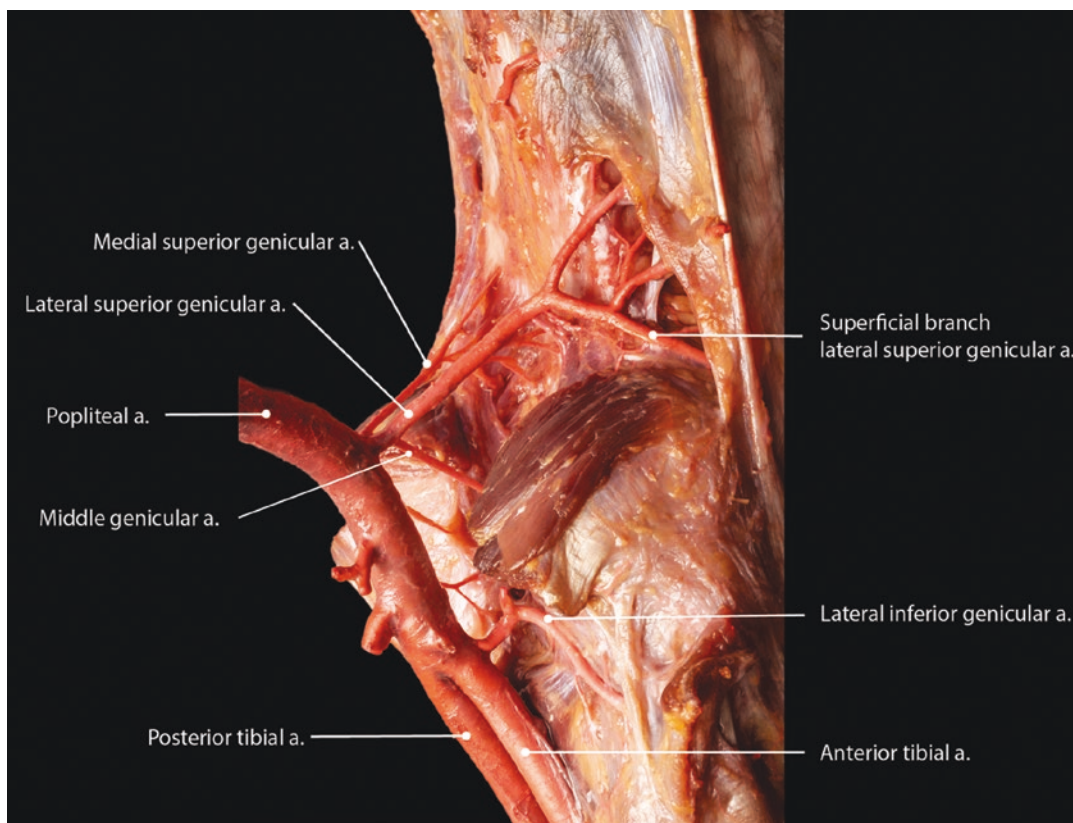


Fig. 8.24 Right knee, posterolateral aspect showing popliteal artery and its branches

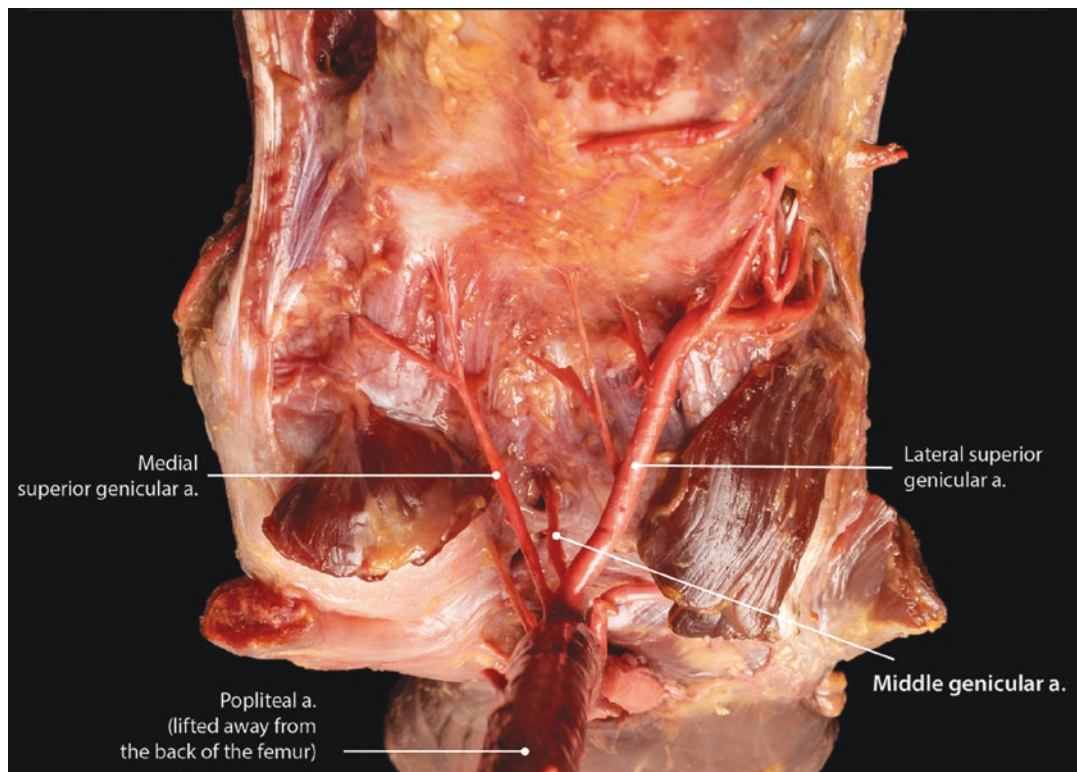


Fig. 8.25 Right knee, posterior aspect looking distally at the upper leg, with the popliteal artery lifted to show its branches. Note the middle genicular artery. It supplies the anterior and cruciate ligaments

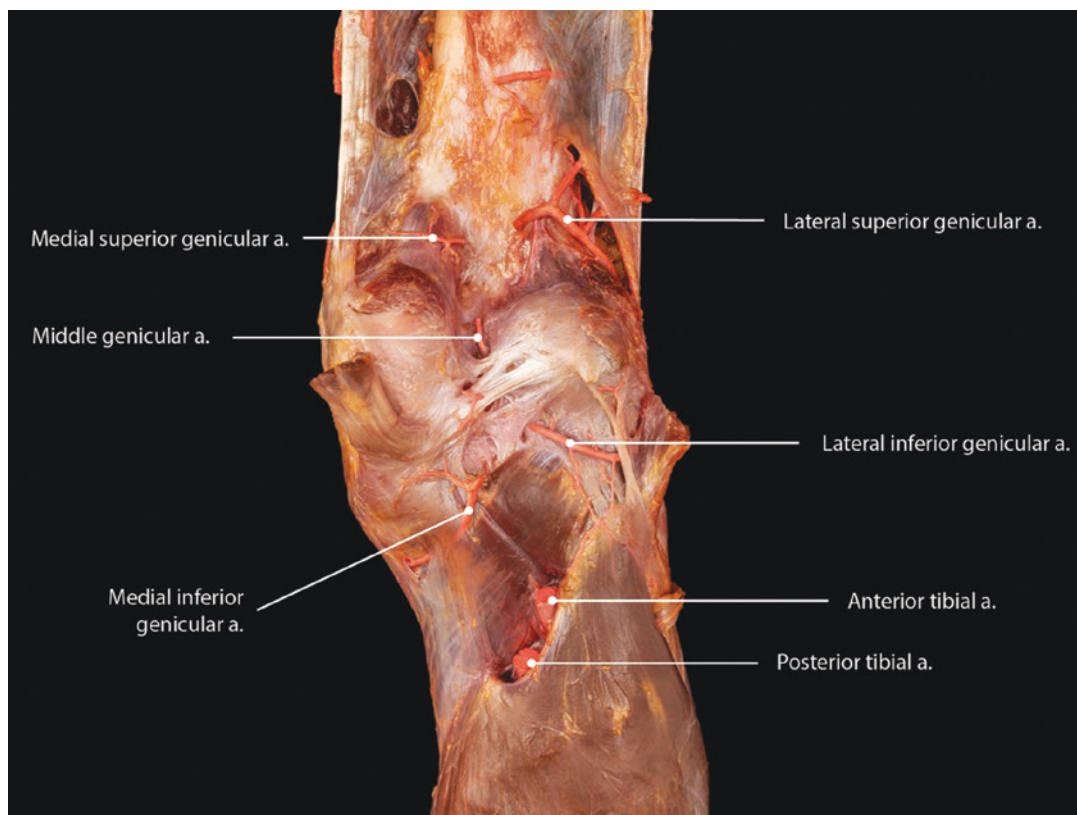


Fig. 8.26 Right knee, posterior, close to capsule

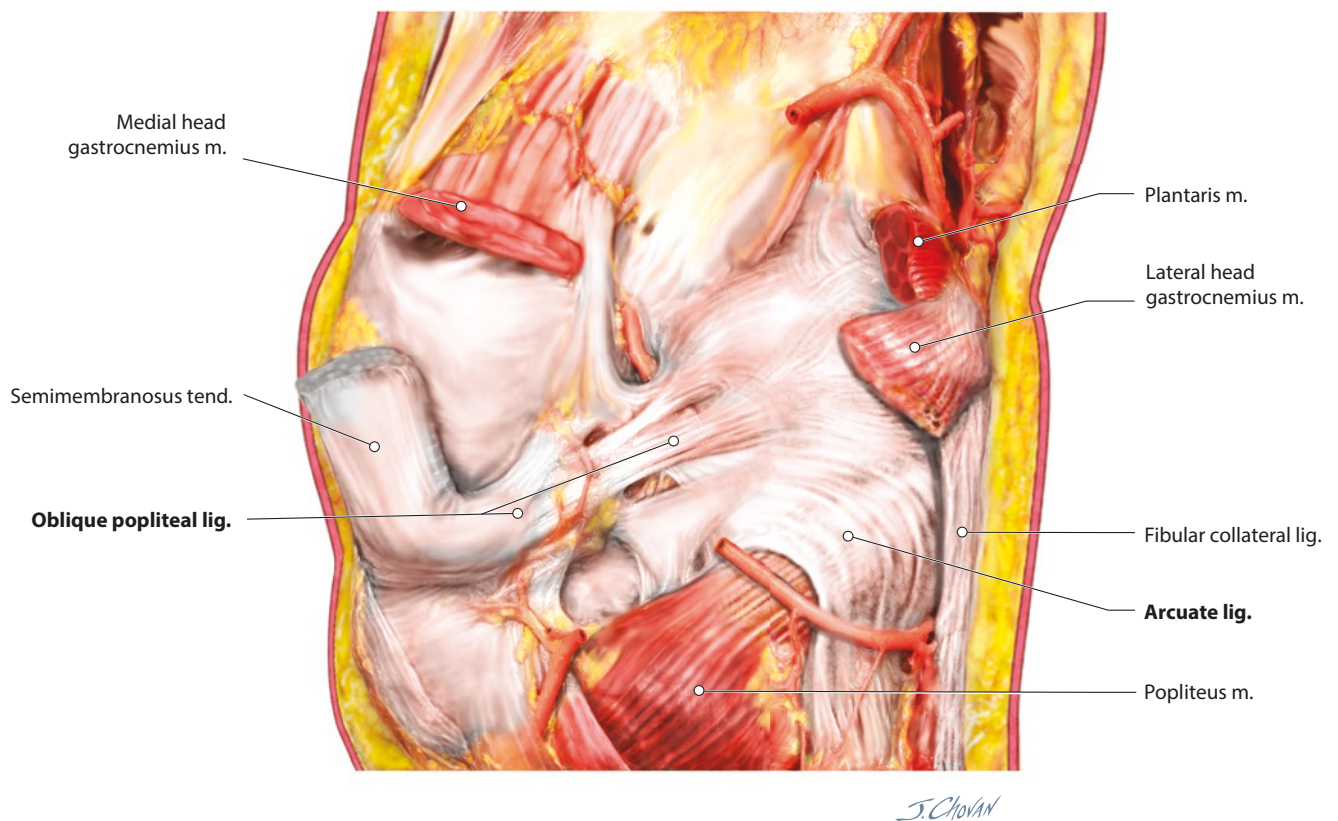


Fig. 8.27 Right knee, posterior capsule

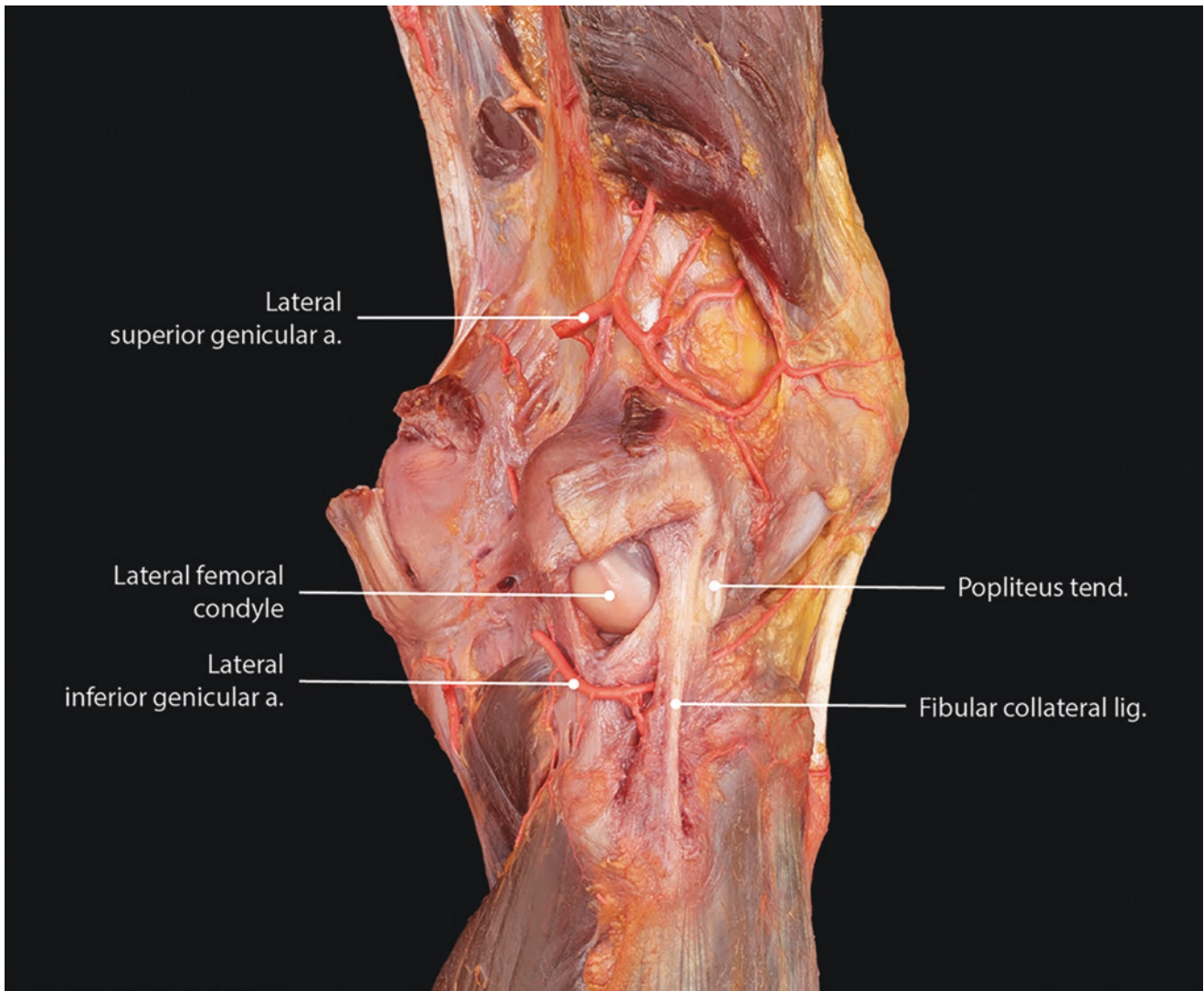


Fig. 8.28 Right knee, posterolateral deep structures

8.6 Posterior Capsule and Ligaments

The posterior knee capsule has two named parts: the oblique popliteal ligament and the arcuate ligament (*see* Fig. 8.29).

The **oblique popliteal ligament (OPL)** is an oblique thickening of the posterior knee capsule going from the medial side distally to the lateral side proximally. It is a tendinous continuation of the semimembranosus tendon insertion [3].

The **arcuate popliteal ligament** is a thickening of the posterior capsule that is found in about 65% of knees [4]. It

forms an arch over the popliteus tendon going from the posterior fibular head, over the popliteus tendon, to blend with the oblique popliteal ligament. If the knee has a large fabella, the arcuate ligament may be absent and replaced by a thick fabellofibular ligament.

In extension, the posterior capsule pulls tightly around the femoral condyles and stabilizes the knee.

If the posterior capsule is intact, the knee will be stable to valgus and varus stress in extension, even if all other stabilizing structures are cut.

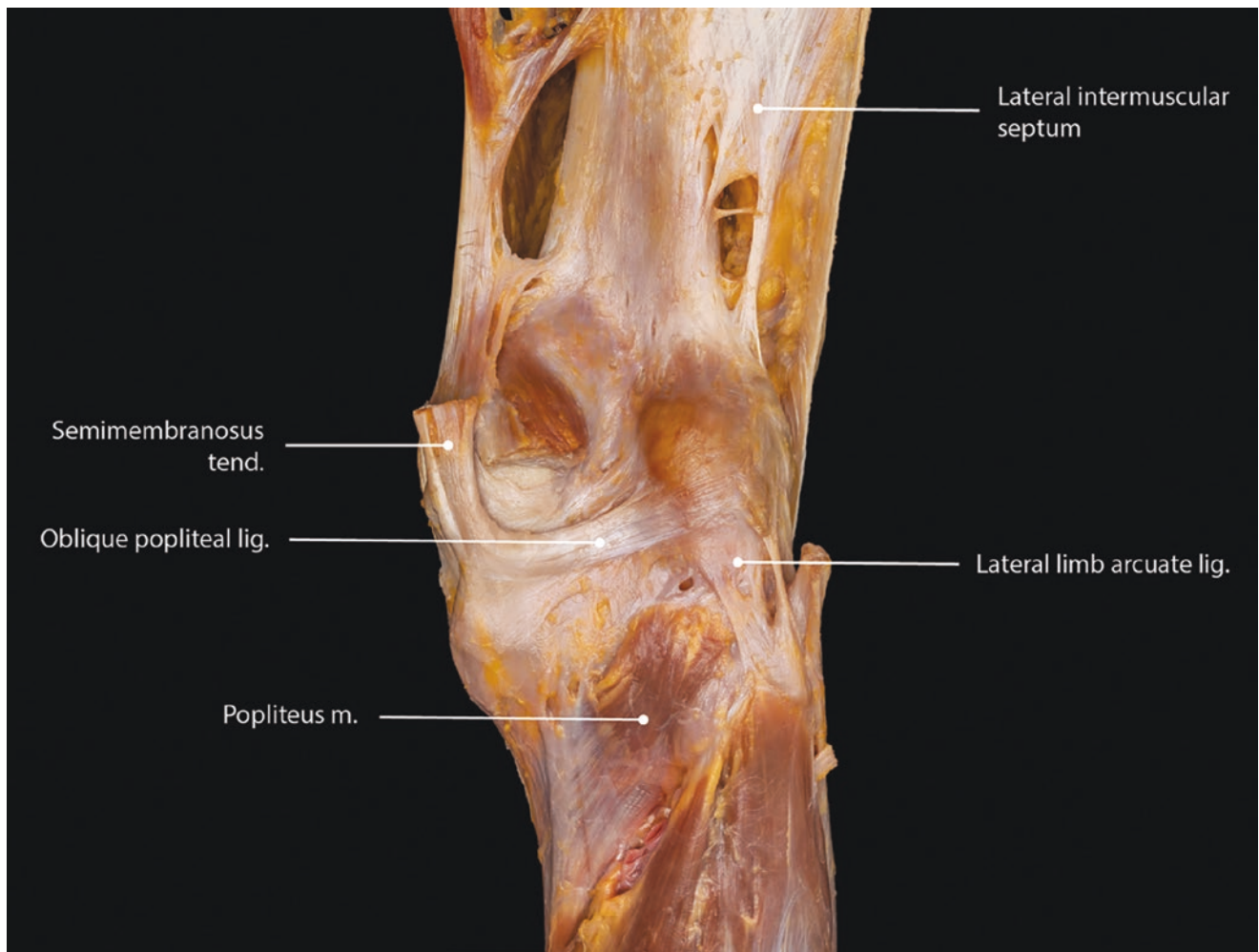


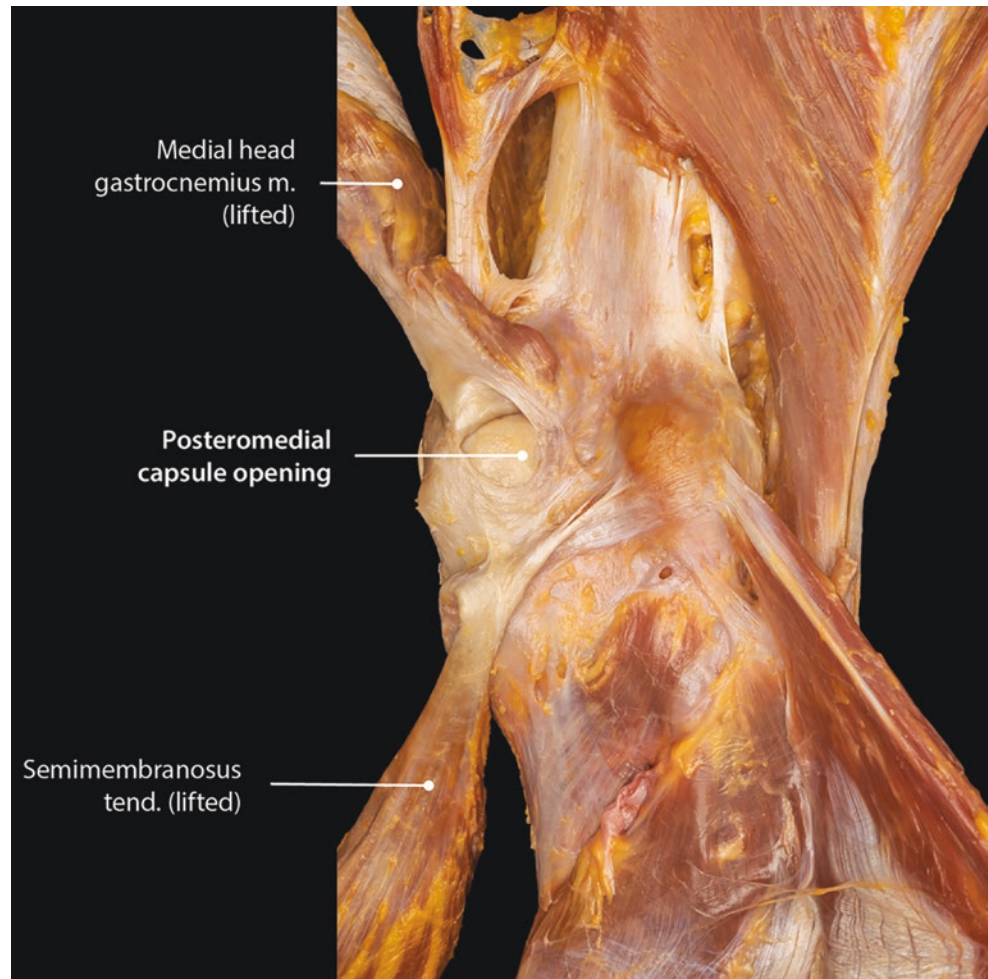
Fig. 8.29 Right knee, posterior capsule

8.7 Popliteal Cyst—Refer to Chap. 6

An opening in the posteromedial capsule connecting the knee joint with the semimembranosus-gastrocnemius bursa is a normal anatomic variant (*see* Fig. 8.30). This is a valv-

ular opening in 40–54% of healthy adult knees [5, 6]. Joint fluid can flow from the knee joint into the bursa but not the reverse, resulting in a popliteal cyst [7].

Fig. 8.30 Right knee, posterior, with muscles lifted. Note the capsular opening under the medial head of gastrocnemius, a common anatomic variant. If the opening is a one-way valve, joint fluid from the knee can be pushed into the bursa causing a **popliteal cyst**



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Part III

Surgical Exposures of the Knee

Tips for Operating on the Knee

9

Bertram Zarins, Robert Śmigielski, and James R. Andrews

9.1 Rowe's Principles of Surgery

Dr. Carter R. Rowe operated on the knee for more than five decades. He was a champion of the anatomic approach to surgery and a pioneer of early range of motion [1].

Dr. Rowe was my mentor (BZ) for almost 25 years (*see* Fig. 9.1). Here are the principles of surgery I learned from Dr. Rowe.

1. Skin incision—follow the skin “wrinkle lines” (Langer’s lines)
2. Layer-by-layer dissection
3. Hemostasis
4. Identify the pathology
5. Repair the lesion
6. Return tissues to their anatomical locations
7. Early range of motion

In addition to expounding anatomical surgical technique, Dr. Rowe set an example to others in his approach to patients. Table 9.1 shows Rowe’s “laws,” or as he used to call them, “Mistakes that I have made.”



Fig. 9.1 Dr. Bertram Zarins (left) with Dr. Carter Rowe in 1976

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Table 9.1 Rowe's laws

#1 A <i>satisfied patient</i> never sues a doctor. (It is not always how good your result is, it's how satisfied your patient is.)
#2 <i>Never promise</i> a 100% cure—otherwise, a 90% result will seem like a failure.
#3 Let <i>surgery be your last resort</i> , not your initial approach to the problem. (<i>Nature with a little support may be better than some surgical procedures.</i>)
#4 <i>When in doubt</i> ask for a consultation:
• Your patient may be thinking the same thing
• And, will appreciate your total concern
#5 <i>Know your patient before</i> you operate:
• Surgery is like marriage, it's difficult to untie the knot
• Is your patient paranoid, vindictive, is he or she suing the referring doctor? Often a minor procedure may indicate how the patient will tolerate a major procedure
• Consider how your patient would react to a complication
#6 When you get a <i>complication</i> (and you will):
• Work your heart out
• The patient will remember your efforts
• And, most likely consider the experience a success, rather than a failure
#7 When your colleague makes a mistake:
• Be careful what you say and how you say it to the patient
• Remember, you may be in the same fix someday, and you'll appreciate kindness and consideration
#8 If you get a <i>rude letter</i> , always send a polite one back. It's much better. (<i>Sir Arbuthnot Lane</i>).
#9 Remember what Dr. Irwin Leinbach said when considering surgery: " <i>Pick the berries, not the nuts.</i> "
#10 And remember Mankin's law: "There is no limit what <i>crazy surgeons</i> will do to <i>crazy patients</i> , for <i>crazy conditions</i> ."

9.2 Tips from Bertram Zarins—Boston, Massachusetts

1. *Anatomic approach.* Use layer-by-layer dissection. Identify the pathology. Repair the lesion and return the tissues to their normal positions. Do not try to improve the anatomy.
2. *Knee positioning:* When using a bolster, place it under the mid-thigh, not the knee, to prevent compressing the posterior neurovascular structures.

Drop the foot of the operating table and place the table in the Trendelenburg position knee when operating on the medial and lateral sides of the knee at 90° flexion (see Fig. 9.2).

3. *Sterile technique:* William S. Halsted at the Johns Hopkins Hospital developed aseptic surgery in the United States. I began my surgical training at Johns Hopkins, and absolute sterile technique was drilled into me. Strict asepsis sometimes takes a back-seat today because of the widespread use of peri-operative antibiotics. Sterile technique is still most important.

Instruct the patient to wash the skin with a hexachlorophene-containing soap for several days before surgery. This decreases the bacterial count on the skin.

Several types of surgical skin-prep solutions are available. Solutions that contain iodine, if allowed to dry, kill bacteria. A solution that contains chlorhexidine leaves a film on the skin which prevents a sterile adhesive drape from adhering to the skin.

You cannot sterilize the skin. But, *you can achieve a sterile operating field* by applying a sterile adhesive drape to the skin. Be sure the skin is dry before you apply the sterile adhesive drape. Otherwise, it will not stick to the skin. Flex the knee to 90° when you apply the drape (see Fig. 9.3).

4. *Skin incisions:* For the best cosmetic result, follow Langer's lines (refer to Chap. 1). However, for practical considerations, these are usually ignored around the knee. In the popliteal space, a gentle S-shaped incision takes advantage of the popliteal skin crease.

Warn the patient that there will be an area of numbness in the anterolateral parapatellar area if an anteromedial incision is made. Most of the numbness will clear in a year or two. Occasionally, a tender neuroma will form at the cut end of the infrapatellar branch of the saphenous nerve.

5. *The tourniquet:* Exsanguinating the limb and inflating a pneumatic tourniquet have several advantages. These include quicker operating time, better visualization of non-vascular structures, and less blood loss. When used during arthroscopy, there is a clearer field of view, but the synovium is blanched.

There are numerous disadvantages of using a tourniquet. When operating on the ischemic limb, hemostasis is not achieved. Therefore, postoperative bleeding and hematomas are common. Other reported complications include nerve injury, muscle atrophy, pressure necrosis, compartment syndrome, deep vein thrombosis, and postoperative edema [2–5].

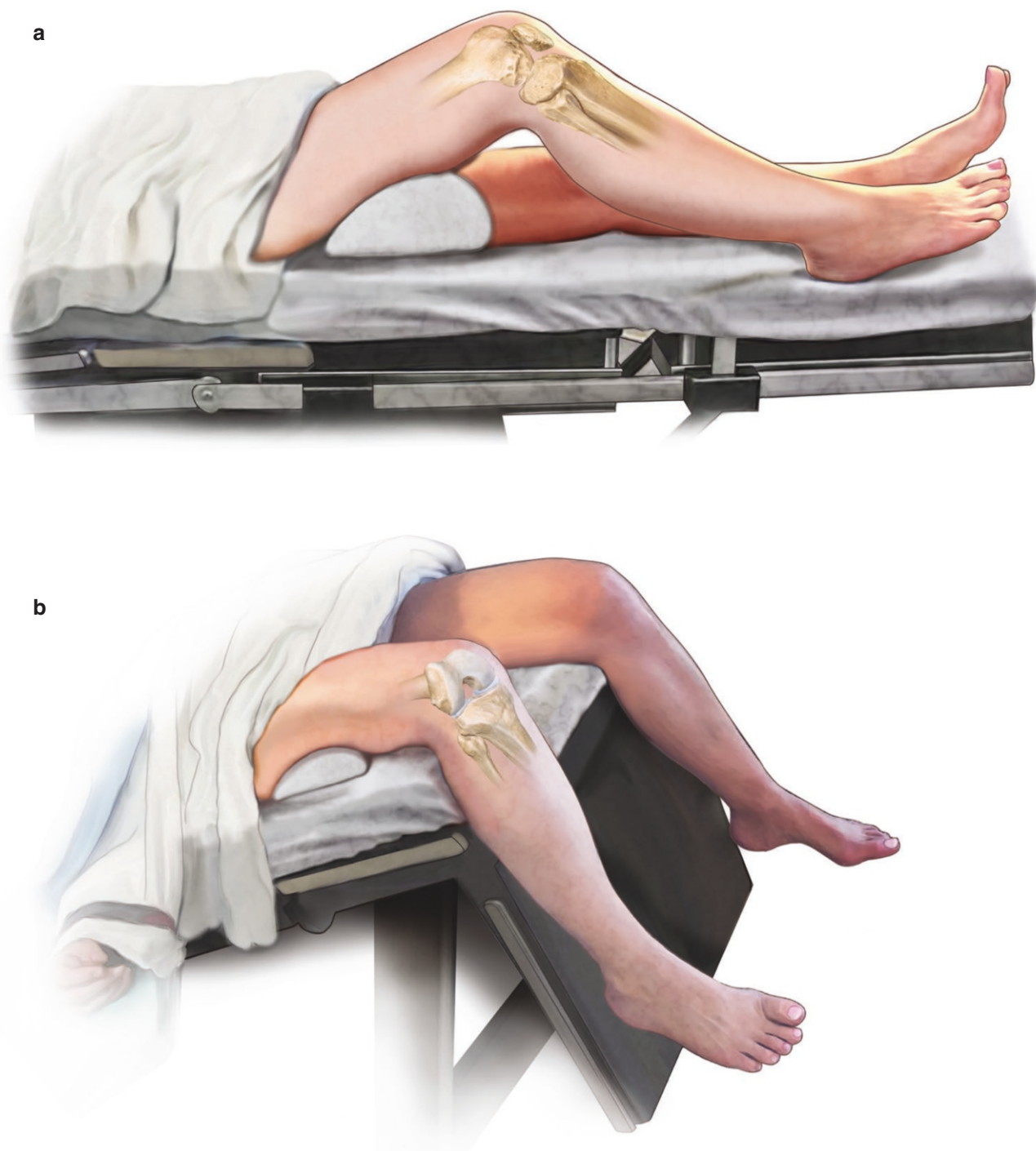


Fig. 9.2 (a) and (b) When using a bolster, place it under the mid-thigh, not the knee. Drop the foot of the operating table and place the table in the Trendelenburg position knee when operating on the medial and lateral sides of the knee at 90° flexion

Most knee operations can be done without the aid of a tourniquet. As dissection proceeds layer-by-layer, hemostasis can be achieved by electrocoagulating small blood vessels and ligating large ones. This will result in infrequent hematoma and better healing.

An inflated tourniquet when performing arthroscopy is not necessary if a pump is used to deliver fluid. The hydrostatic pressure from the pump suppresses bleeding. An exception is when doing a complete synovectomy, when it is advantageous to use a tourniquet.



Fig. 9.3 To achieve a sterile operating field, apply sterile adhesive drape to the skin. Prepare the skin with an iodine preparation and let it dry. Apply the drape with the knee flexed

6. *Layer-by-layer approach*: There is a layer of loose, subcutaneous connective tissue, the so-called **superficial fascial layer**, below the subcutaneous fat on the medial, anterior, and lateral aspects of the knee. Take advantage of this layer to develop a surgical plane when operating on the knee (*refer to Chap. 1*).

In the posterior aspect of the knee, there is an additional layer, the **stratum membranosum**, that separates the superficial from the deep subcutaneous fat (*refer to Chap. 13*).

Skin incisions can be kept small if a plane is developed between the skin and superficial subcutaneous fat and the deep fascia. Incise the skin sharply and continue the sharp dissection lightly through the subcutaneous fat

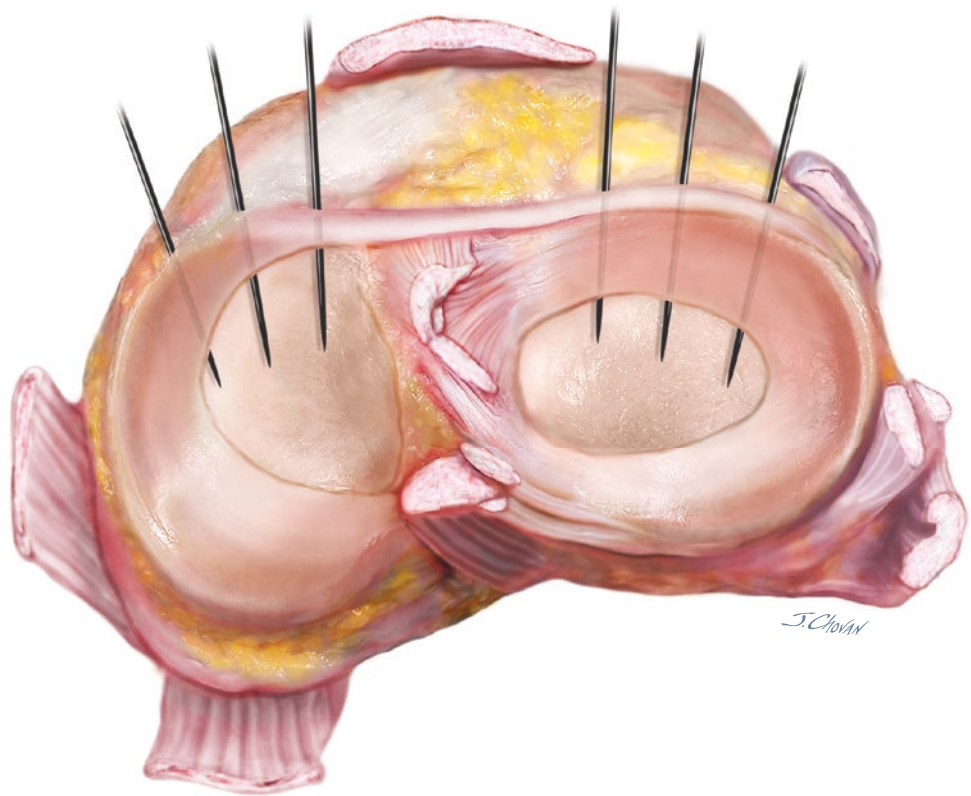
down to deep fascia. Lift the skin using hooks or other retractors to find the subcutaneous loose connective tissue and stretch it to make it areolar. Then, use blunt dissection to create a plane and a wide space. Bony landmarks become easily palpable. The superficial nerves usually stay attached to the deep fascial layer.

Medially, *do not dissect between the superficial and deep fascia posterior to the midline*. To proceed further posteriorly, incise the deep fascia and continue postero-medially under the deep fascia. Otherwise, you risk injuring the saphenous nerve, which is located somewhere near the musculo-tendinous junction of the sartorius muscle. The sartorius muscle is the most superficial muscle near the medial part of the knee. The epimysium of the sartorius muscle is continuous with the deep fascial layer (*refer to Chap. 11*).

When performing a knee arthrotomy, it is useful to think of the knee in terms of three layers: the **deep fascia, capsule, and synovium**.

7. *Bony landmarks*: On the medial aspect of the knee, the medial epicondyle and adductor tubercle are useful bony landmarks, especially for locating the site of a postero-medial arthrotomy (*Refer to Chap. 11*).
- Laterally, the lateral epicondyle, fibular head, and Gerdy's tubercle form a useful triangle (*refer to Chap. 12*).
8. *Vascularity*: The knee has an extensive anastomotic vascular network (*refer to Chap. 1*). However, there is a limit to how many blood vessels can be safely divided during surgery before the tissues become ischemic. This is especially true around the patella, where simultaneous medial and lateral arthrotomies can de-vascularize the patella.
9. *Finding the joint line*: Don Slocum taught me this tip in 1975: To identify the plane of the tibial plateau, such as when doing a high tibial osteotomy, slide three long Keith needles under the medial meniscus and three under the lateral meniscus. The needles form an array that helps define the top of the tibia (*see Fig. 9.4*).
10. *Do not give "optional" nerve blocks for postoperative pain*: Every anesthetic has potential complications and the advantages should be weighed against the risks. To give an anesthetic agent for surgery and then a second anesthetic for postoperative pain is double jeopardy. The incidence of a complication from pain, especially after arthroscopy, is close to zero. The incidence of complications from a nerve block is not zero.

Fig. 9.4 To identify the plane of the tibial plateau, such as when doing a high tibial osteotomy, slide three long Keith needles under the medial meniscus and three under the lateral meniscus. The needles form an array that helps visualize the top of the tibia



Precautions

1. The sterile adhesive drape must remain adherent to the skin throughout the operation. Otherwise, fluid can collect underneath the plastic drape and flow back into the wound. Some surgeons consider the sterile adhesive drape to be optional for arthroscopic procedures, but I use sterile adhesive drape for every operation.
2. Skin can never be sterilized. When performing arthroscopy, be careful not to introduce pieces of the plastic drape into the wound when pushing instruments through small arthroscopy portals.

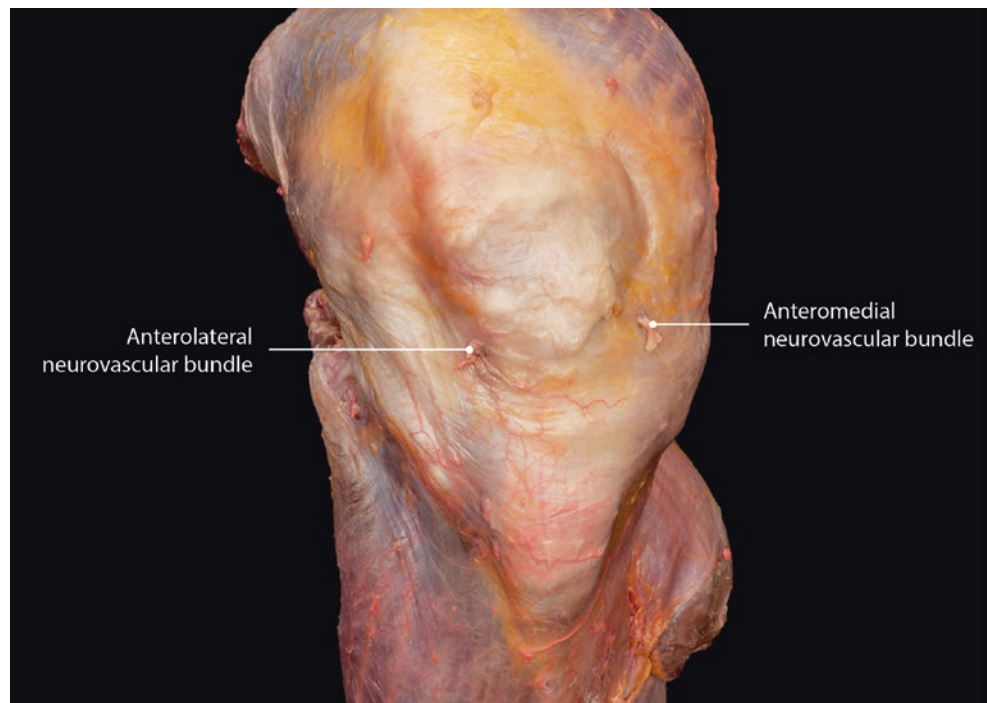
9.3 Tips from Robert Śmigielski, Warsaw, Poland

1. **Vascularity**—Because of the extensive anastomotic vascular network about the knee, vascularity usually receives scant attention from surgeons. When operating with a pneumatic tourniquet inflated, attention is not directed

toward blood vessels. However, it is easy to de-vascularize tissues when operating, especially the patella. Avoid simultaneous medial and lateral parapatellar arthrotomies.

2. **Menisci**—The posterior portion of the medial meniscus receives a direct branch from the popliteal artery. It runs along the peripheral edge of the meniscus. A similar branch from the lateral inferior genicular artery courses along the lateral meniscus. Circumferential sutures from meniscus repair can cut off the blood supply from these vessels.
3. **Medial femoral condyle**—The medial femoral condyle receives an important branch from the descending genicular artery. This should not be disrupted when performing medial patellofemoral ligament repairs.
4. **Arthroscopy portals**—Keep anterolateral and anteromedial portals high above the joint line to stay above the infrapatellar fat pad and to avoid the neurovascular bundles that pierce the deep fascia. Cutting a bundle causes excess bleeding and results in hypesthesia (see Fig. 9.5). When making an anteromedial portal be aware of the location of the infrapatellar branch of saphenous nerve. Injury to the nerve may be a source of postoperative anterior neuropathic knee pain.

Fig. 9.5 Anterior aspect right knee. Arthroscopy portals in the anterolateral and anteromedial aspects of the knee should be placed high above the joint line to stay above the infrapatellar fat pad and to avoid neurovascular bundles that pierce the deep fascia. Cutting a bundle causes excess bleeding and results in hypesthesia



9.4 Tips from Frank Noyes, Cincinnati, Ohio, USA

9.4.1 Phase 1: Prior to Surgery

1. The over-riding principle of treating patients involves an expert knowledge base combined with compassion and kindness as if the patients were “members of your family.”
2. Control the process from preoperative optimization, operative phase, postoperative phase, rehabilitation, and return to activity and sports. This requires an integrated team approach that includes physical therapists, athletic trainers, and performance specialists.
3. Patients are greatly benefited by meeting their therapy team BEFORE surgery, to learn the exercises they will do and the outpatient rehabilitation programs they will follow after surgery.
4. Operate when the patient is ready. That means the knee should have a full range of knee motion, good muscle control, and a functioning extensor mechanism. This applies to both acute and chronic knee injuries and disorders. Take time to address muscle atrophy before surgery.
5. Never guarantee an operative result. Do not quote percentages or literature reports for outcomes. Be optimistic.

Give options and alternatives so the patient arrives at a truly informed decision.

9.4.2 Phase 2—At Surgery

1. Preparing for surgery: have a 90% plan and a 10% alternative plan for change. Make sure your operating room crew has the necessary instrumentation and special requests. Review the pertinent anatomy prior to surgery.
2. Stage a complex surgical procedure into two if appropriate. I would rather do two operations that have the possibility of achieving 100% success rather than one long operation that has a projected 90% result [2].
3. Greet your patient in the preanesthetic unit before surgery.
4. Examine the patient’s knee under anesthesia.
5. Carefully position the patient and lower limb. The hip should be flexed 15° on the operative table to avoid hyper-extension of the joint and excess tension on the femoral nerve. The thigh holder for arthroscopy should be padded and placed so it does not suspend the thigh. When doing open procedures, place a bolster beneath the thigh, not the knee joint, to relax the posterior neurovascular structures.

6. I perform a comprehensive arthroscopic evaluation before open procedures and document the injury and the status of the articular cartilage.
7. When doing an open procedure make a cosmetic incision and closure of the skin. Avoid making incisions over bony prominences that have limited subcutaneous tissue (such as directly over the patella and tibial tuberosity).
8. Knee skin incisions that do not follow Langer's lines result in scar hypertrophy. An exception is the popliteal area.
9. Sterile technique is absolutely important.
10. Learn how to properly use a head light to truly visualize tissue planes, small nerves, and vessels.
11. Use sharp dissection to develop clean tissue planes and do not "spread the tissues."
12. To minimize tissue necrosis, avoid unnecessary use of electrocoagulation.
13. Use careful tissue dissection in the correct plane beneath the deep fascia (and not in the more superficial subcutaneous plane).
14. When closing, eliminate "dead spaces" with sutures on the skin flap. Achieve meticulous hemostasis after the tourniquet is deflated.
15. Avoid removing the peroneal nerve from its anatomic bed to prevent damage to the delicate perineural blood supply.
16. Do not do major dissection of both medial and lateral parapatellar tissues to avoid compromising the vascular supply to the patella.
17. Do not over-tighten tissues. Maintain isometric length to allow immediate range of knee motion postoperatively. This will help to prevent knee arthrofibrosis.
18. Have a plan for to decrease tourniquet time throughout the operative procedure. Use the tourniquet during difficult exposures, such as dissection of the peroneal nerve, major medial reconstructive procedures or with revision operations.
19. Closure should involve balancing the extensor mechanism at twenty degrees knee flexion to restore normal medial and lateral glide tests and avoid a tight medial repair. Recheck at zero degrees flexion for proper soft tissue tension and patellar stability. Flex the knee to 90° to make sure there is no restriction due to a tight closure. Contracted medial or lateral peripatellar tissues may requiring a longitudinal Z-plasty to lengthen parapatellar tissues to avoid losing patellar mobility [2].
20. The skin closure should be cosmetic.

21. The compressive dressing should have adequate padding and an elastic bandage. Add an additional pad over the common peroneal nerve.
22. Some form of postoperative cold therapy is important.

9.4.3 Phase 3: Postoperative Rehabilitation and Orthopaedic Care

1. Make an appointment for the patient to see the doctor and physical therapist within 24 to 72 hours after surgery. Confirm that the patient can perform a voluntary quadriceps contraction.
2. Standardize further rehabilitation appointments, which should include written instructions. Establish a home therapy program that includes range of motion and muscle strengthening.
3. The four most important red flags in the first weeks after surgery are: (a) early detection of infection, (b) deep vein thrombosis, (c) range of motion deficits, and (d) complex regional pain syndrome. The fifth red flag is delay in muscle control of the lower extremity [2, 3].
4. The return of sports and athletics requires objective tests for muscle strength that includes isokinetic testing, agility tests, hip muscle function, core strength, hop tests, and drop jump tests [4].
5. The incidence of ACL injury in young female athletes can be reduced by implementing a neuromuscular training program. This involves muscle strengthening, plyometrics, agility, balance, and flexibility training [5].

9.5 Tips from James Andrews, Birmingham, Alabama, USA

1. Examine the opposite knee to make side to side comparisons for stability and range of motion.
2. Always using a sterile adhesive drape to cover the skin, even for the simplest surgical procedure. This includes arthroscopy, as well as all open knee procedures.
3. *Know your knee anatomy!* With so many procedures being done arthroscopically today, it is common for young surgeons to be unfamiliar with knee anatomy and open approaches. Anatomy should not to be learned in the operating room but studied in the cadaver lab. Repeat doing anatomical dissections over-and-over again during your entire career.

4. *Open knee approaches*—Remember the location of the cutaneous nerves. Anterior midline knee incisions always transect some sensory skin nerves. The nerves come to the front of the knee from the sides, so warn the patient about the loss of sensation lateral and distal to the skin incision. Make your anterior midline skin incision just lateral to midline along the lateral border of the patella tendon and as short as possible. Also, make the incision proximal and curvilinear. Then dissect through the prepatellar subcutaneous bursa (an avascular plane) to expose the medial parapatellar anatomy. A lateral curvilinear incision has several advantages:
 - Less numbness from cutting the cutaneous nerves.
 - Better healing with less stretching; the scar looks more “pencil line.”
 - When a patient sits with the knee flexed, the scar is less visible compared to a straight midline incision.
 - When an athlete lands or slides on the knee, the scar will not come into contact.
5. Use absorbable sutures for joint-line repairs. Permanent sutures at the joint line can produce a scar that can block knee motion.
6. Exsanguinate the leg and use a tourniquet to control bleeding during the procedure. Be cognizant of your tourniquet time. Let the tourniquet down before closing the incisions and get good hemostasis. Use Hemovac. Close large skin incisions with a permanent mattress sutures and skin glue, and not with a subcuticular stitch.
2. Popliteal artery entrapment syndrome is an uncommon developmental anomaly which can be asymptomatic or can cause symptoms of pain in young athletes, during or after exercise. It is mainly due to aberrant anatomic relationships between the popliteal artery and the surrounding myofascial structures in the popliteal fossa.
3. The most common variant is due to lateral attachment of the medial head of the gastrocnemius muscle to the femoral condyle causing the popliteal artery to deviate medially and inferiorly. This could lead to unexpected encounter of the popliteal artery during medial approach to the knee.
4. The popliteal vein can be displaced medially with possible separation from the popliteal artery by an intervening muscular band. This can complicate the posterior approach to the knee.
5. These anatomic variants can be clarified with MRI or CT angiography imaging prior to performing knee surgery.

9.6 Tips from Donald Shelbourne and Rodney Benner, Indianapolis, USA

1. Postoperative knee stiffness can result in a worse outcome, in both the short and long term, than instability. Prior to surgery, full knee extension range of motion, equal to the opposite normal knee, must be attained. Surgery should be delayed until this goal is met. After surgery, the patient needs to regain full knee extension. By following these steps, postoperative arthrofibrosis can be prevented.
2. Arthrofibrosis, especially after ACL surgery, is best treated anteriorly to correct the graft-notch mismatch.

9.7 Tips from Christopher Zarins, Austin, Texas, USA

1. Be aware of the potential for abnormal positions and course of the popliteal artery and vein. These anomalies can complicate medial and posterior approaches to the knee, especially when performing osteotomies.

9.8 Tips from Ramon Cugat – Barcelona, Spain

1. To boost tissue regeneration, inject leukocyte-free platelet rich plasma (PRP) into the joint at the end of surgery. It is coded as 24-00-11 [6]. This will improve the “bio-friendly” environment for the tissues [7].
2. Before you undertake surgery for a torn anterior cruciate ligament, the knee must meet three pre-requisites:
 - (a) No effusion.
 - (b) Good range of motion.
 - (c) No pain.

9.9 Tips from Andy Williams—London, U.K.

1. *Pre-surgery preparation*—Draw the surgical approach on paper, layer by layer. “Visualize” the entire operation.
2. Don’t get too close to anatomic structures with the arthroscope. Utilize the value of a 30° lens and rotate the arthroscope to widen your field of view.
3. *Stick to bone*—In open surgery, sharp dissection against bone avoids neurovascular structures.
4. *Keep to anatomic planes*: Get straight down to a layer and then dissect sideways. This results in less bleeding and improved anatomical demonstration.
5. *Avoid using scissors, especially around nerves*. It is better to cut a nerve with a knife than crush it with scissors.
6. *To reduce iatrogenic nerve injury, when isolating nerves, find the nerve proximally and dissect it distally to the site of injury*. The best example is for the common peroneal

nerve in posterolateral corner injuries. If the biceps tendon has been avulsed, with or without bone, the nerve can be drawn by the tendon into a non-anatomic position [8].

9.10 Tips from Levan Natchkebia, Tbilisi, Georgia

1. Side support—Instead of using a leg holder device during knee arthroscopy, use a side support (padded post). This allows you to easily manipulate the knee.
2. Approach—To visualize the posteromedial joint for medial meniscus repair, apply varus stress with knee suspended in 60 to 90 degrees of flexion. The position of the knee also widens the anterior/lateral joint and gives clear visualization for middle and anterior portion of the lateral meniscus.

9.11 Tip from Bertrand Sonnery-Cottet, Lyon, France

1. Before operating on a knee, especially following acute injury, be sure that arthrogenic muscle inhibition (AMI) has been abolished [9]. AMI is characterized by failure to activate the quadriceps muscle, with or without extension deficit. If AMI has not been corrected, there is a high chance of postoperative stiffness, such as cyclops syndrome and arthrofibrosis.

9.12 Tips from Bruce Levy, Rochester, MN, USA

1. When performing posterolateral corner knee surgery, it is important to understand the branches of the common peroneal nerve: (1) articular trunk, which consists of the recurrent articular branch to the proximal tibiofibular joint and a motor branch to the tibialis anterior muscle, (2) deep peroneal nerve, and (3) superficial peroneal nerve (see Fig. 7.25).
2. The tibialis anterior muscle is innervated by both the articular trunk and the deep peroneal nerve, so extreme care must be taken when retracting the peroneus longus off the fibular head-neck region when creating fibular tunnels.
3. To avoid a neuroma caused by swelling of the nerve, follow the common peroneal nerve to the fibular tunnel, where the nerve trifurcates at the level of the fibular head-neck junction. To decompress the nerve thoroughly, it is

important to release the superficial and deep peroneus longus fascia in this region.

4. When performing a 2-tailed posterolateral corner reconstruction with a tibial tunnel, using fluoroscopy can be a helpful aid to avoid neurovascular injury. The popliteal artery sits right behind the posterior horn of the lateral meniscus and can be damaged when drilling the tibial tunnel from an anterior to posterior direction.

9.13 Additional Tips from Surgeons Around the World

The following surgeons also sent tips: **Valdis Andersons**, Riga, Latvia, **Moises Cohen**, Sao Paulo, Brazil, **Chakra Raj**, Pandey, Nepal, and **Chen Shiyi**, Shanghai, China.

Tips that are similar are summarized herein:

1. *Safety*—This is paramount. The entire operating team, including the surgeon, nurse, and anesthesiologist, as well as the patient, must agree on **correct patient, correct side** (right versus left), and **correct procedure** to be performed. This should be done before induction of anesthesia and before prepping begins.
2. *Anatomy*—It is essential to be completely familiar with the anatomy. Operate within anatomical planes.
3. *Patient expectations*—Be realistic. Do not give the patient expectations that may not be met.
4. *Pre-surgery*—Review notes and anatomy.
 - *Planning*—Prepare a detailed preoperative plan in the clinic when you see the patient. Be aware of potential pitfalls and how to deal with them.
 - *Equipment*—Check to be sure you have everything you might need.
5. *Set-up*—Standardize patient and equipment placement and rituals in the operating theater.
 - *Patient positioning and transfer*—Optimize access and secure workspace.
 - *Personnel*—Create a cohesive, well-trained operative team.
 - *Sterile technique*—This is extremely important, especially skin preparation.
6. *After surgery*—Communicate with the family.
7. *Complications*—Do not abandon patient, be transparent, take responsibility.

A final tip from Dr. Henry Makin, Massachusetts General Hospital: “Whenever you do an operation, ask yourself: ‘What will I do for an encore if it doesn’t work out?’”

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Suggested Readings

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Anterior Knee Exposures

10

Robert Śmigielski and Bertram Zarins

10.1 Anterior Arthrotomy and Technique

To expose the anterior knee joint, an arthrotomy can be made medial to the patellar tendon and patella. The arthrotomy can be moved further medially and its angle changed, depending on which part of the anterior knee joint you need to expose.

Make a longitudinal incision parallel to the medial edge of the patellar tendon (*see* Fig. 10.1). Locate the medial edge of the patellar tendon (*see* Fig. 10.2). Incise the deep fascia to expose the capsule (*see* Fig. 10.3). Continue the incision along the medial edge of the quadriceps tendon, patella, and patellar tendon. When incising close to patella, leave enough strong tissue along the medial edge of the patella for closure. The incision can be extended proximally through the medial edge of quadriceps tendon and distally to top of tibia (*see* Fig. 10.4). Excise or retract the infrapatellar fat pad if necessary for additional exposure (*see* Fig. 10.5). Dislocate the patella laterally and flex the knee to 90° (*see* Fig. 10.6).

For a more extensive anterior exposure, extend the incision proximally as much as necessary (*refer to* Chap. 14).

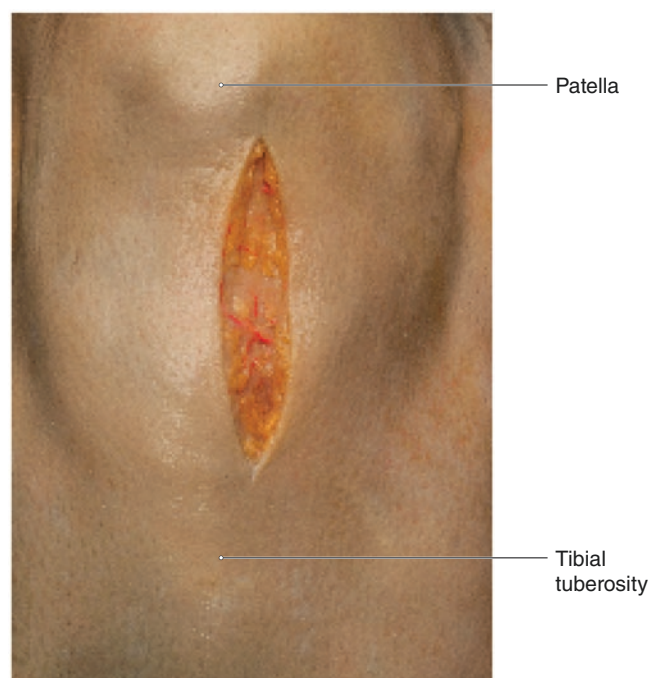


Fig. 10.1 Make a skin incision for a small anterior medial arthrotomy

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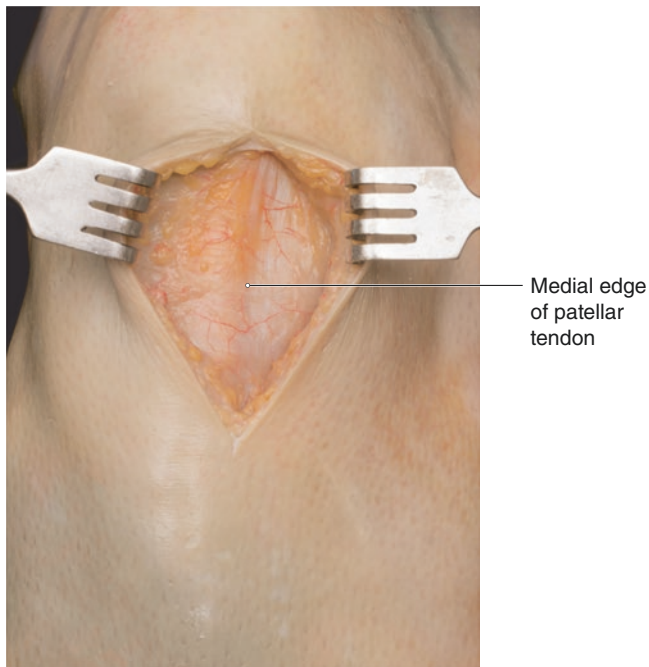


Fig. 10.2 Incise the skin and expose the deep fascia. Locate the medial edge of the patellar tendon

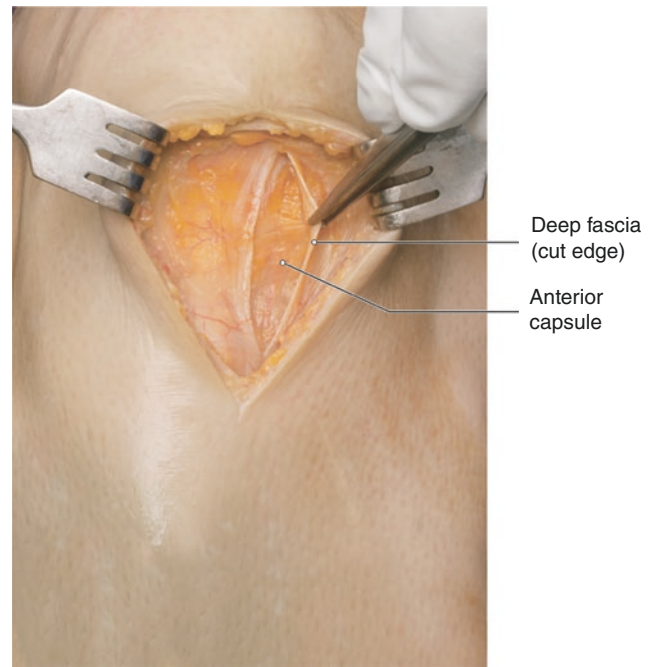


Fig. 10.3 Incise the deep fascia to expose the capsule. The incision can be moved further medially, and its angle changed, depending on which part of the anterior knee joint you need to approach

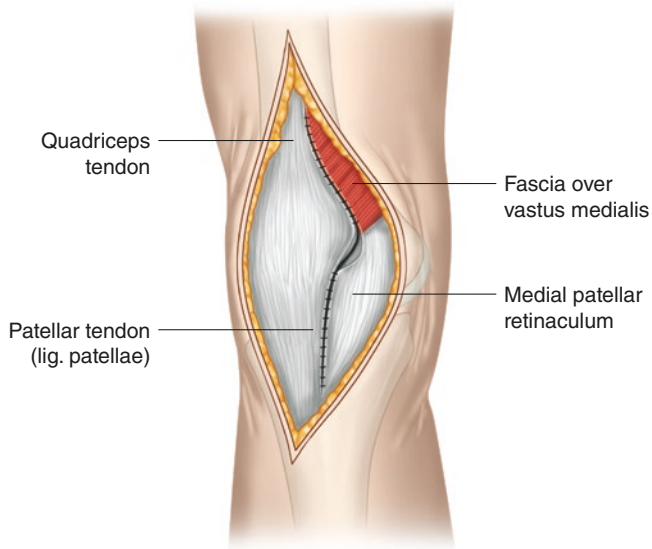


Fig. 10.4 For a wider exposure, extend the incision proximally and distally ncision through the deep fascia proximally and distally deep fascial

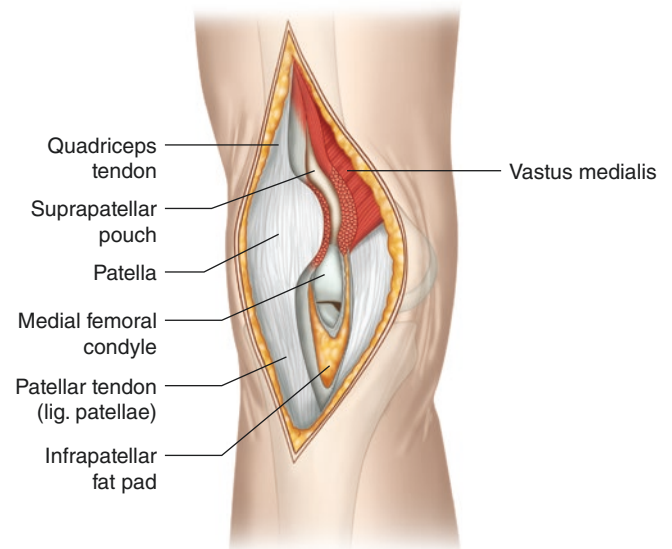
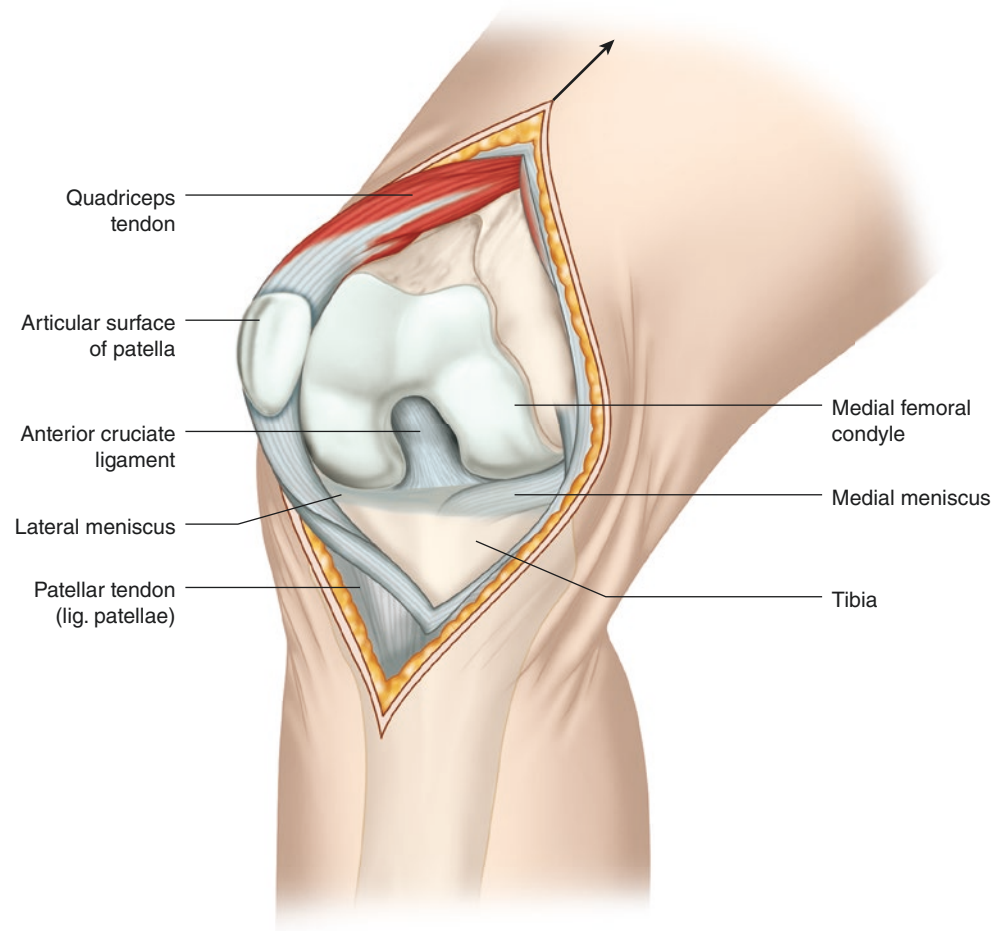


Fig. 10.5 Continue the incision through the joint capsule and along the quadriceps and patellar tendons to gain access to the joint

Fig. 10.6 Dislocate the patella laterally and flex the knee to 90 degrees



10.2 Mid-Third Patellar Tendon Graft Harvest (Bone-Patellar Tendon-Bone) and Technique

With the knee at 90° flexion, incise the deep fascia over the patellar tendon. The fascia is thick proximally over the patella but becomes thin at the tibial tuberosity (*see* Fig. 10.7).

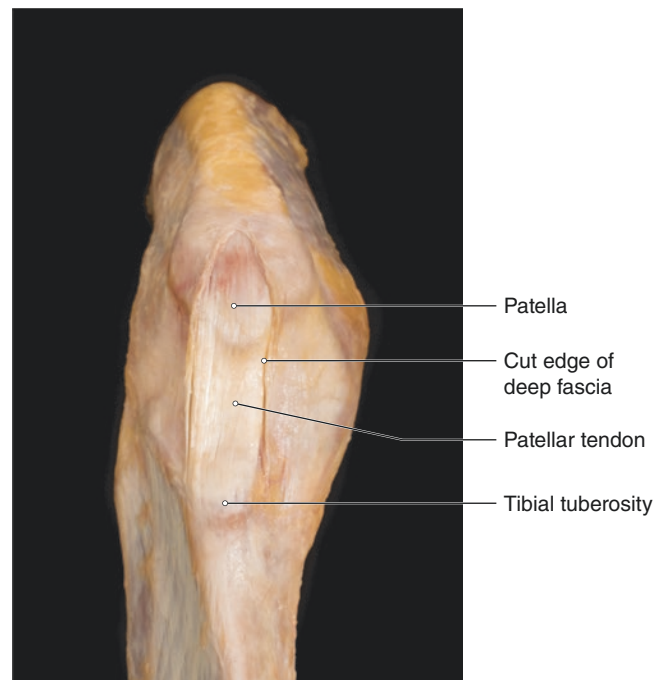


Fig. 10.7 Anterior aspect of flexed right knee with the deep fascia incised exposing the patellar tendon. The fascia becomes thin distally at the tibial tuberosity

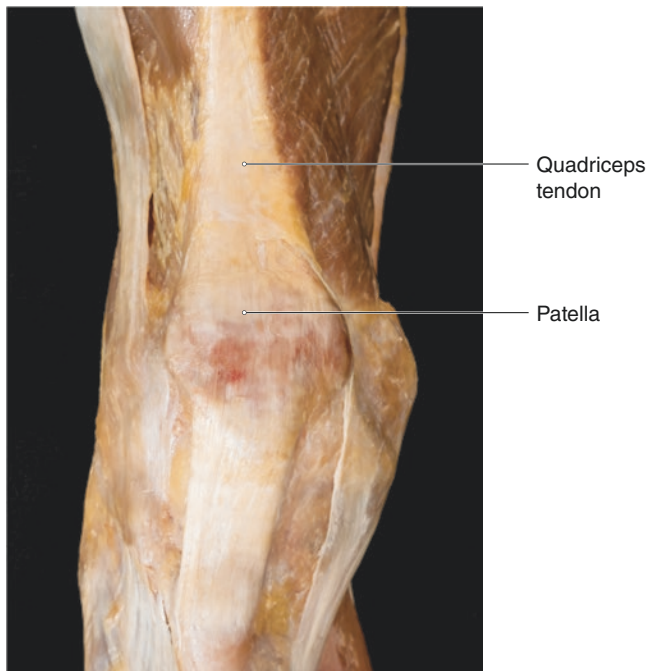


Fig. 10.8 The deep fascia has been removed to show the quadriceps tendon and patella

10.3 Quadriceps Tendon—Patella Graft Harvest and Technique

Incise the deep fascia that overlies the quadriceps tendon and patella (*see* Fig. 10.8).

10.4 Hamstring Tendon Graft Harvest and Technique

Expose the deep fascia of the anteromedial aspect of the upper tibia and knee. Palpate the top of the pes anserinus (*see* Fig. 10.9). It is located three fingerbreadths (6 cm) distal to the joint line (*see* Fig. 10.10). What you feel is the underlying gracilis tendon. The sartorius tendon has flattened into an aponeurotic expansion that is in continuity with the fascia cruris (deep fascia). Incise the deep fascia at the upper border of the



Fig. 10.9 Expose the deep fascial layer. Palpate the gracilis tendon under the deep fascia. This is the upper edge of the pes anserinus (arrow)

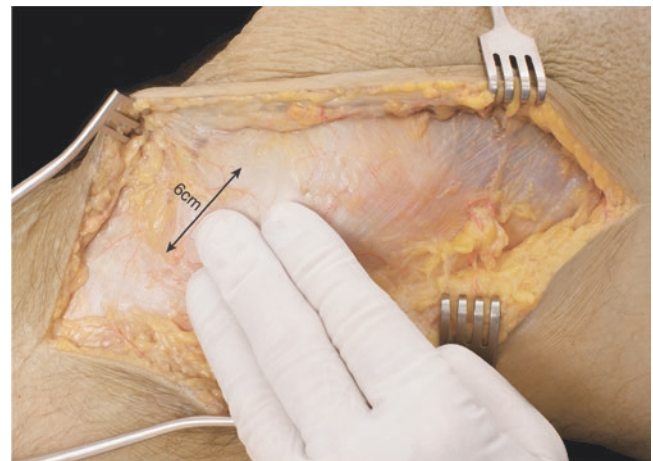


Fig. 10.10 The top of the pes anserinus (gracilis tendon) is 3 fingerbreadths (6 cm) distal to the joint line when the knee is flexed 90°

pes anserinus (gracilis tendon), being careful not to cut the underlying tibial collateral ligament (*see* Fig. 10.11). Lift the sartorius tendon (which is in continuity with the deep fascial layer). The gracilis tendon pops into view (*see* Fig. 10.12). The semitendinosus tendon is harder to find. It is hiding further distally on the undersurface of the deep fascia (*see* Fig. 10.13).

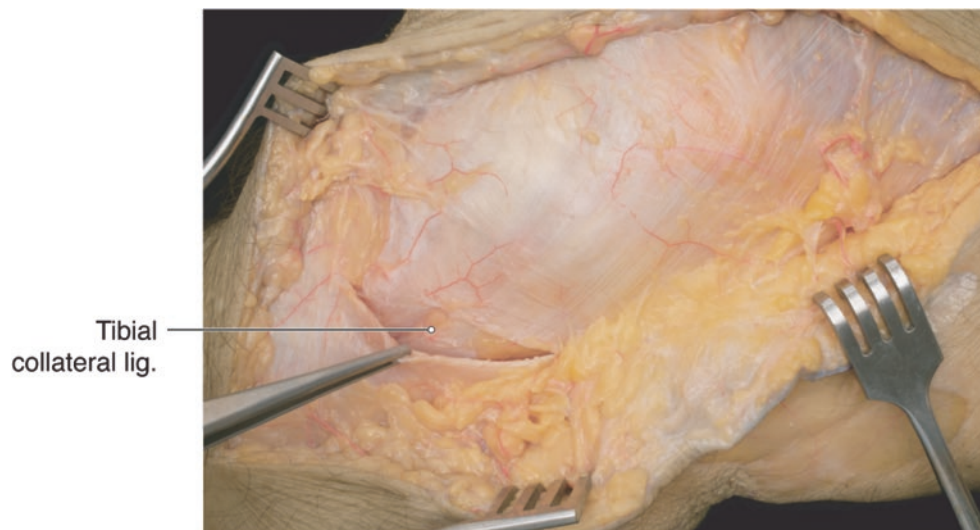


Fig. 10.11 Incise the deep fascia at the upper border of the pes anserinus. Be careful not to cut the underlying tibial collateral ligament

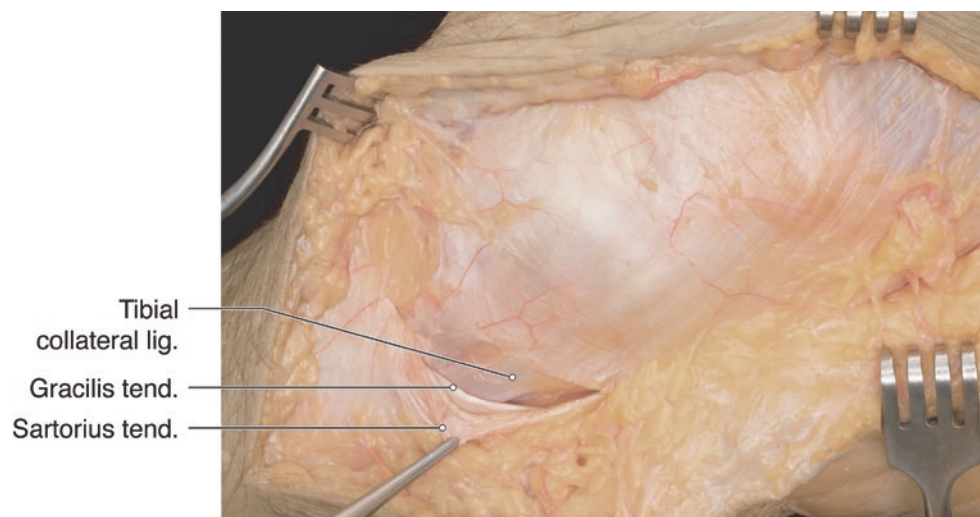


Fig. 10.12 Lift the sartorius tendon (deep fascia). The gracilis tendon pops into view

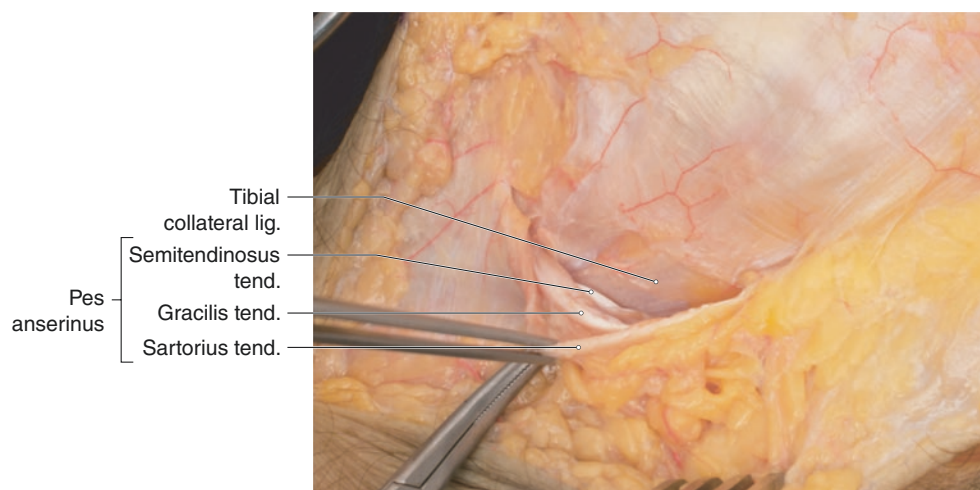


Fig. 10.13 The semitendinosus tendon is harder to find. It is located further distally and is on the undersurface of the deep fascia

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Medial Knee Exposures

11

Robert Śmigielski, Bertram Zarins,
Christopher Kristaps Zarins, Scott D. Martin,
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11.1 Anteromedial Arthrotomy

An arthrotomy can be done at various locations in the anteromedial knee to give access to the different parts of the anterior joint. The angle of the arthrotomy can be altered, depending upon the procedure to be performed. The flexion angle of the knee during the procedure can vary from partial flexion to 90° flexion. The arthrotomy can be extended proximally to gain as much exposure as needed (*refer to Chap. 14*).

11.1.1 Technique

Expose the deep fascia on the anteromedial aspect of the knee and identify the joint line (*see Fig. 11.1*). Incise the deep fascia and the anteromedial capsule. Extend the incision distally to the joint line. Be aware of cutting into the medial meniscus (*see Fig. 11.2*). Be aware of the infrapatellar (geniculate) branch of the saphenous nerve, it is close to the joint line and usually is sacrificed (*see Fig. 5.4*). Incise the synovium (*see Fig. 11.3*). Insert retractors to expose the anterior medial joint (*see Fig. 11.4*).

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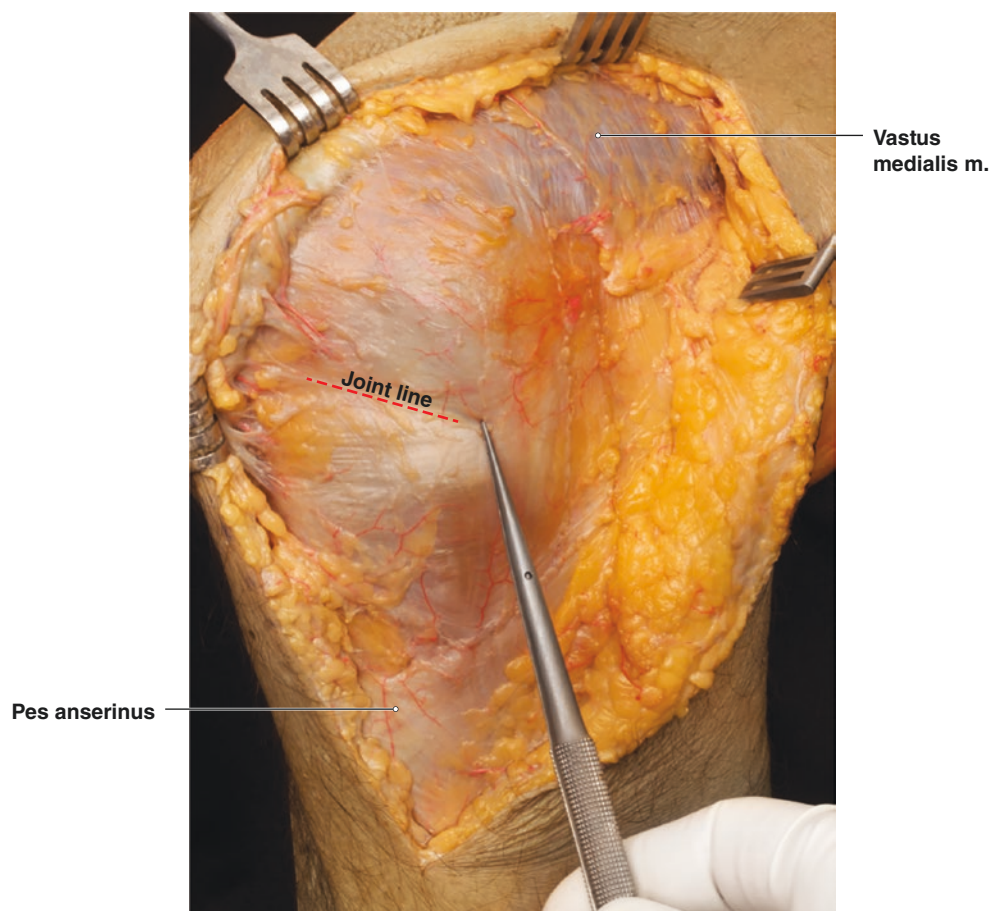


Fig. 11.1 With the knee at 90° flexion, the deep fascial layer has been exposed. The instrument points to the joint line (dotted line)

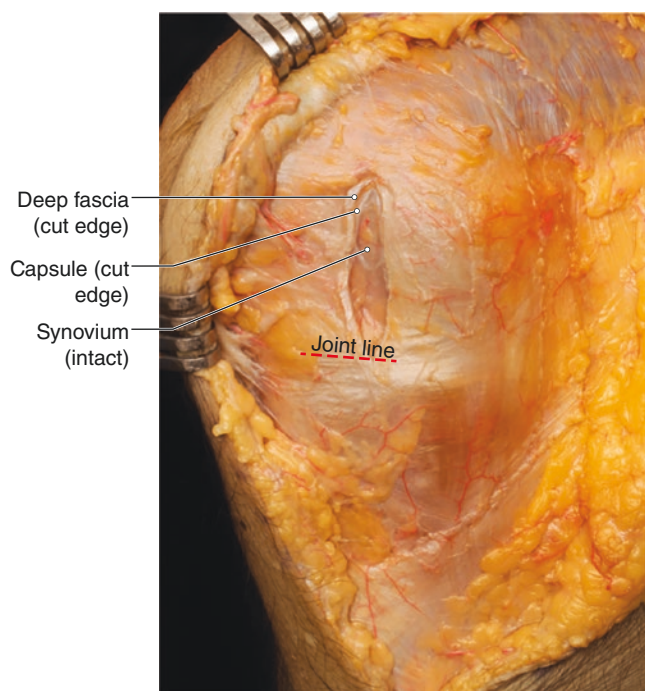


Fig. 11.2 Incise the deep fascia and the anteromedial capsule. Extend the incision distally to the joint line (dotted line). Beware of cutting into the medial meniscus

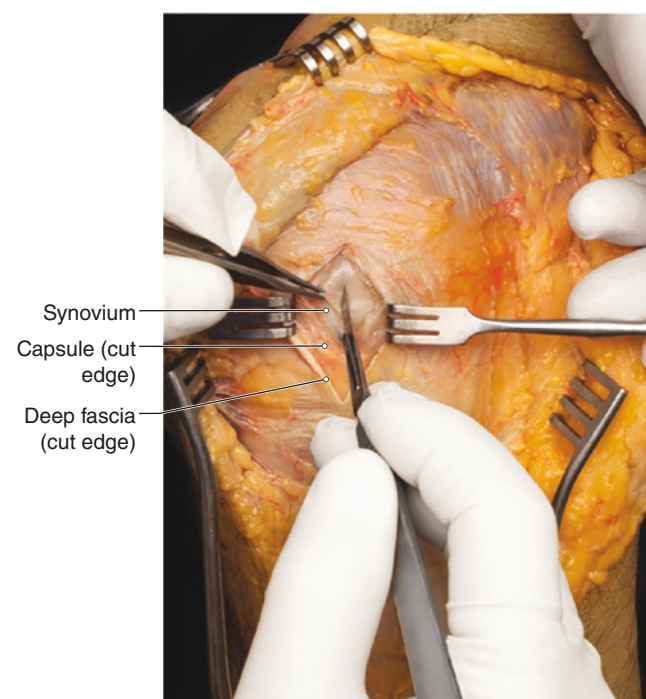


Fig. 11.3 Incise the synovium

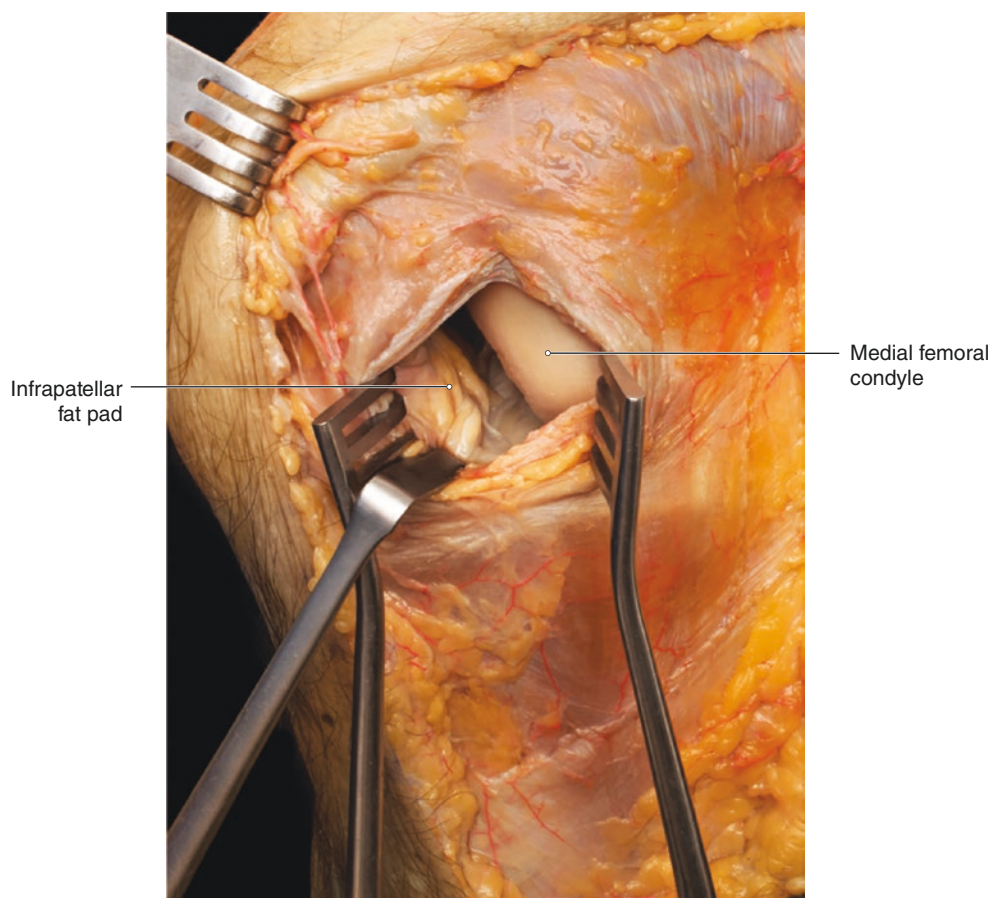


Fig. 11.4 The anterior medial joint has been exposed

11.2 Posteromedial Arthrotomy and Technique

Position the knee at 90° flexion. Incise the skin and subcutaneous fat and clear the tissues to expose the deep fascia (*see* Fig. 11.5). Palpate the medial epicondyle and adductor tubercle. There is a small indentation or saddle between these bony landmarks (*see* Fig. 11.6). Incise the capsule vertically starting at this groove and extend the incision distally to almost the joint line. The capsule at the junction of the mid-third and posterior third medial capsule is thin. This junction is just posterior to the tibial collateral ligament (*see* Fig. 11.7). Spread the fat to clear the posteromedial capsule (*see* Fig. 11.8). Be sure you are under the deep fascia. Otherwise, you risk cutting the saphenous nerve (*refer to* Chap. 1). Incise the posteromedial capsule (*see* Fig. 11.9) to expose the posteromedial knee joint (*see* Fig. 11.10).

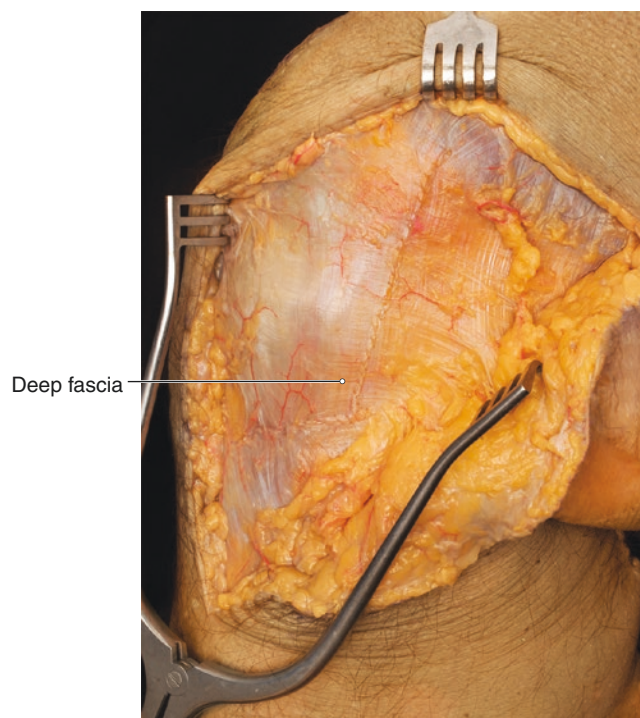


Fig. 11.5 The skin and subcutaneous tissues on the medial side of the knee have been cleared widely from the underlying deep fascia for demonstration

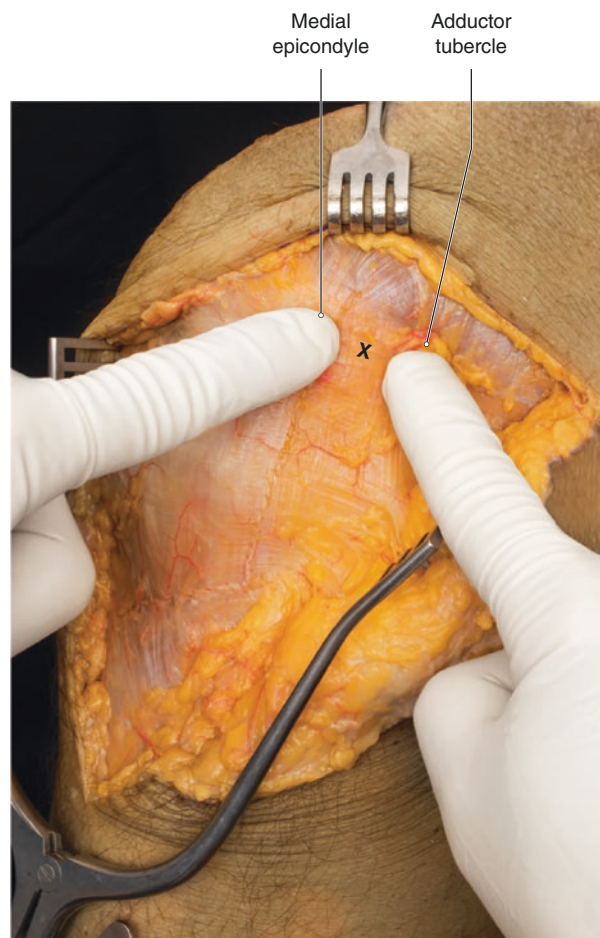


Fig. 11.6 Palpate the medial epicondyle (left) and adductor tubercle (right). There is a small indentation or saddle between these bony landmarks (X)

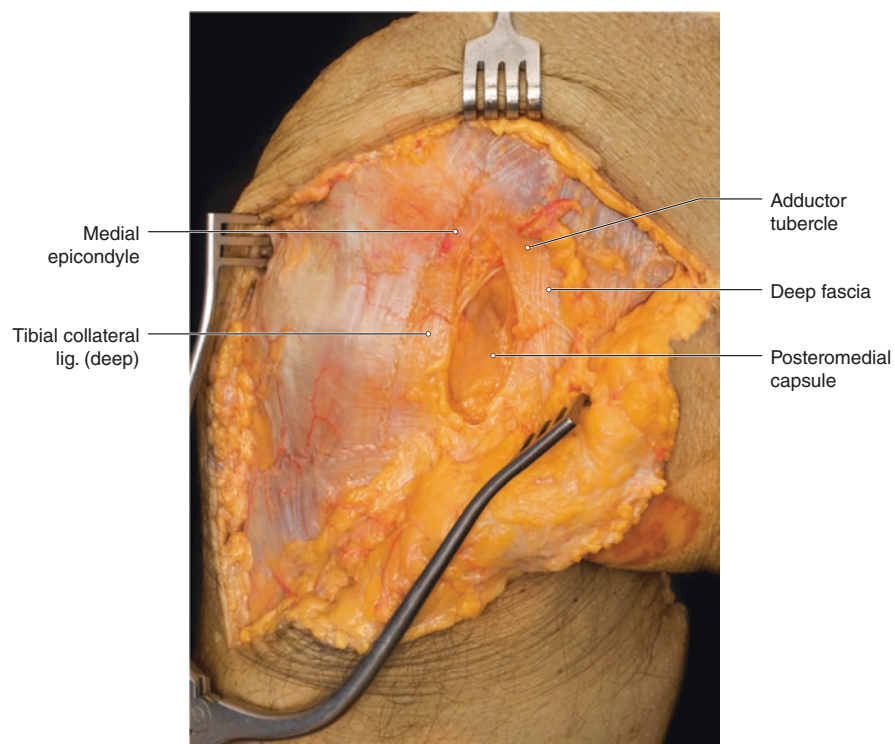


Fig. 11.7 Make a vertical capsular incision in the deep fascia posterior to the tibial collateral ligament to expose the posteromedial capsule

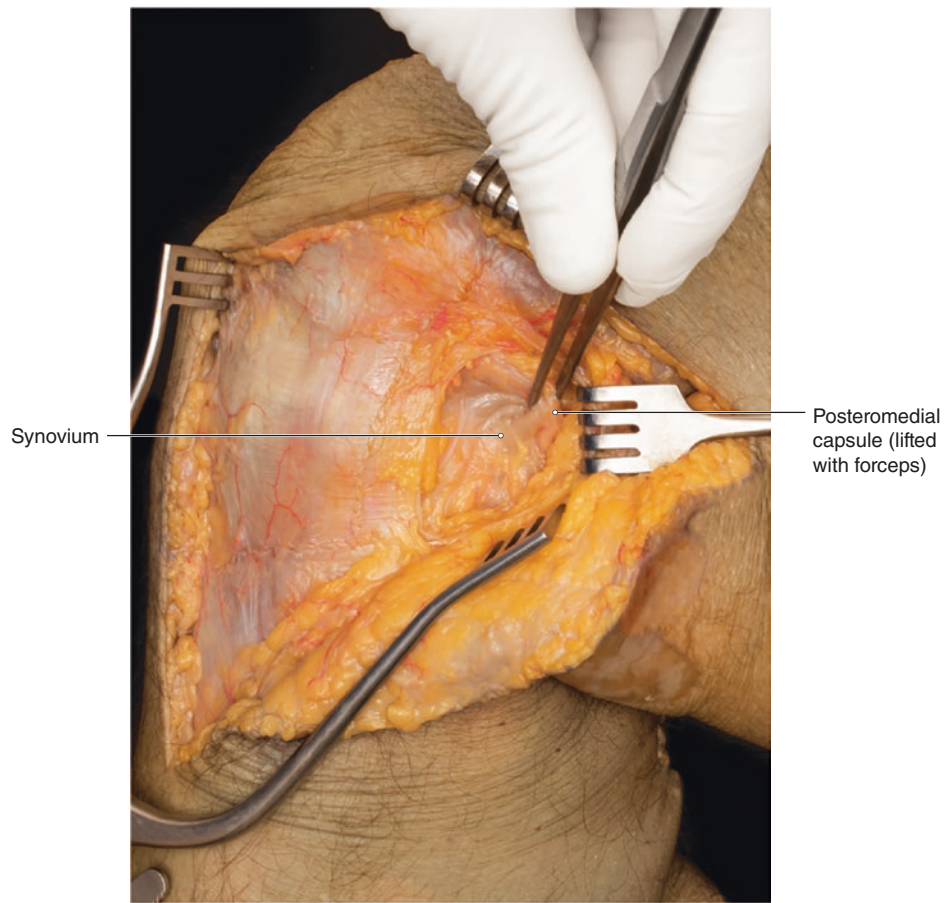


Fig. 11.8 Dissect the posteromedial capsule free from the adjacent fat

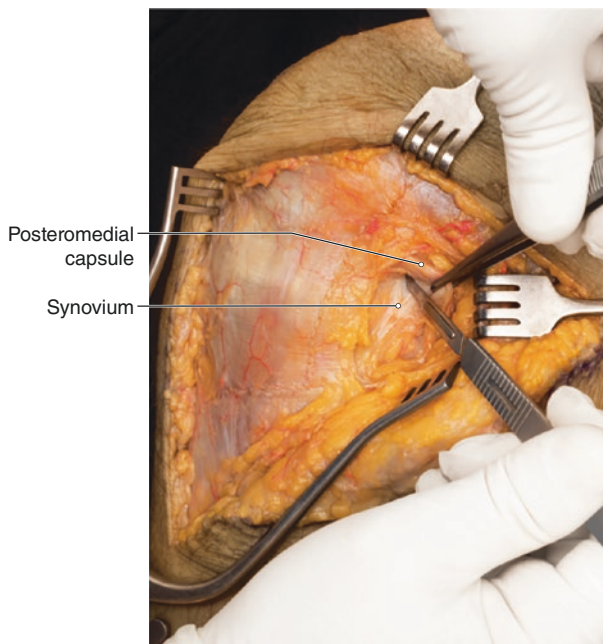


Fig. 11.9 Incise the posteromedial capsule

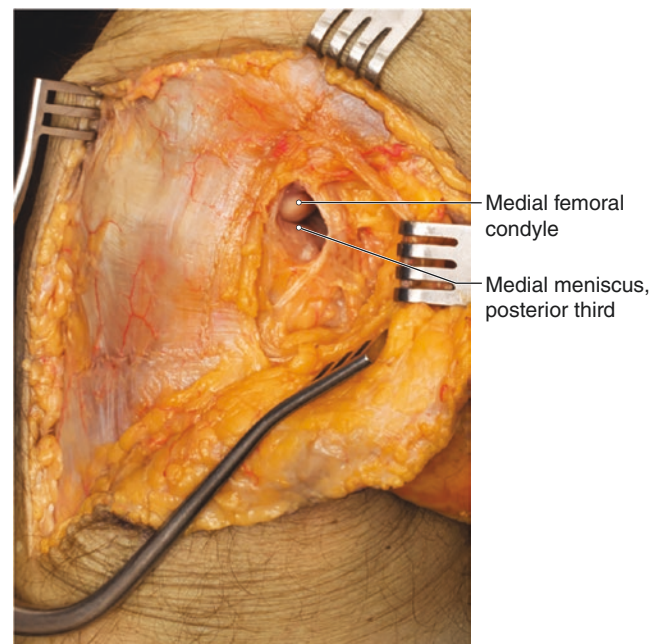


Fig. 11.10 The posteromedial arthrotomy has been completed exposing the posterior surface of the medial femoral condyle and the posterior third of the medial meniscus

11.3 Medial Knee Utility Exposure and Technique

To expose the medial aspect of the knee, such as to address the medial collateral ligament, the following medial utility approach can be used:

Position the knee at 45° flexion. Dissect through the subcutaneous tissues down to the deep fascia (*see* Fig. 11.11). Palpate the medial epicondyle for a reference point fascia (*see* Fig. 11.12). Expose the deep fascia (*see* Fig. 11.13). Incise the deep fascia in the midline to expose the medial collateral ligament (*see* Fig. 11.14).

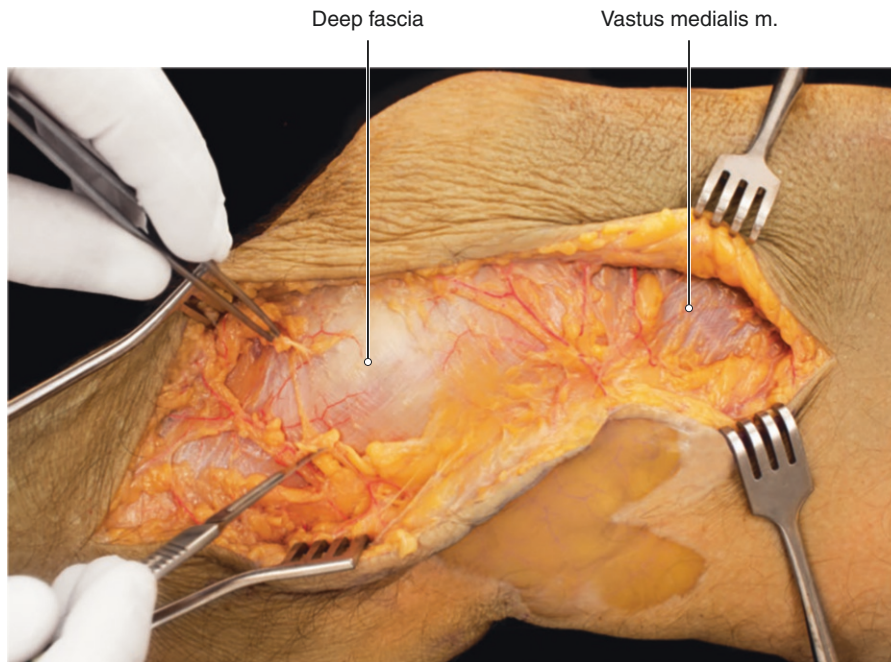


Fig. 11.11 With the knee at 45° flexion, cut the skin and fat down to the deep fascia

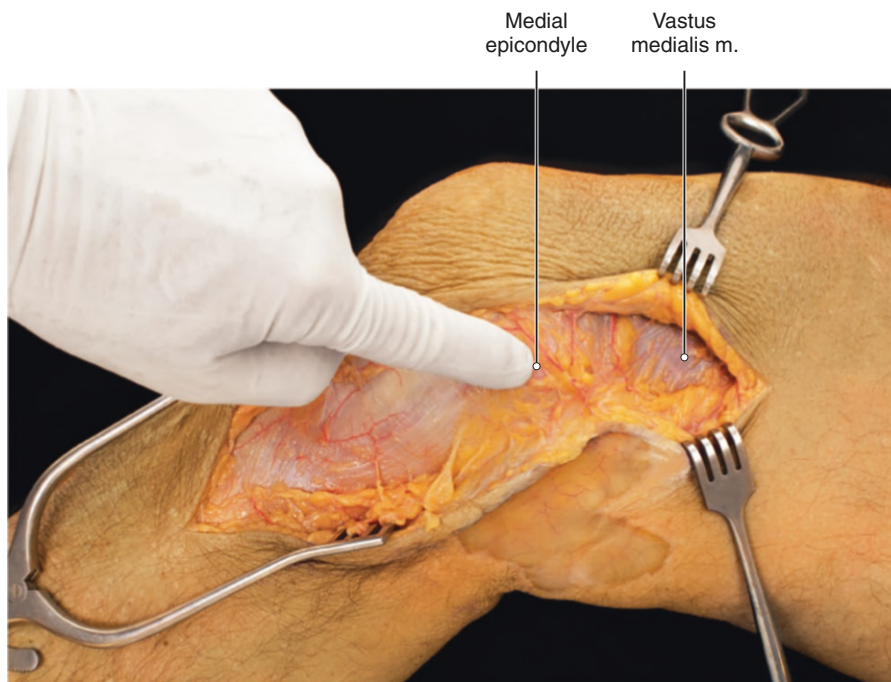


Fig. 11.12 Palpate the medial epicondyle for a reference point

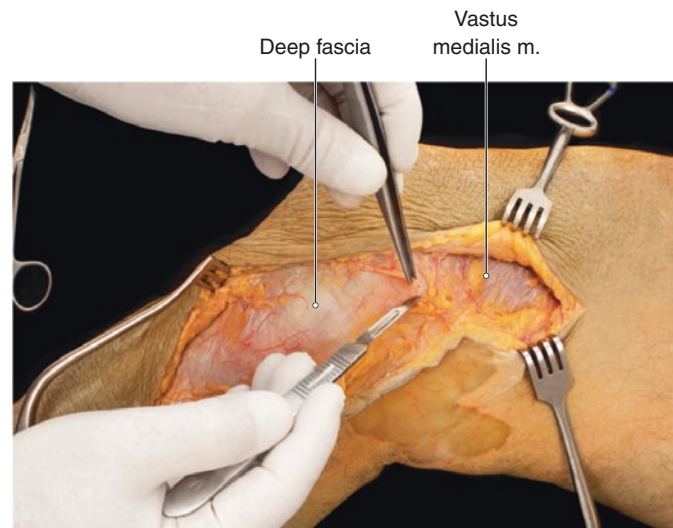


Fig. 11.13 Clear the subcutaneous tissues to expose the deep fascia

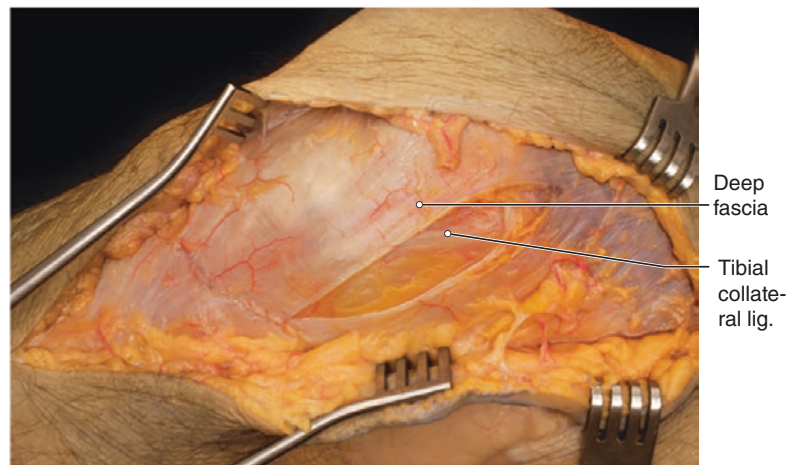


Fig. 11.14 Incise the deep fascia in the midline, exposing the medial collateral ligament

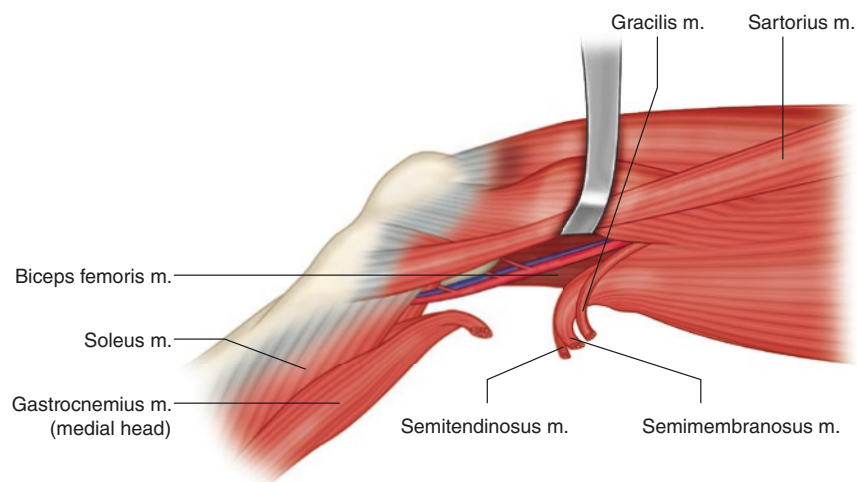


Fig. 11.15 The semimembranosus, semitendinosus, and gracilis tendons are divided. The sartorius muscle is left intact and retracted anteriorly. The tendon of the medial head of the gastrocnemius muscle is

divided and retracted posteriorly to expose the popliteal artery and vein which lie deep within the popliteal fossa

11.4 Posteromedial Vascular Approach to Popliteal Artery

The semimembranosus, semitendinosus, and gracilis tendons are divided. The sartorius muscle is left intact and retracted anteriorly. The tendon of the medial head of the gastrocnemius muscle is divided and retracted posteriorly to expose the popliteal artery and vein which lie deep within the popliteal fossa (see Fig. 11.15).

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Lateral Knee Exposures

12

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12.1 Introduction

The *iliotibial tract* is a thick fibrous structure on the lateral aspect of the knee that must be dealt with when exposing the joint. It is usually split lengthwise to gain access (*refer to Chap. 7*).

The *bony landmarks* that can be palpated on the lateral aspect of the knee form a triangle. They are the *lateral epicondyle*, *fibular head*, and *Gerdy's tubercle* (*see Fig. 12.1*).

The lateral utility exposure will be described first since it can lead to several other lateral knee exposures.

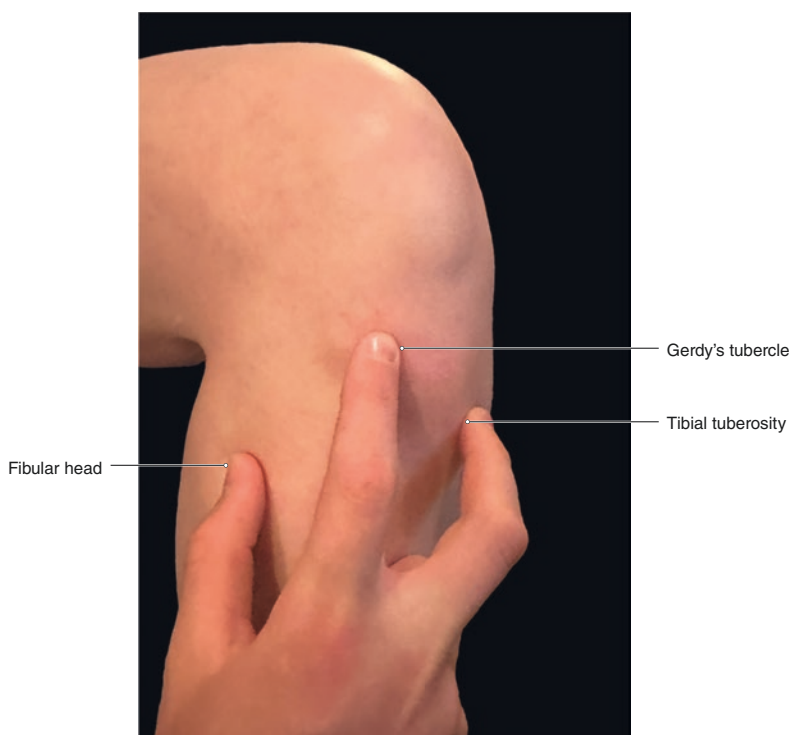


Fig. 12.1 Three bony landmarks that can be palpated on the lateral aspect of the right knee form a triangle: *fibular head*, *tibial tuberosity*, and *Gerdy's tubercle*

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12.2 Lateral Utility Exposure

12.2.1 Technique

Incise the skin and superficial fascia lengthwise on the lateral aspect of the knee (see Fig. 12.2). Lift the skin to stretch out the loose subcutaneous connective tissue (see Fig. 1.2). Use blunt dissection to create a wide subcutaneous plane through the areolar tissue to expose the deep fascia (fascia lata) (see Fig. 12.3). Locate the posterior edge of the iliotibial tract. This marks the lengthwise attachment of the lateral intermuscular septum to the iliotibial tract (see Fig. 12.4). Palpate



Fig. 12.2 The skin incision on lateral aspect of the knee is done with knee in flexion

the common peroneal nerve just distal to the fibular head (see Fig. 12.5). Cut and retract the thin posterolateral deep fascia that covers the short head of the biceps femoris muscle and the biceps femoris tendon (see Fig. 12.6). Working posterior to the biceps femoris tendon near its insertion, make a small opening into the deep fascia and introduce an instrument to create space (see Fig. 12.7). Carefully incise the deep fascia, taking care to protect the peroneal nerve (see Fig. 12.8). This exposes the peroneal nerve (see Figs. 12.9 and 12.10). Palpate the fibular collateral ligament that goes from the lateral epicondyle to the fibular head (see Fig. 12.11). Incise the deep fascia just above the biceps tendon at its insertion to expose the fibular collateral ligament (see Fig. 12.12). Pass an instrument under the deep fascia toward the lateral epicondyle (see Fig. 12.13). Incise the iliotibial tract at the tip of the instrument (see Fig. 12.14).

An easier, albeit less precise, way to find the lateral epicondyle is by palpation (see Fig. 12.15).

Make a longitudinal incision in the iliotibial tract and retract the edges. Retract the vastus lateralis muscle anteriorly. The lateral intermuscular septum attaches lengthwise to the posterior edge of the iliotibial tract (see Figs. 12.4 and 12.16). The arterial supply to the vastus lateralis muscle vasculature comes from branches of the superior lateral genicular artery (see Fig. 12.17) [refer to Chap. 7].

To locate where to incise the mid-lateral capsule, palpate the lateral epicondyle as a reference point (see Fig. 12.18). The origin of the popliteus tendon on the femur is just distal to the lateral epicondyle.

With the knee at 90° flexion make a vertical incision in the lateral capsule. Start in the middle, not the upper or lower end of the incision. The upper end of the incision should be distal to the lateral epicondyle. Take care at the upper end of the incision because of the underlying *popliteus tendon* origin. Extend the capsulotomy distally toward the joint line. Take care at the distal end of the incision because of the *lateral inferior genicular artery*. Securely ligate the lateral inferior genicular artery if it is to be cut (see Fig. 12.19). Retract the edges of the capsule to expose the joint (see Fig. 12.20).

Flex the hip to 90° and the knee to 90° and applying maximal external rotation to the hip to open the *lateral joint space*.

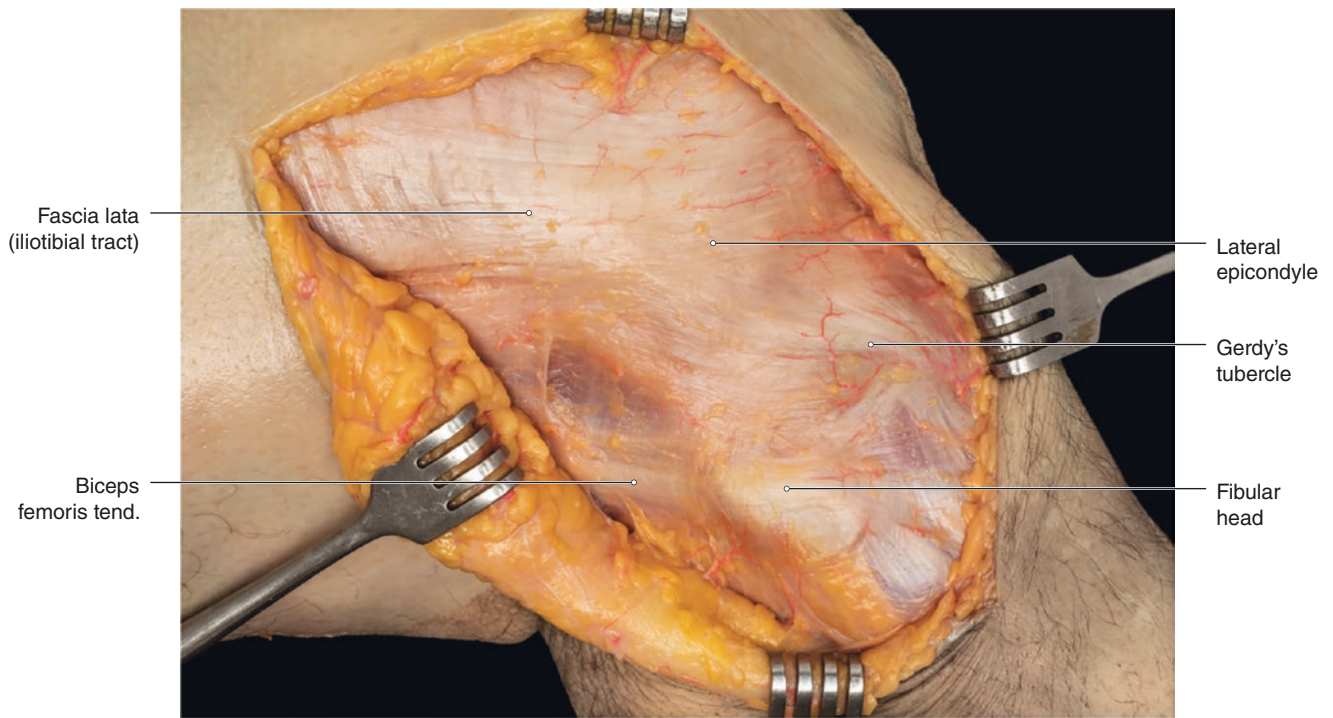


Fig. 12.3 Right knee. Expose the deep fascial layer on the lateral side

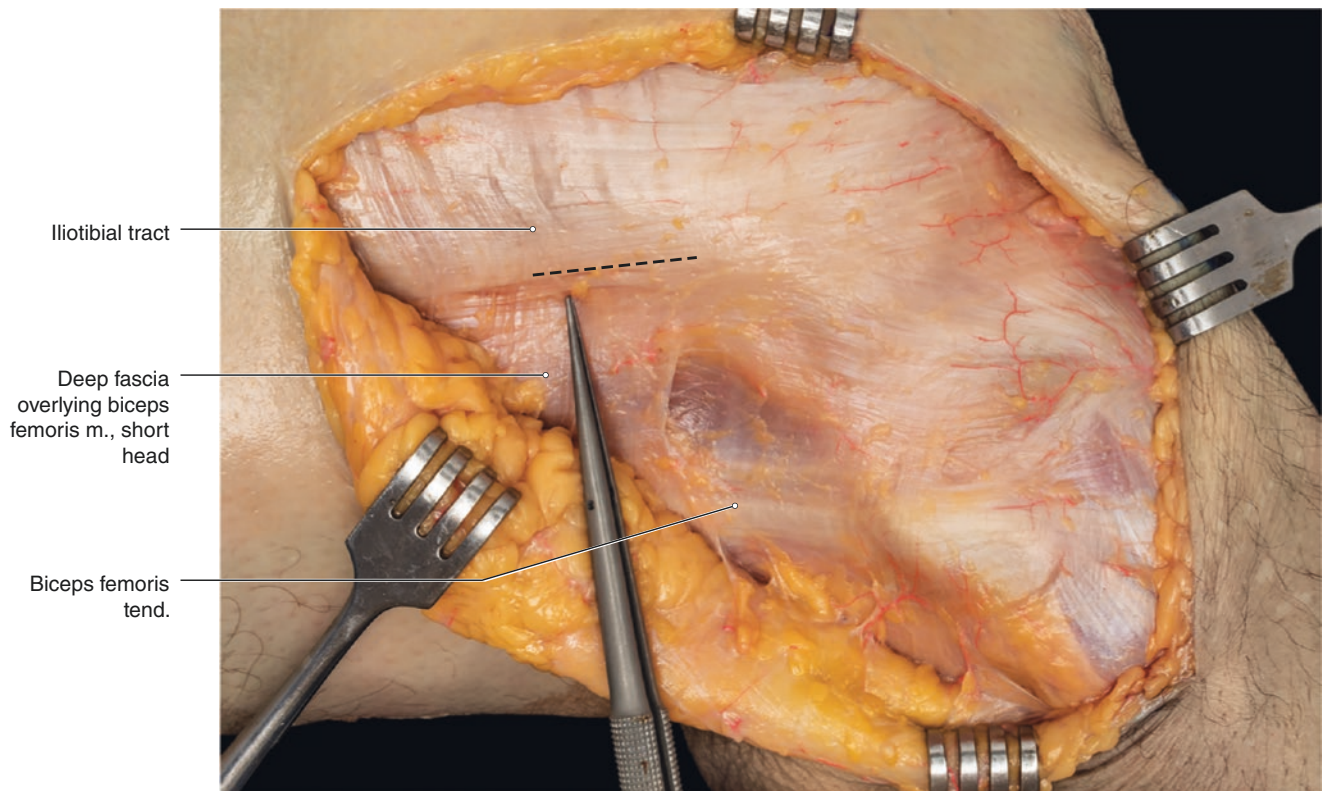


Fig. 12.4 Locate the posterior edge of the iliotibial tract (tip of instrument). The lateral intermuscular septum attaches to the fascia lata at this level (dotted line)



Fig. 12.5 Palpate the common peroneal nerve

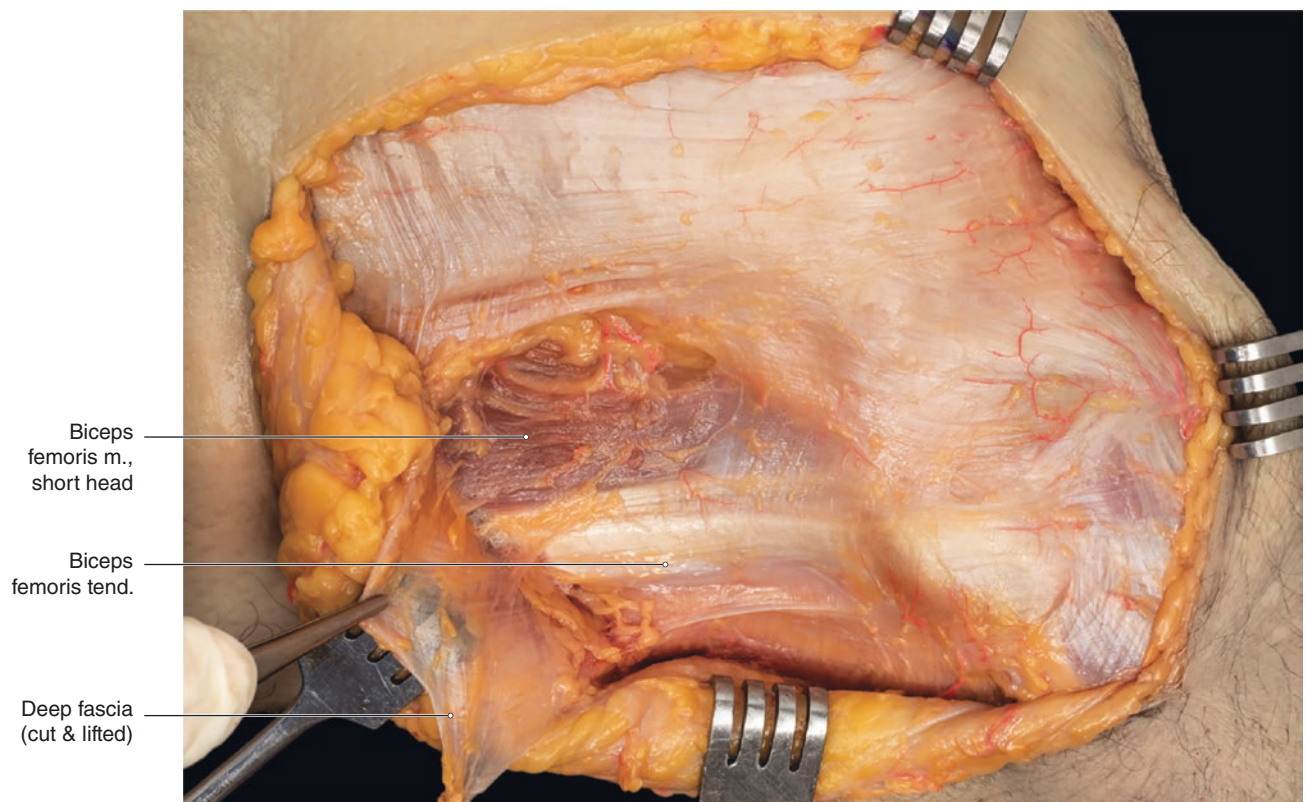


Fig. 12.6 Cut the thin posterolateral deep fascia and lift it to expose the underlying biceps femoris tendon and short head of biceps femoris muscle

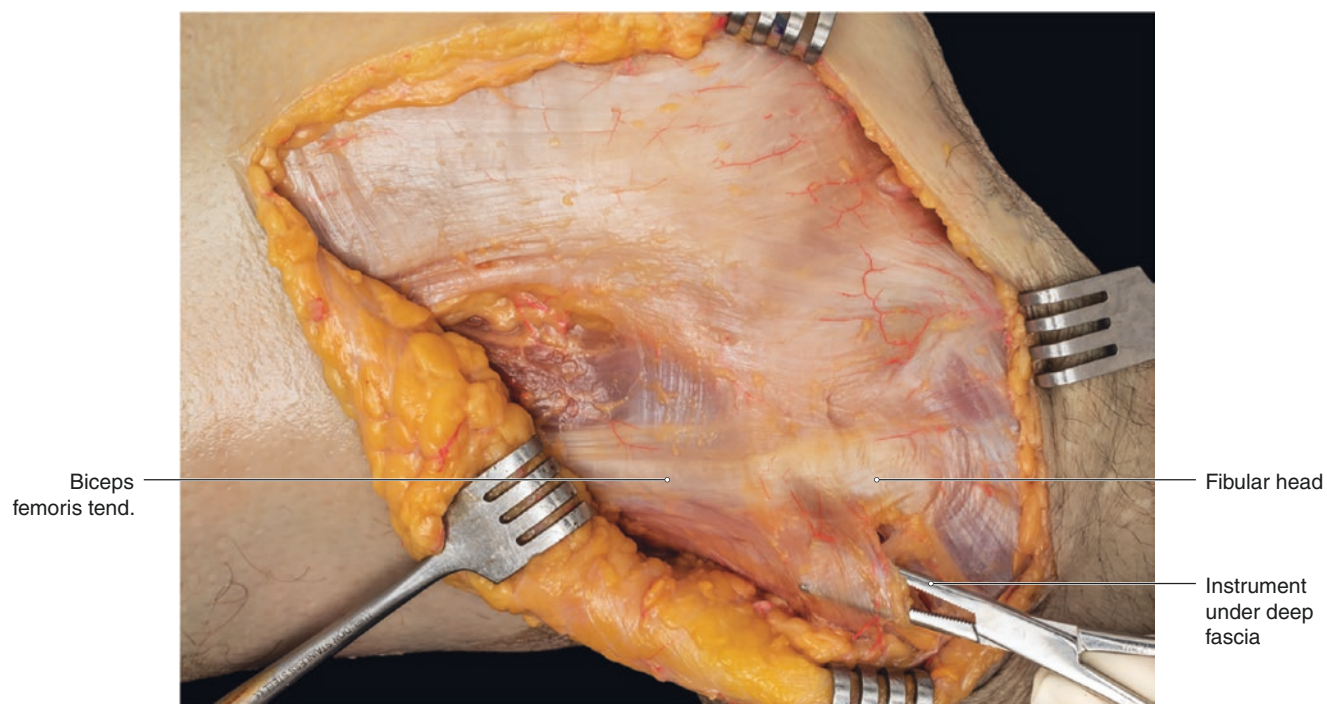


Fig. 12.7 Introduce an instrument under the deep fascia posterior to the biceps femoris tendon

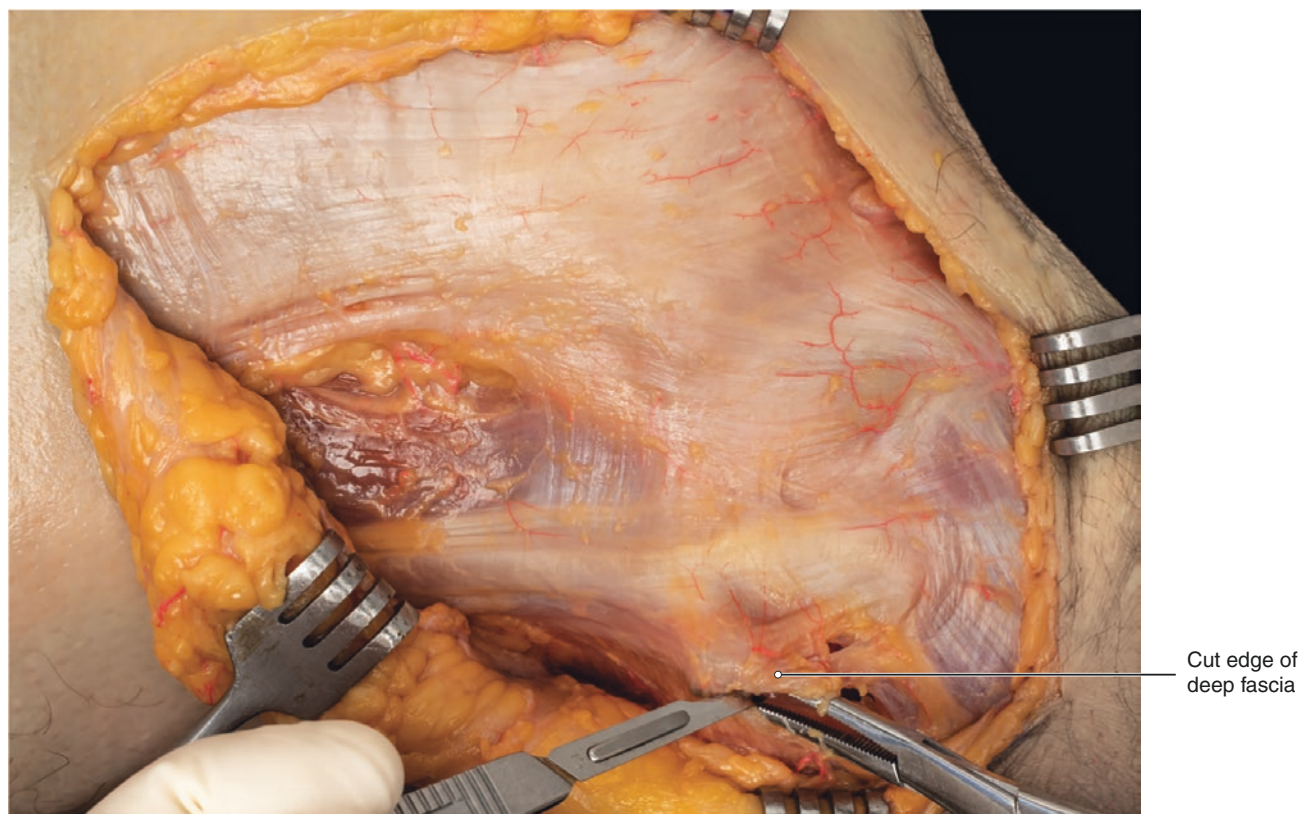


Fig. 12.8 Protect the common peroneal nerve with an instrument. Cut the overlying deep fascia

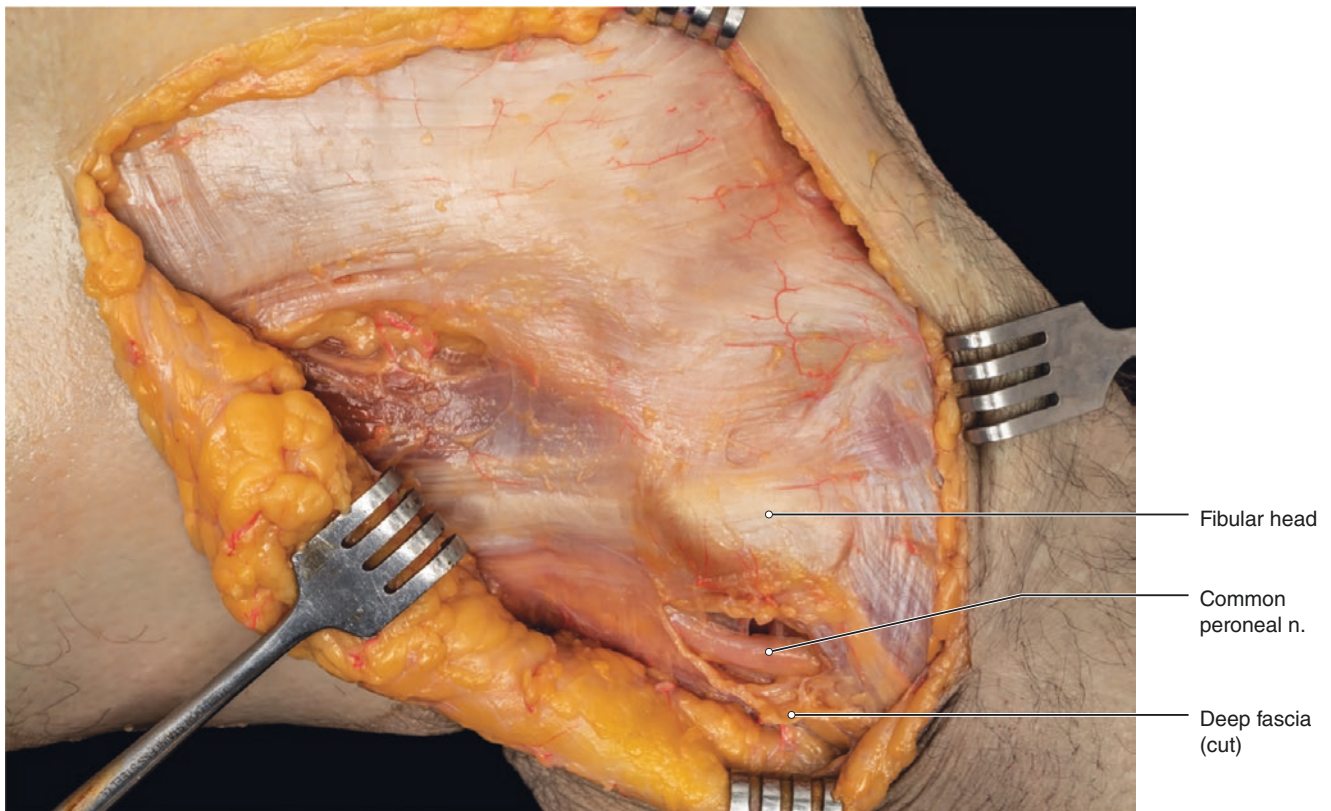


Fig. 12.9 Incise the deep fascia to expose the common peroneal nerve

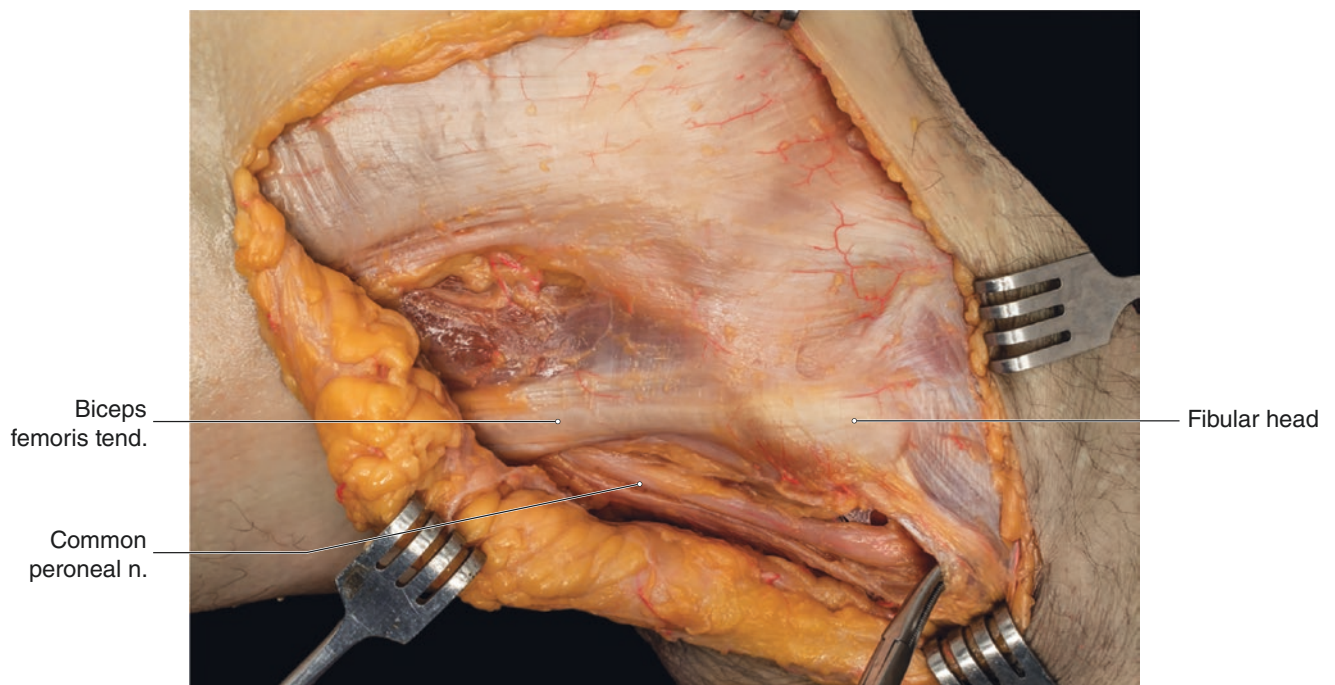


Fig. 12.10 Extend the incision in the deep fascia along the posterior border of the biceps femoris tendon to further expose the common peroneal nerve

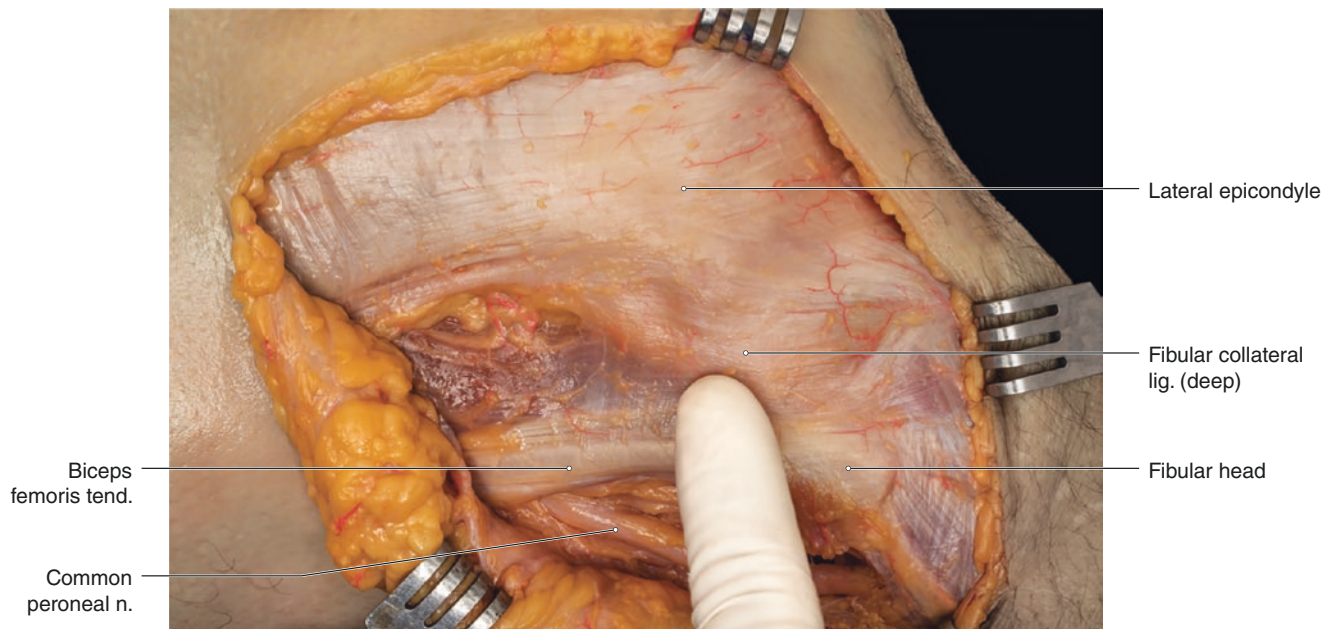


Fig. 12.11 Palpate the fibular collateral ligament

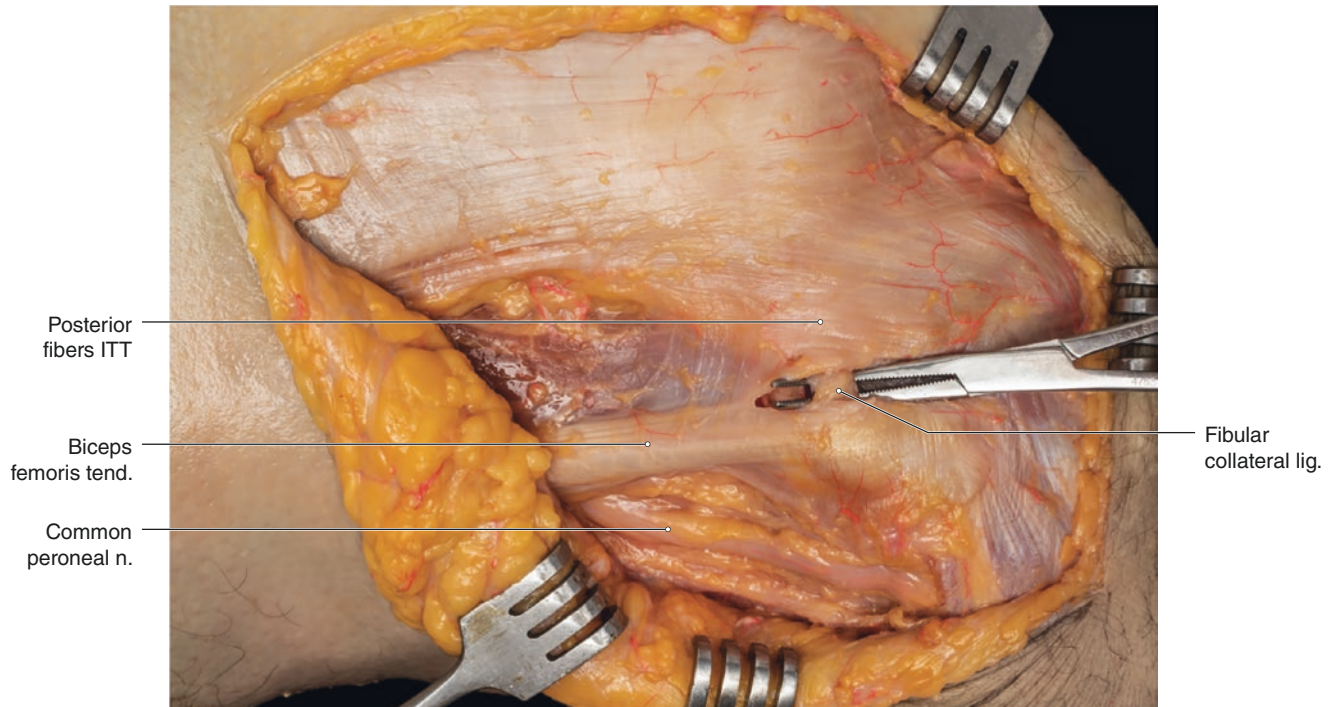


Fig. 12.12 Incise the deep fascia at the posterior edge of the iliotibial tract (ITT). Pass a curved instrument under the fibular collateral ligament



Fig. 12.13 Pass a curved instrument under the deep fascia toward the lateral epicondyle

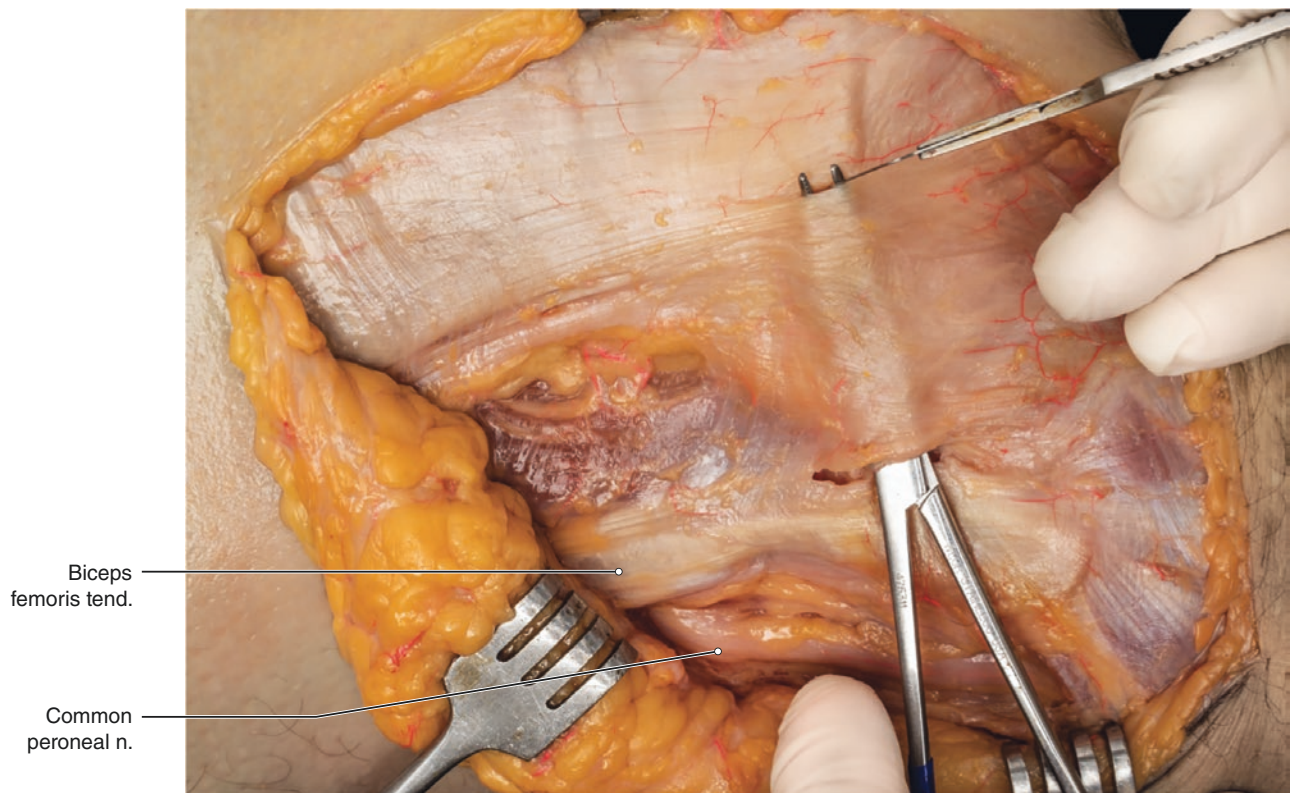


Fig. 12.14 Incise the iliotibial tract at the tip of the instrument

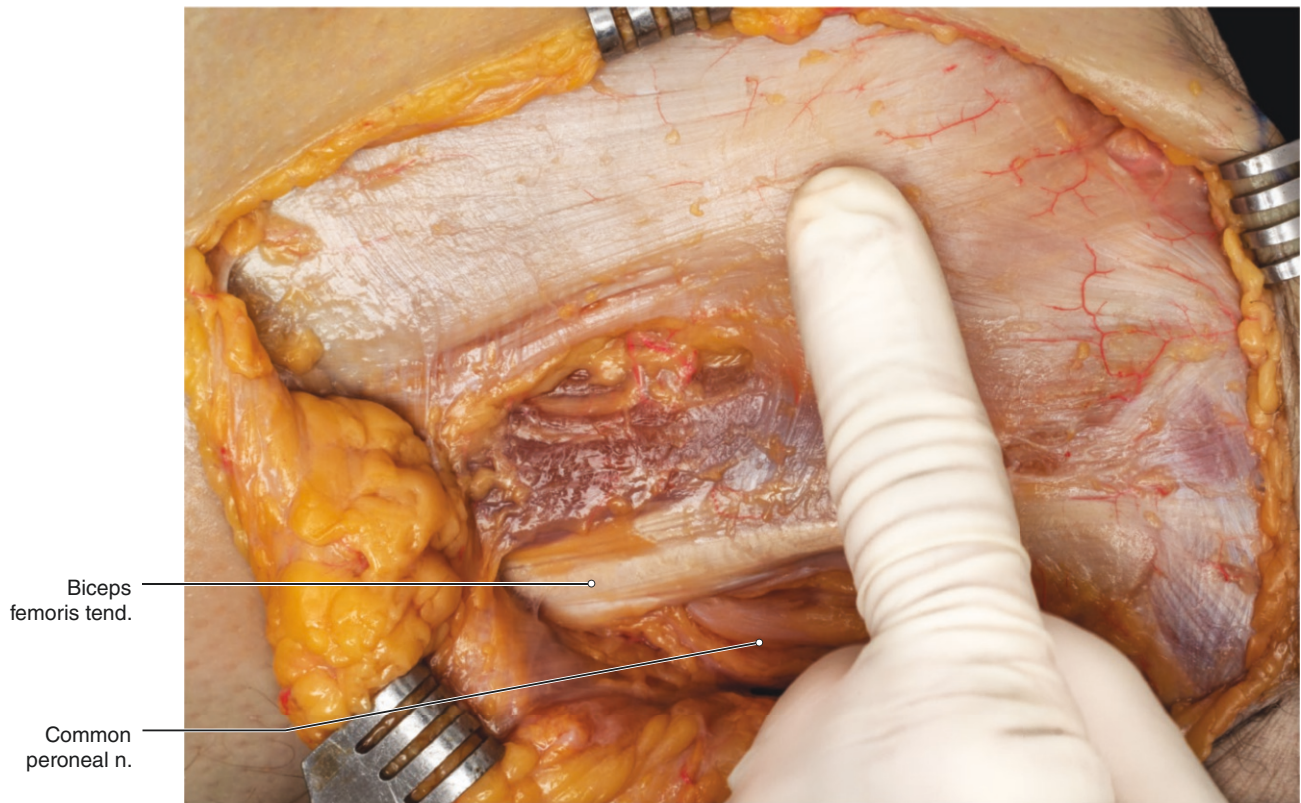


Fig. 12.15 An easier, albeit less precise, way to find the lateral epicondyle by palpation

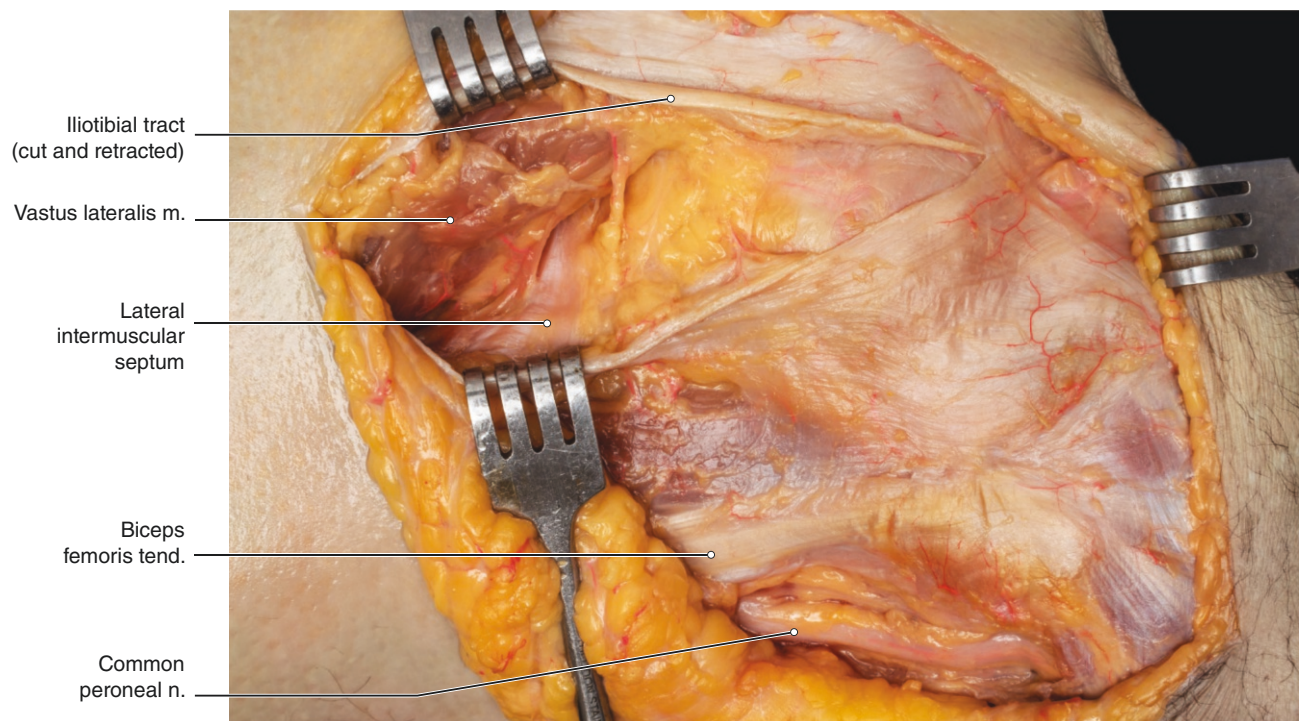


Fig. 12.16 Incise the iliotibial tract and retract the edges to expose the vastus lateralis muscle (anteriorly) and the anterior surface of the lateral intermuscular septum (posteriorly)

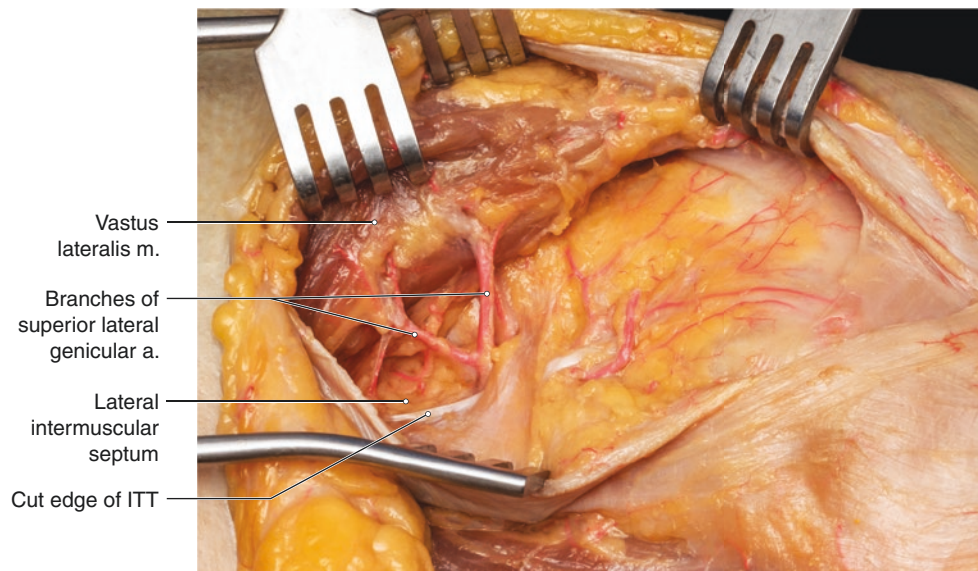


Fig. 12.17 The blood supply to the vastus lateralis muscle comes from branches of the superior lateral genicular artery

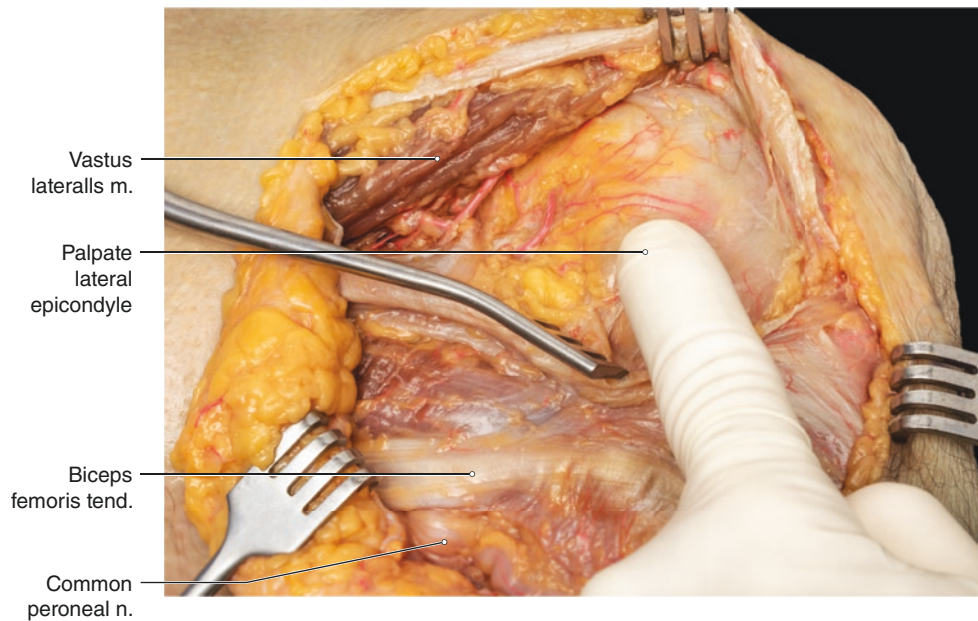


Fig. 12.18 Palpate the lateral epicondyle to find a reference point for incising the lateral capsule

12.2.2 Mid-Third Lateral Arthrotomy and Technique

The lateral knee can be approached with a mid-third lateral arthrotomy [1]. The ITB is split in line with its fibers. The lateral capsule is incised lengthwise anterior and parallel to the FCL (*see* Figs. 12.19 and 12.20).

The popliteus tendon origin is located slightly distal to the lateral femoral epicondyle. This puts it at the upper end of

the capsular incision. Start the incision in the mid capsule to avoid cutting it. Then extend the arthrotomy in both directions.

The lateral inferior genicular artery runs along the periphery of the lateral malleolus. This puts it at risk at the lower end of the arthrotomy. The lateral inferior geniculate artery should be double suture-ligated if cut.

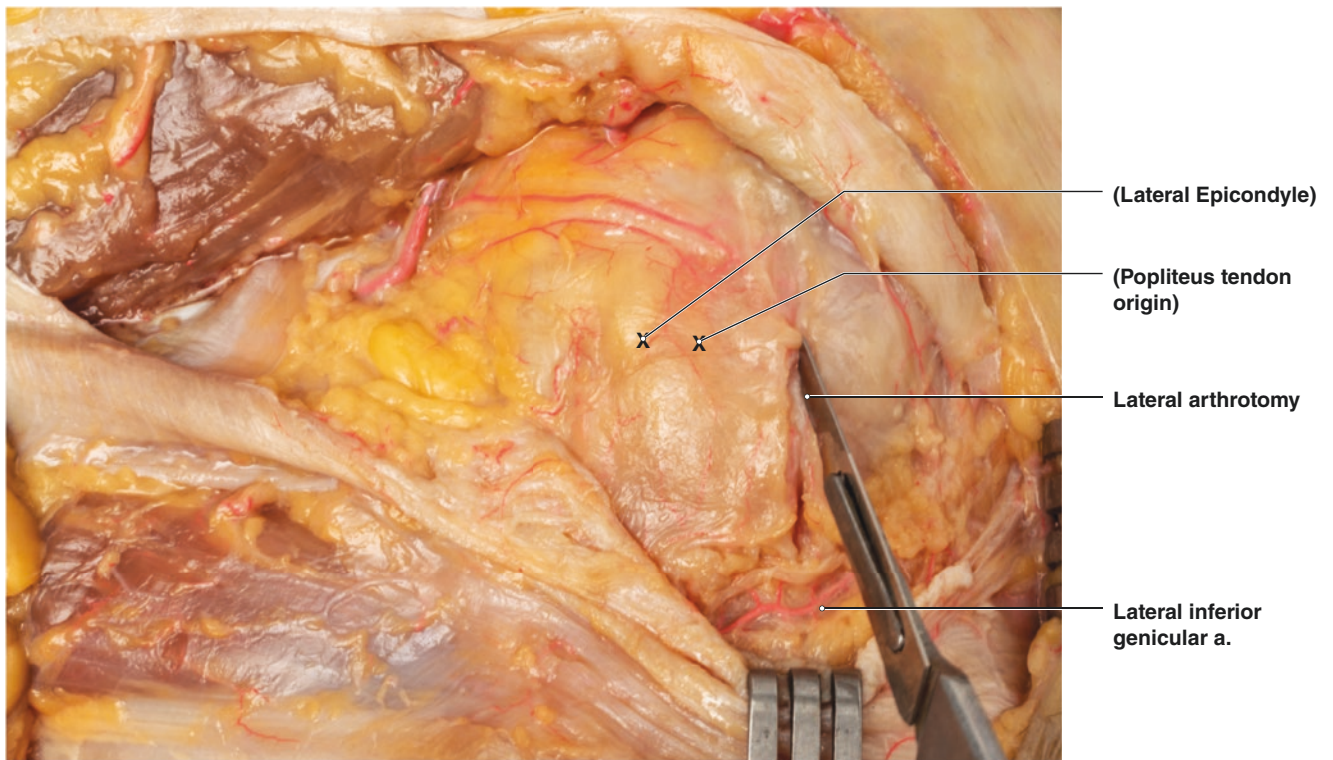


Fig. 12.19 With the knee at 90° flexion make a vertical incision in the capsule. The upper end of the capsulotomy is located distal to the lateral epicondyle. Care must be taken at the upper end of the incision because

of the underlying *popliteus tendon*. Care must be taken at the distal end of the incision because of the *lateral inferior genicular artery*

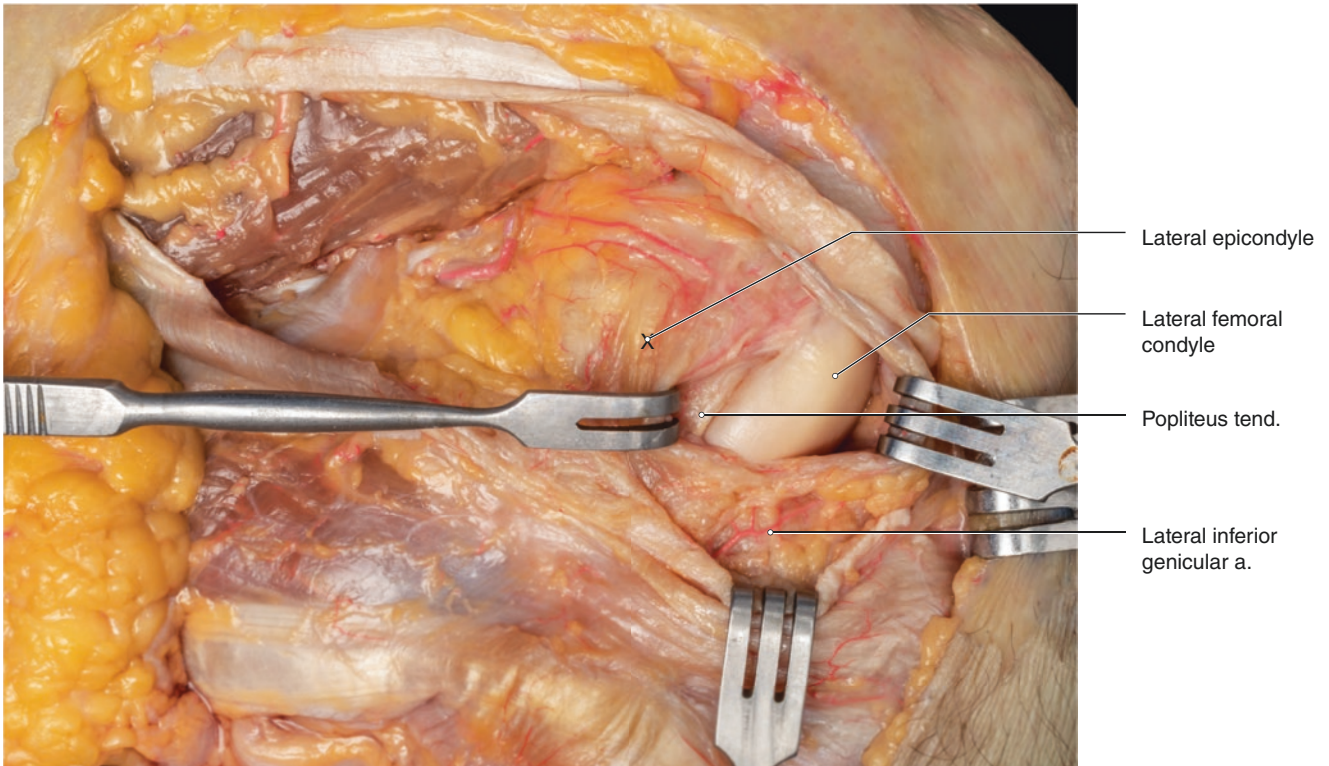


Fig. 12.20 Retract the capsule posteriorly. Note the popliteus tendon

12.3 Posterolateral Arthrotomy and Technique

Locate the posterior border of the iliotibial tract. The lateral intermuscular septum attaches to the iliotibial tract at this level (*see* Fig. 12.4). Palpate the posterior contour of the lateral femoral condyle (*see* Fig. 12.21). Incise the fascia lata behind the posterior edge of the iliotibial tract.

This will place you in the posterior thigh compartment, i.e., posterior to the lateral intermuscular septum (*see* Fig. 12.22). Lift the vastus lateralis muscle and carefully dissect under it to expose the superior lateral genicular artery (*see* Fig. 12.23).

Retract the plantaris muscle and expose the posterolateral capsule (*see* Fig. 12.24). Incise the posterolateral capsule (*see* Fig. 12.25).

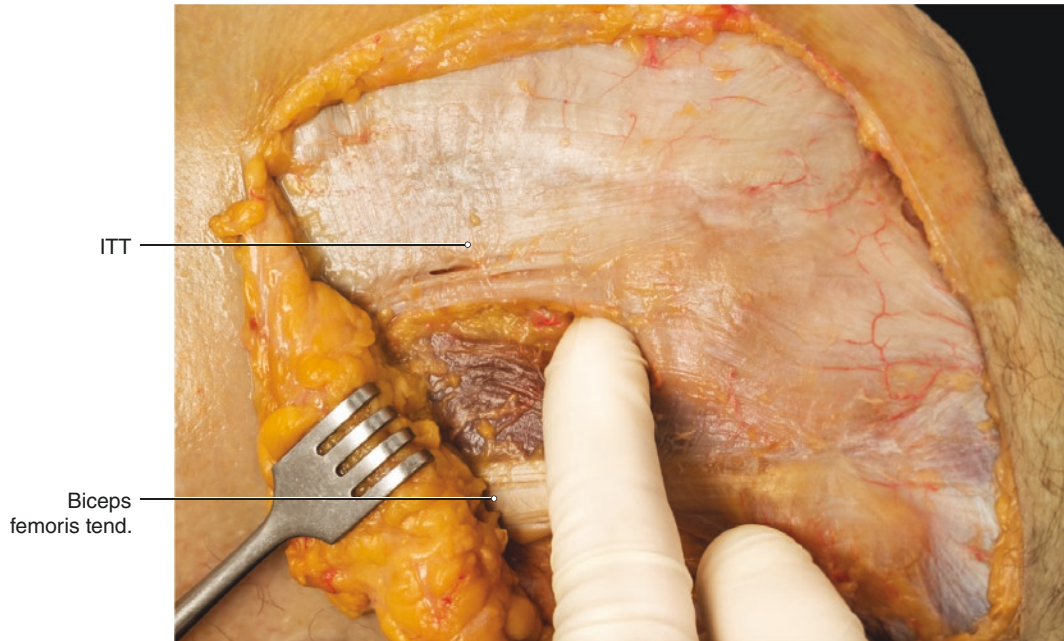


Fig. 12.21 Palpate the posterior contour of the lateral femoral condyle

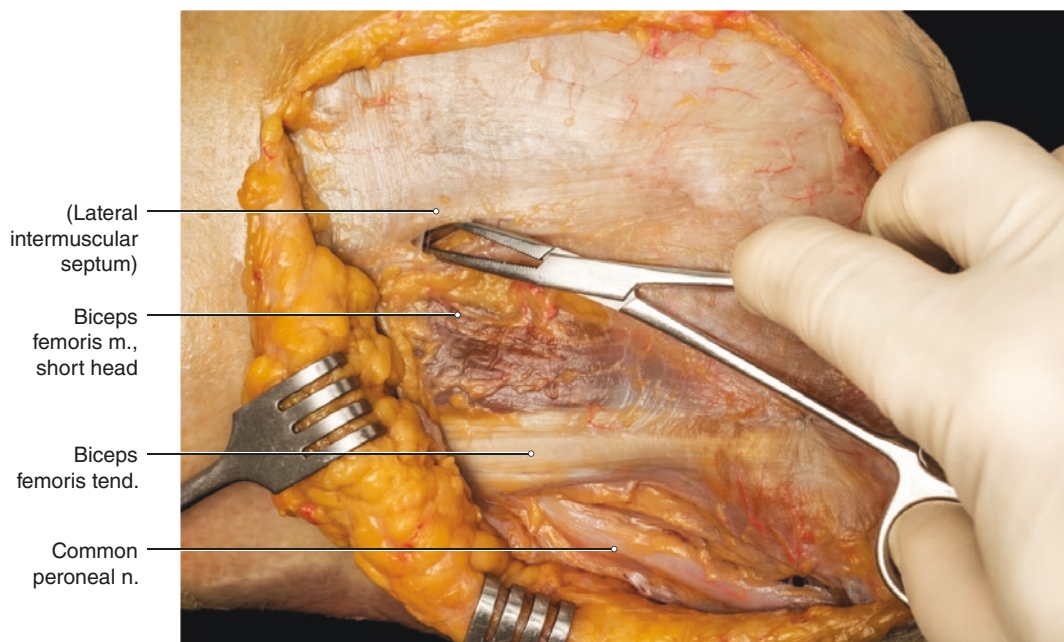


Fig. 12.22 Spread the fascia lata with an instrument posterior to the lateral intermuscular septum

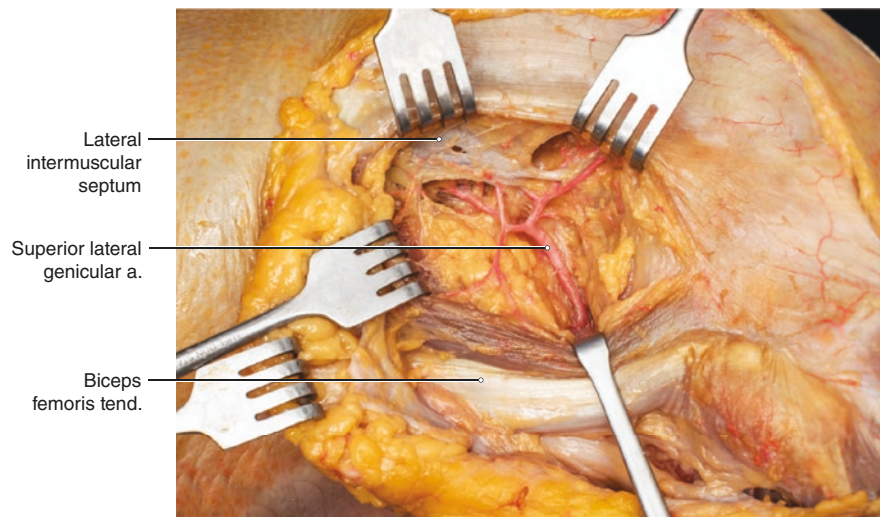


Fig. 12.23 Retract the vastus lateralis muscle to expose the superior lateral genicular artery. *Note the branch of superior lateral genicular artery that pierces the lateral intermuscular septum to enter the anterior thigh compartment.* When dissecting anterior to the intermuscular

septum, it is critical to double suture ligate this artery. Otherwise, the cut artery retracts below the septum into the posterior compartment and becomes virtually impossible to find and control

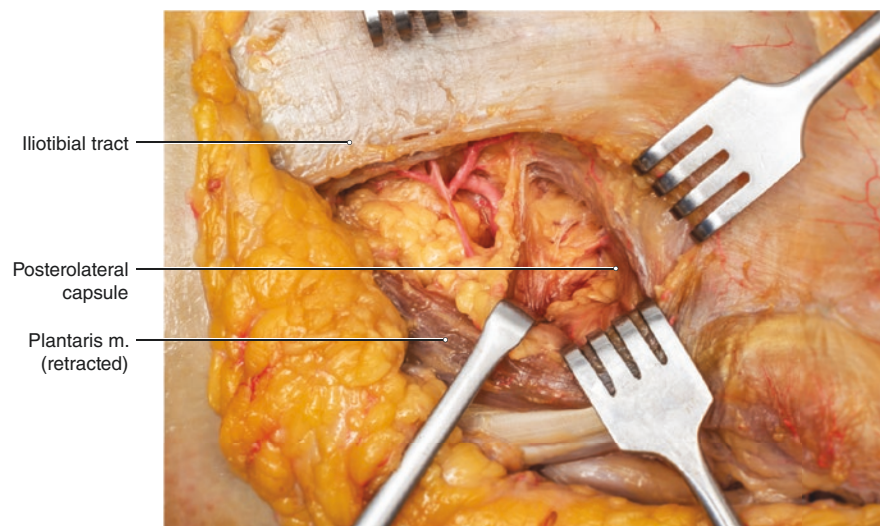


Fig. 12.24 Retract the plantaris muscle to expose the posterolateral capsule

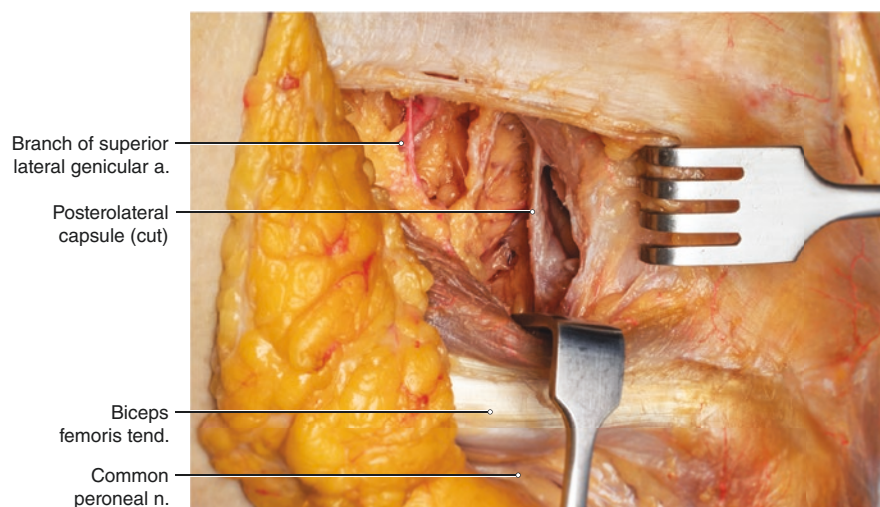


Fig. 12.25 The posterolateral capsule has been incised

12.4 Lateral Parapatellar Arthrotomy

The lateral parapatellar arthrotomy approach is almost a mirror image of the medial approach (*refer to Chap. 11*).

12.4.1 Technique

Incise the deep fascia, capsule and synovium close to patella, leaving enough strong capsular tissue along the lateral edge of the patella for closure. The incision can be extended proximally through the lateral edge of quadriceps tendon, and distally to top of tibia. Be aware of the lateral superior genicular artery.

Important Note on Lateral Retinacular Release

If a lateral release is performed, the knee remains swollen for a long period of time due to synovial fluid extravasation [1, 2]. Medial patellar subluxation is a frequent complication off lateral retinacular release [1, 3, 4].

To lengthen the lateral patellofemoral tissues, Z-lengthening achieves the same result as a complete release [5] with a quicker recovery and fewer complications [5, 6].

Z-Lengthening Technique

For the entire length of the patella, partially incise the deep fascia for a thickness of 2 millimeters. Make the incision close to the lateral edge of the patella. Using a sharp knife, skive within the fascia laterally for the distance of about 1 ½ cm, gradually cutting deeper. Laterally incise the capsule parallel to the first cut for the length of the patella. Leave the synovium intact. Suture the free edge to the deep fascia to the free edge of the cut capsule using interrupted 0-Vicryl or similar sutures.

12.5.1 Technique

Expose the fascia lata. Drill a hole in the center of Gerdy's tubercle that will later accept a 6- or 6-millimeter diameter screw (*see Fig. 12.26*). Make parallel longitudinal incisions in the iliotibial tract 1½ cm apart ending at Gerdy's tubercle (*see Fig. 12.27*). Mark three sides of a square centered on Gerdy's tubercle and cut the edges using an oscillating saw screw (*see Fig. 12.28*). Use a curved osteotome to divide the fourth wall (*see Fig. 12.29*). Lift Gerdy's tubercle together with the strip of iliotibial tract to expose the lateral knee capsule (*see Fig. 12.30*). The fibular collateral ligament can be exposed using this exposure (*see Fig. 12.31*). The exposure can be extended proximally to access the posterolateral capsule.

For closure, reposition the bone block and fix it with a screw and washer screw (*see Fig. 12.32*). Repair the edges of the iliotibial tract (*see Fig. 12.33*).

12.5.2 Exposure of Distal Lateral Femur and Technique

Make an incision in the distal lateral thigh 10 cm long parallel to the indentation between the biceps femoris tendon and the iliotibial tract (*see Fig. 12.34*). Expose the underlying deep fascia (iliotibial tract) (*see Fig. 12.35*). Incise the iliotibial tract just anterior to the lateral intermuscular septum (*see Fig. 12.36*). Retract the iliotibial tract to expose the vastus lateralis muscle (above) and the anterior surface of the lateral intermuscular septum (below) (*see Fig. 12.37*). Insert a retractor over the anterior surface of the distal femur to lift the vastus lateralis muscle out of the way (*see Fig. 12.38*). Securely ligate (do not use electrocautery) the branches of the lateral superior genicular artery that come through the lateral intermuscular septum from the posterior into the anterior thigh compartment (*see Fig. 12.39*).

12.5 Lateral Exposure with Osteotomy of Gerdy's Tubercle—(Cugat Technique)

To gain wide exposure of the lateral knee, a strip of iliotibial tract can be lifted together with a bone block taken from Gerdy's tubercle. This approach is useful to repair disruptions of the lateral ligament and popliteus tendon and to reconstruct the posterolateral corner of the knee.

Precautions

It is very important that the lateral superior genicular artery is ligated *anterior* to the lateral intermuscular septum. If the artery is disrupted without being tied off, it will retract behind the septum and be virtually impossible to control. The result will be an extensive hematoma to posterior thigh.

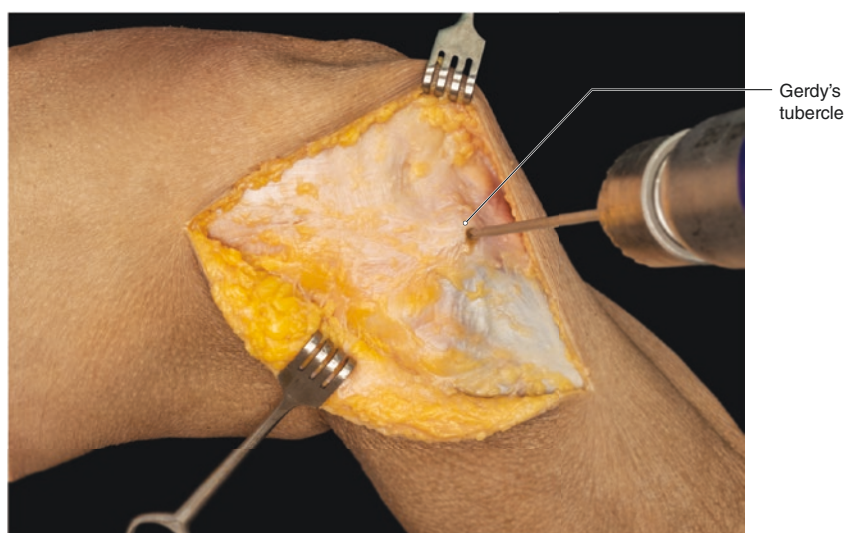


Fig. 12.26 Right knee. Drill a hole in the tibia at Gerdy's tubercle to later accept a screw

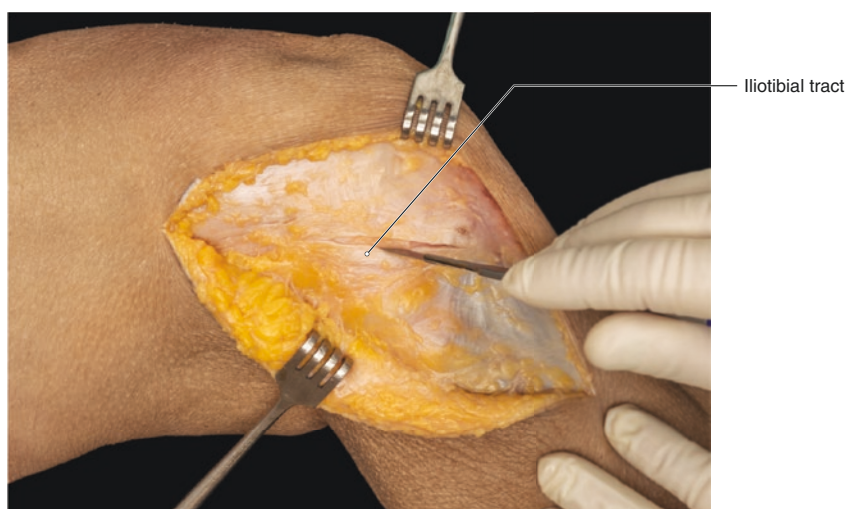


Fig. 12.27 Incise the iliotibial tract to create a 1 ½ cm-wide strip ending distally at Gerdy's tubercle

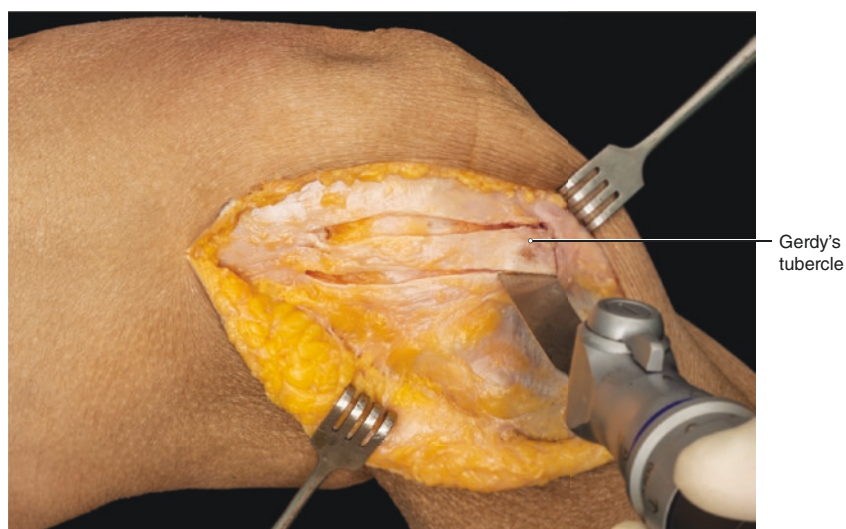


Fig. 12.28 Cut three edges of Gerdy's tubercle using a reciprocating saw

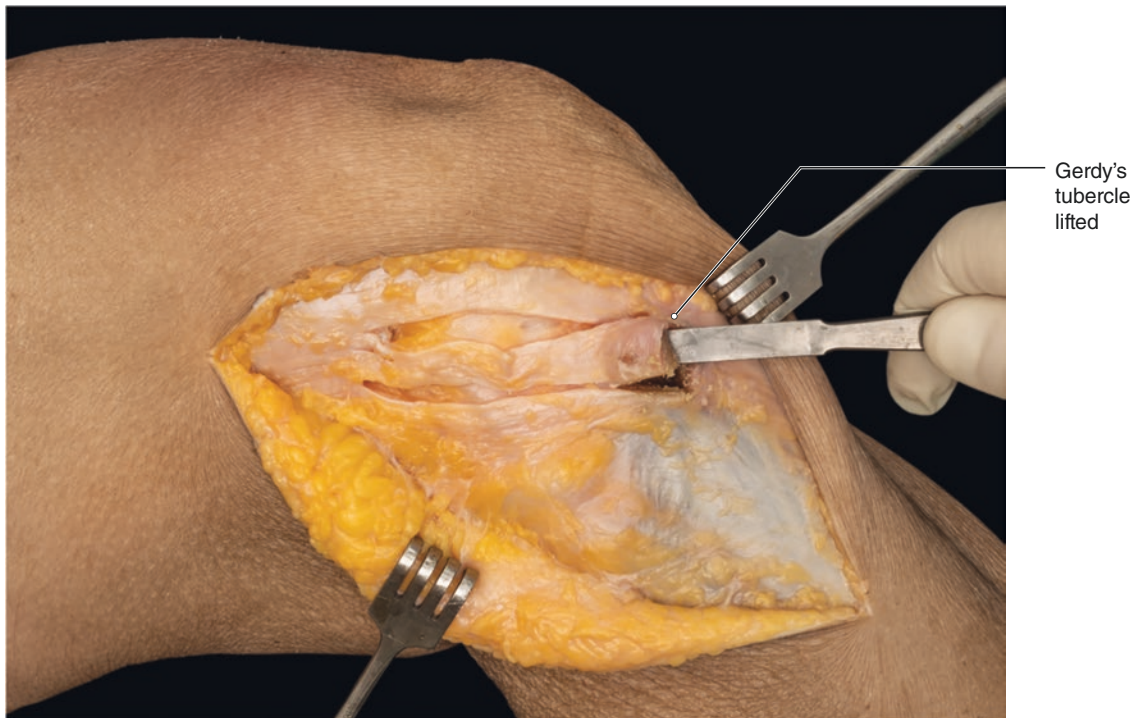


Fig. 12.29 Divide Gerdy's tubercle using an osteotome

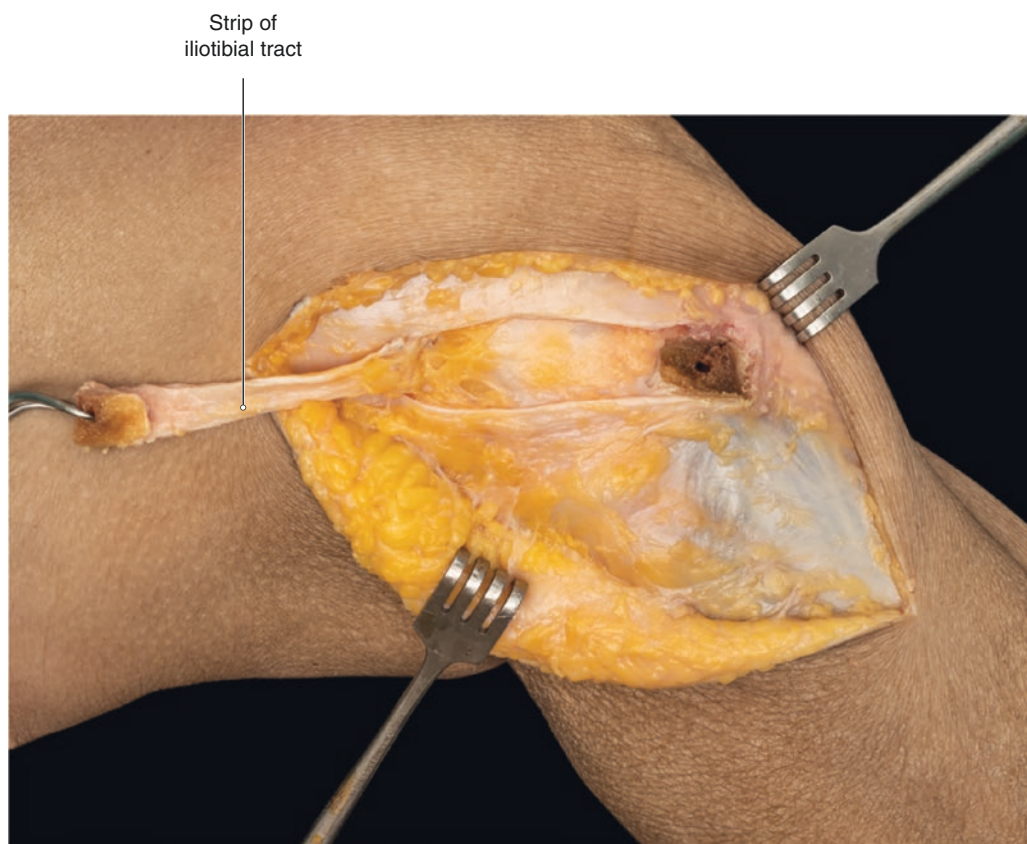


Fig. 12.30 Lift Gerdy's tubercle, together with the strip of iliotibial tract

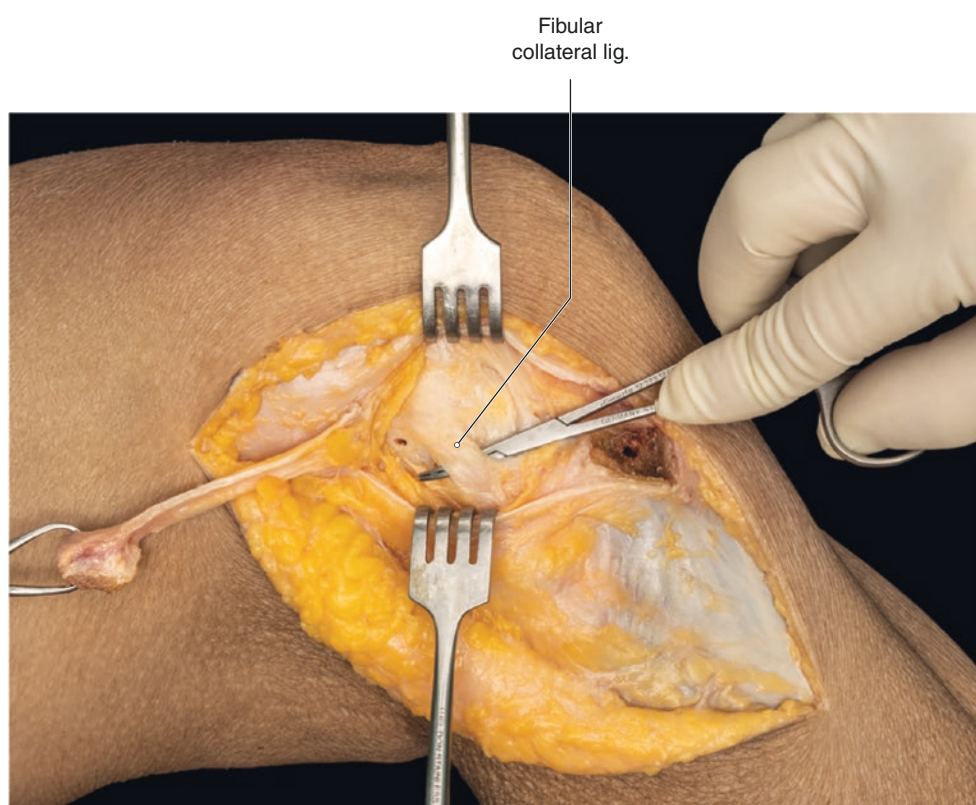


Fig. 12.31 Expose the fibular collateral ligament

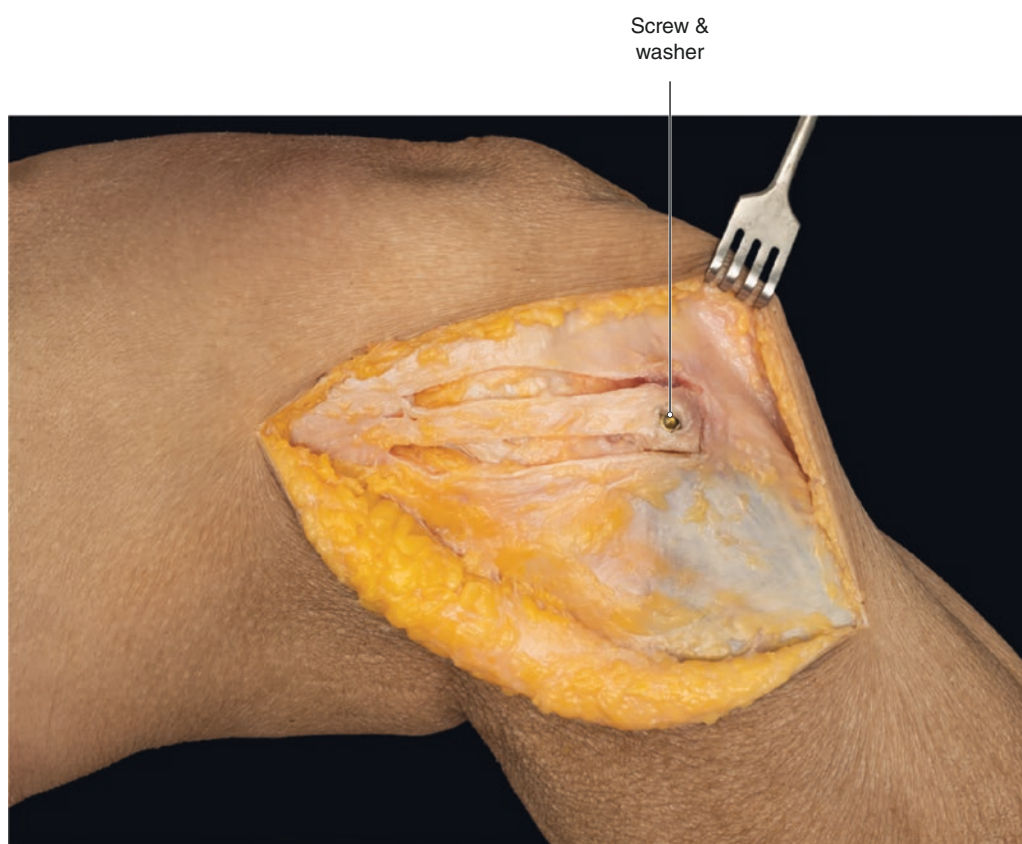


Fig. 12.32 Reattach Gerdy's tubercle with a screw and washer

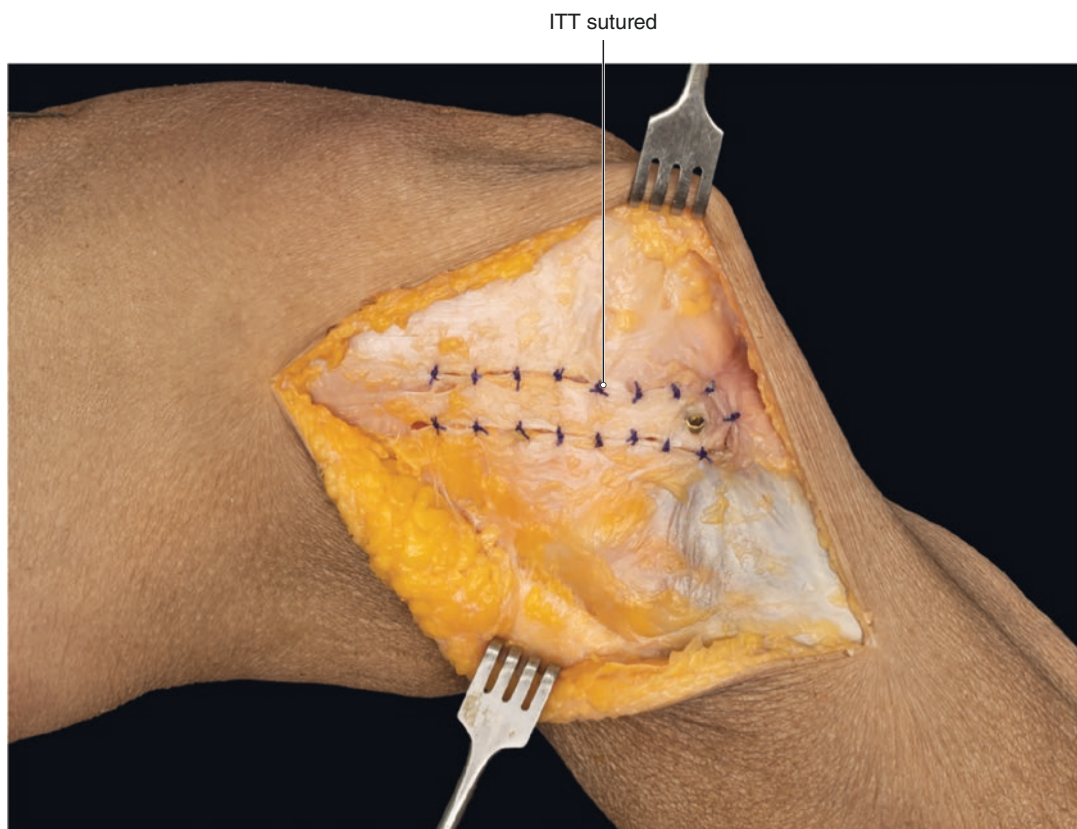


Fig. 12.33 Suture the edges of the iliotibial tract

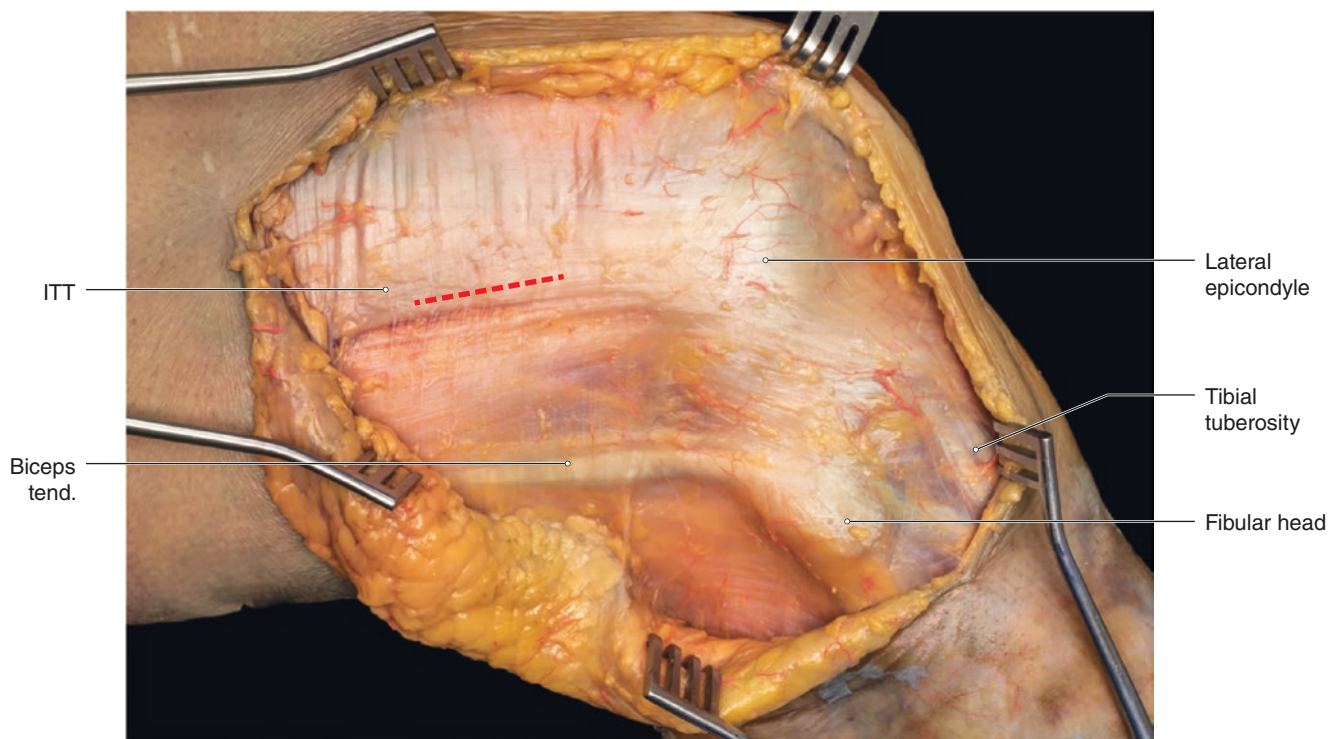


Fig. 12.34 Right knee. Expose the deep fascia on the lateral side. The dotted lined indicates where the lateral intermuscular septum attaches to the iliotibial tract (ITT)

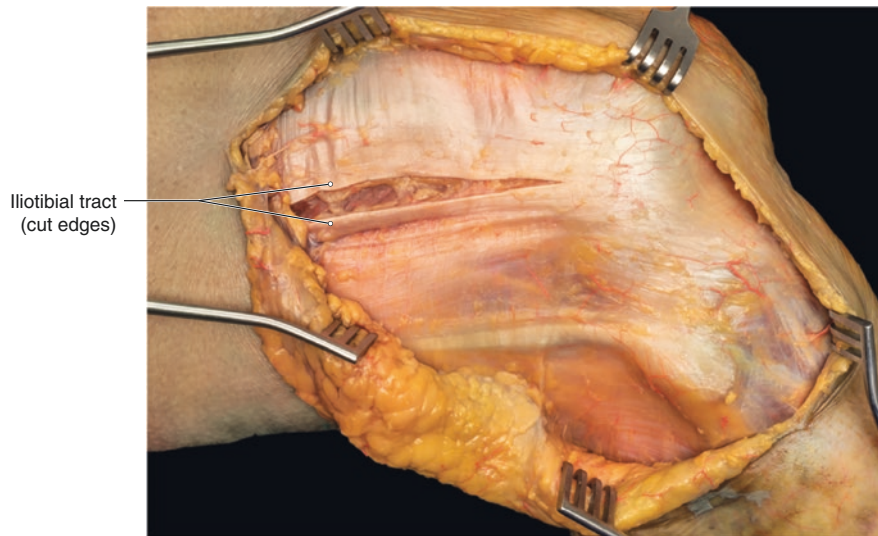


Fig. 12.35 Incise the iliotibial tract just anterior to the lateral intermuscular septum

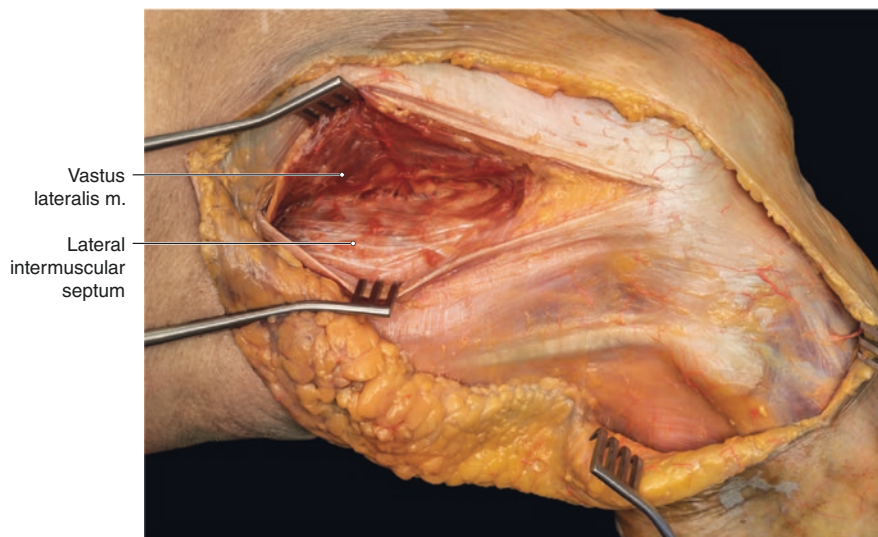


Fig. 12.36 Retract the iliotibial tract to expose the vastus lateralis muscle (above) and the anterior surface of the lateral intermuscular septum (below)

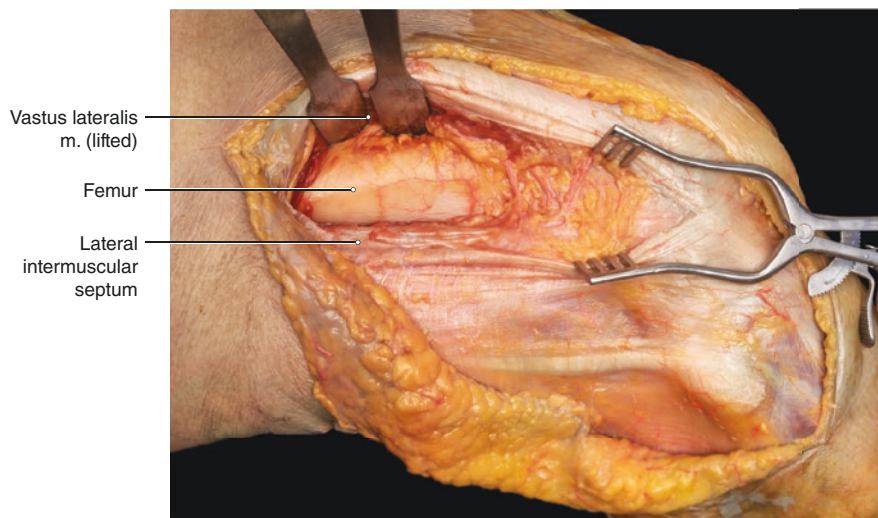


Fig. 12.37 Lift the vastus lateralis muscle and hold it up by retractors hooked over the anterior femur

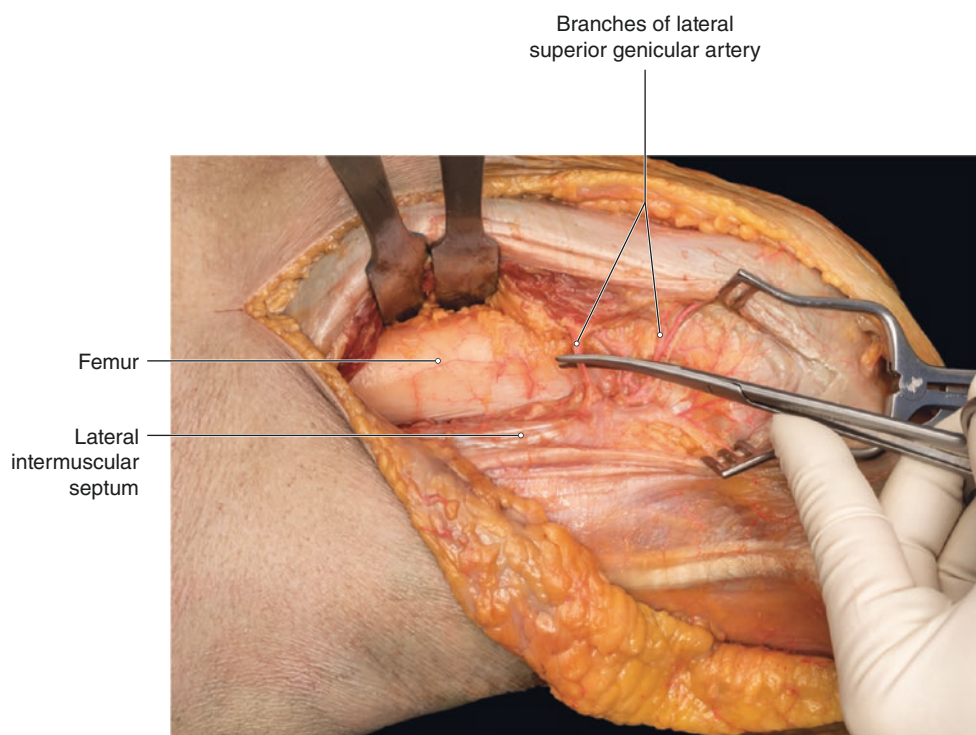


Fig. 12.38 Securely ligate the arterial branches of the lateral superior genicular artery that come up through the lateral intermuscular septum

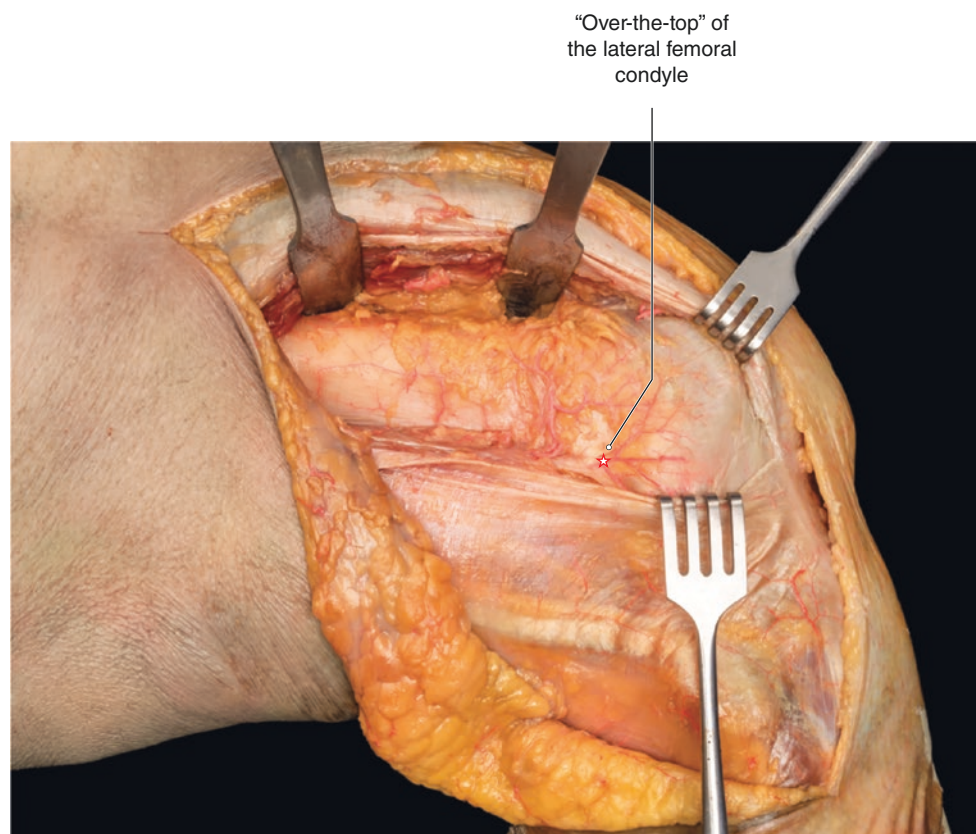


Fig. 12.39 The lateral distal femur has been exposed. If the dissection is carried distally to the junction of posterior shaft of the femur and the flare of the lateral femoral condyle (“over-the-top” of the lateral femo-

ral condyle) (star) the large branch of the lateral superior genicular artery must be suture-ligated. Otherwise, it can retract below the lateral intermuscular septum and become inaccessible

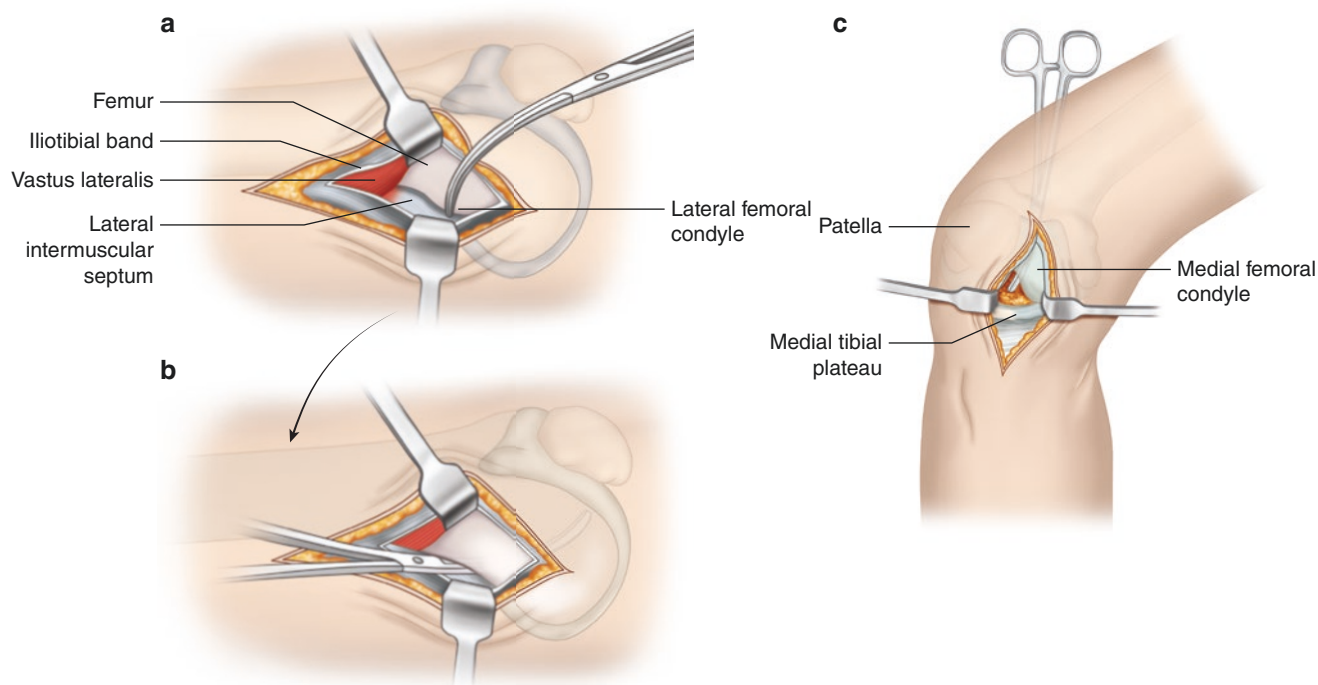


Fig. 12.40 (a) To go from the posterolateral knee to the anterior knee, pass a curved instrument behind the posterolateral flare of the lateral femoral condyle (“over-the-top”). (b) Advance the instrument distally

and medially into the intercondylar notch. (c) Advance the tip of the instrument until it enters the anterior knee

12.6 “Over-the-top” of the Lateral Femoral Condyle

The “over-the-top” of the lateral femoral condyle method has been used in the past for femoral attachment or passage of anterior cruciate ligament grafts [7]. With the refinement of arthroscopic intra-articular fixation of the femoral attachment of anterior cruciate ligament grafts, the over-the-top approach is rarely used today. There may be a limited role for this technique, such as following multiple failed procedures leaving poor femoral bone quality.

12.6.1 Technique

Expose the lateral distal femur down to the flare of the lateral femoral condyle. Securely ligate the large branch of the lateral superior genicular artery before it retracts below the lateral intermuscular septum and cannot be found (see Figs. 12.38 and 12.39). Pass a curved instrument (Kelly clamp) behind the posterolateral flare of the lateral femoral condyle (see Fig. 12.40a). Continue passing the instrument distally and medially over the top of the lateral femoral condyle until it can be felt entering in the intercondylar notch (see Fig. 12.40b). Advance the tip of the instrument anteriorly until it is visible in the knee as viewed from the antero-medial incision (see Fig. 12.40c).

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Further Reading

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Posterior Knee Surgical Exposures

13

Robert Śmigielski and Bertram Zarins

13.1 Posterior Knee: To Expose Proximal Tibia

Henry described a posterior surgical approach the knee [1]. This midline popliteal approach exposes the posterior distal femur. We modified the approach to expose the proximal tibia and the steps are shown herein.

Important neurovascular structures are located in the back of the knee. Dissect bluntly in the deep popliteal fossa. Do not cut sharply when you are deep but gently spread the tissue before you cut. Push the large neurovascular structures out of the way with your finger and retract very gently.

The veins and arteries are important landmarks. Exsanguinating the limb and applying a pneumatic tourniquet remove these guides. To always know where the popliteal artery is located, it is useful to feel its pulsations. Arteries should be identified, and suture ligated. Therefore, apply a tourniquet but do not use it unless necessary.

The level of the knee joint is one fingerbreadth above the head of the fibula (*see* Fig. 13.1).

A gentle S-shaped skin incision gives wide exposure and results in a good scar. Make the proximal limb lateral, transverse part at the flexion crease and the distal limb medial (*see* Fig. 13.2). A straight skin incision requires less dissection but gives a more narrow file of view. Either incision can be used successfully.

To operate on the back of the knee position, position the patient prone with the knee slightly flexed. When the dissection is well under way and the posterior capsule is reached, the knee can be flexed further to relax the struc-

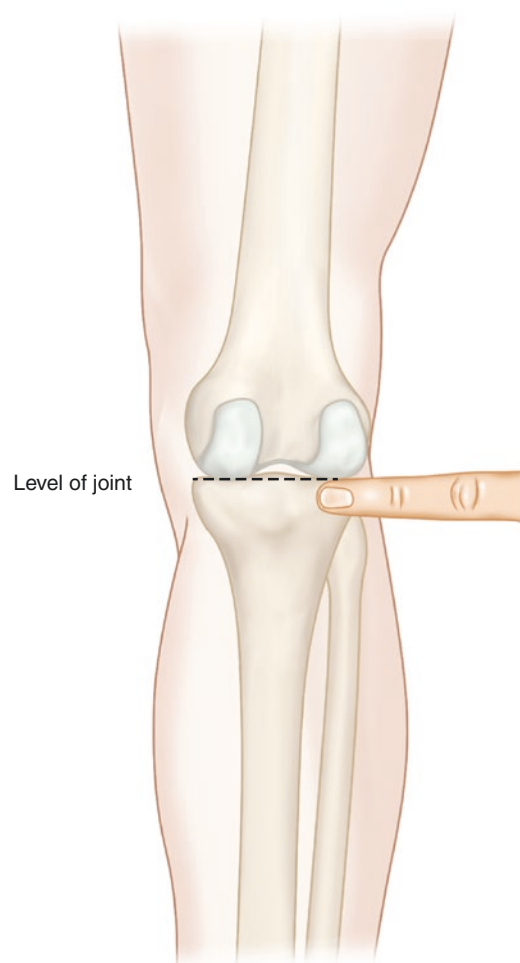


Fig. 13.1 The level of the knee joint is one fingerbreadth above the head of the fibula

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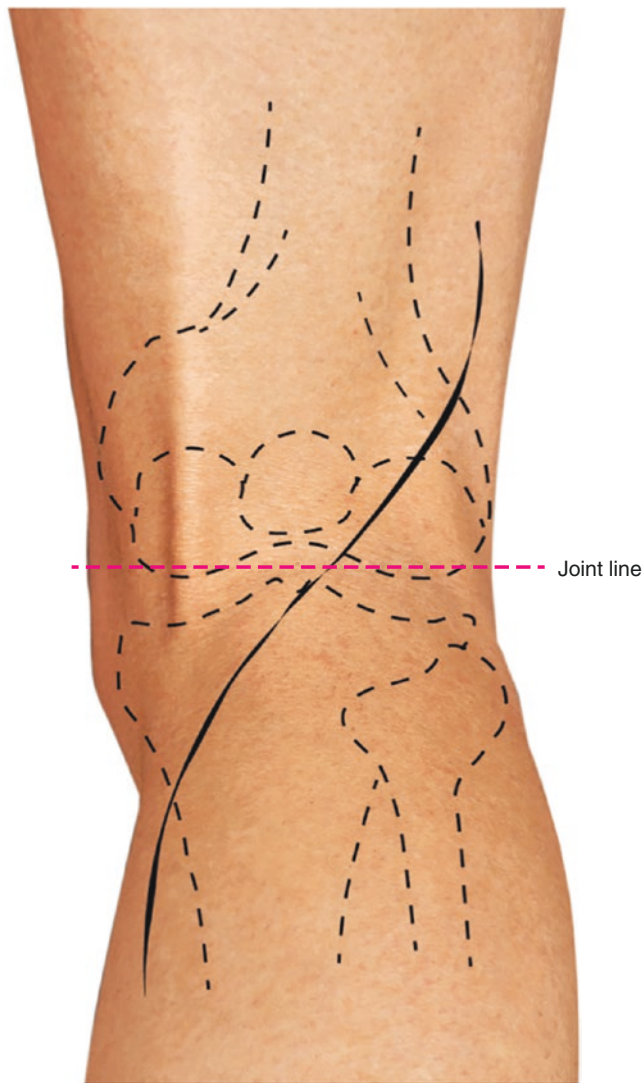


Fig. 13.2 If an *S-shaped* incision made, cross the back of the knee at the joint crease. The distal limb of the incision should be medial to avoid the peroneal nerve laterally. Avoid sharp turns. If a *straight* incision is used, less dissection is required but the field of view is smaller

tures. Henry has warned that “relaxation sets peculiar traps, and semitendinosus may drift limply into the middle of the wound” [1].

13.1.1 Technique

Incise the skin in the back of the knee and the superficial subcutaneous fat. Spread the fat to expose the underlying stratum membranosum (see Fig. 13.3). The popliteal fossa has an extra layer of fibrous connective tissue within the subcutaneous fat: the stratum membranosum. It separates the superficial subcutaneous fat from the deep subcutaneous fat. This layer is common in other parts of the body, such as the abdominal wall (Scarpa’s fascia), but is not present in the anterior, medial, or lateral aspects of the knee (refer to Chap. 1).

Spread the fat to create space under the stratum membranosum and incise the stratum membranosum (see Fig. 13.4). Below the stratum membranosum is the *small saphenous vein*. This is Henry’s “blue guide to the middle line.” It lies on top of the deep fascia (see Fig. 13.5). Create space in the popliteal fossa using blunt dissection (see Fig. 13.6).

Retract the small saphenous vein medially and incise the deep fascia (see Fig. 13.7). Incising the deep popliteal fascia exposes the deep popliteal fat (see Fig. 13.8). Locate the *medial sural cutaneous nerve*. This is Henry’s “white guide.” It lies in the midline below the deep fascia. Trace it proximally to the *tibial nerve* (see Fig. 13.9). Locate and protect the neurovascular bundle that goes to the medial head of gastrocnemius muscle (see Fig. 13.10).

If additional exposure is needed, extend the skin incision distally and spread seam between the medial and lateral heads of gastrocnemius muscle (see Fig. 13.11).

During this exposure we have not seen the *popliteal artery* but have been able to feel its pulsations. The popliteal artery is cloaked by the popliteal vein, and the two are inseparable (see Figs. 8.9 and 13.12). Arteries and veins guard the entrance to the popliteal fossa. They must be suture-ligated and divided (see Figs. 13.13 and 13.14). Retract the medial head of gastrocnemius muscle medially and the neurovascular bundle laterally. This exposes the *posterior capsule* (see Figs. 13.15 and 13.16). Incise the posterior capsule (see Fig. 13.17).

The posterior upper edge of the tibial plateau has been exposed. This exposure allows internal screw fixation of an avulsion fracture of the posterior cruciate ligament (see Fig. 13.18).

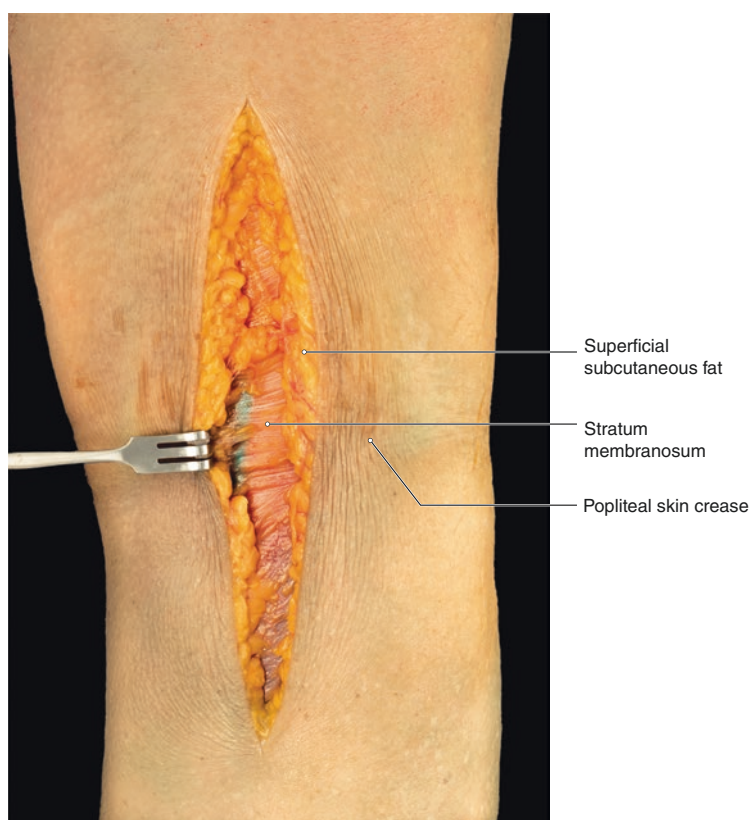


Fig. 13.3 Incise the skin and superficial subcutaneous fat down to the *stratum membranosum*. Note the level of the popliteal skin crease

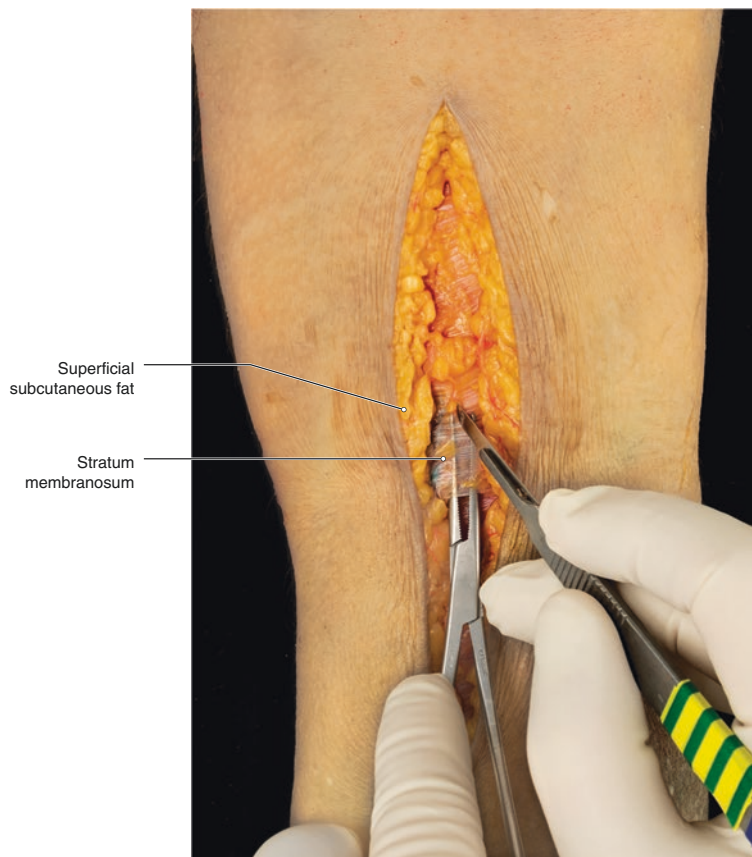


Fig. 13.4 Spread the tissue below the *stratum membranosum*. Incise the stratum membranosum

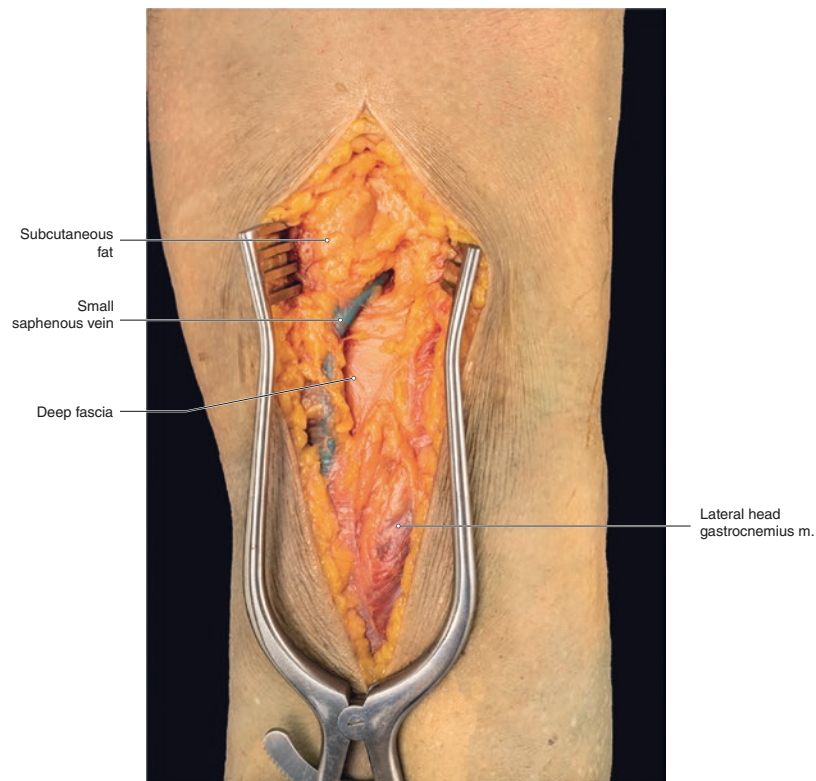


Fig. 13.5 Below the stratum membranosum is the small saphenous vein. It is Henry's "blue guide to the middle line." It lies on top of the deep fascia. *Note: The veins of these specimens were injected with blue dyestuff. When shining through, the veins appear green*

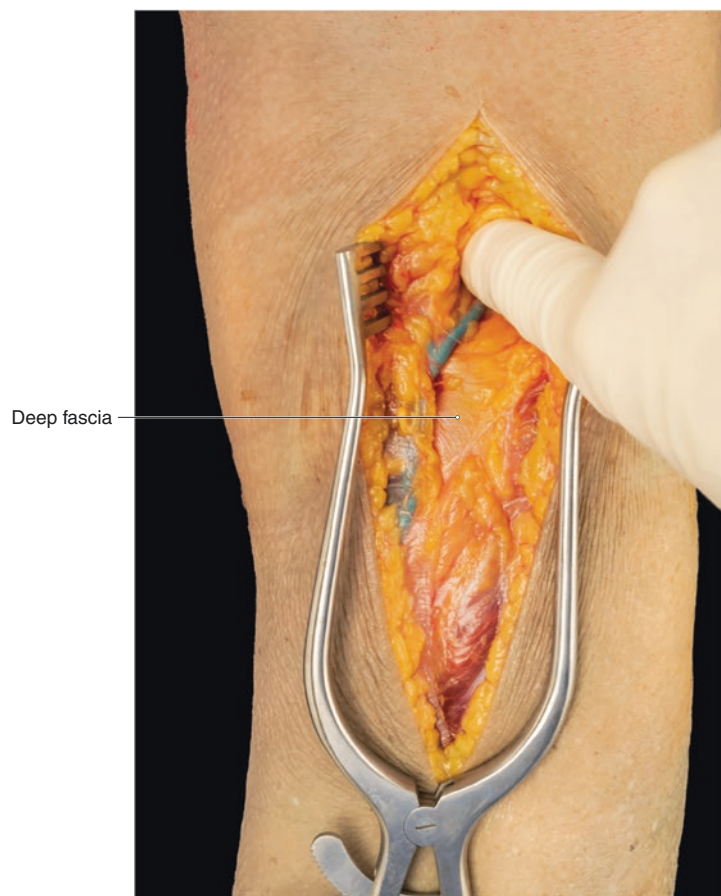


Fig. 13.6 Create space in the popliteal fossa using blunt dissection

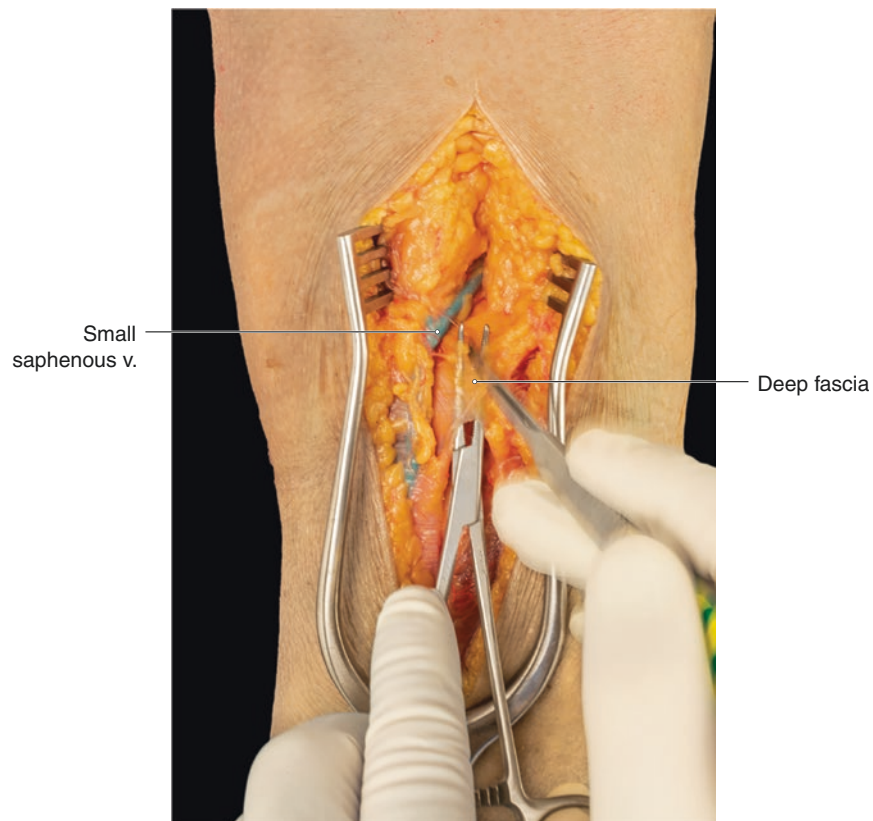


Fig. 13.7 Retract the small saphenous vein medially and incise the *deep fascia*

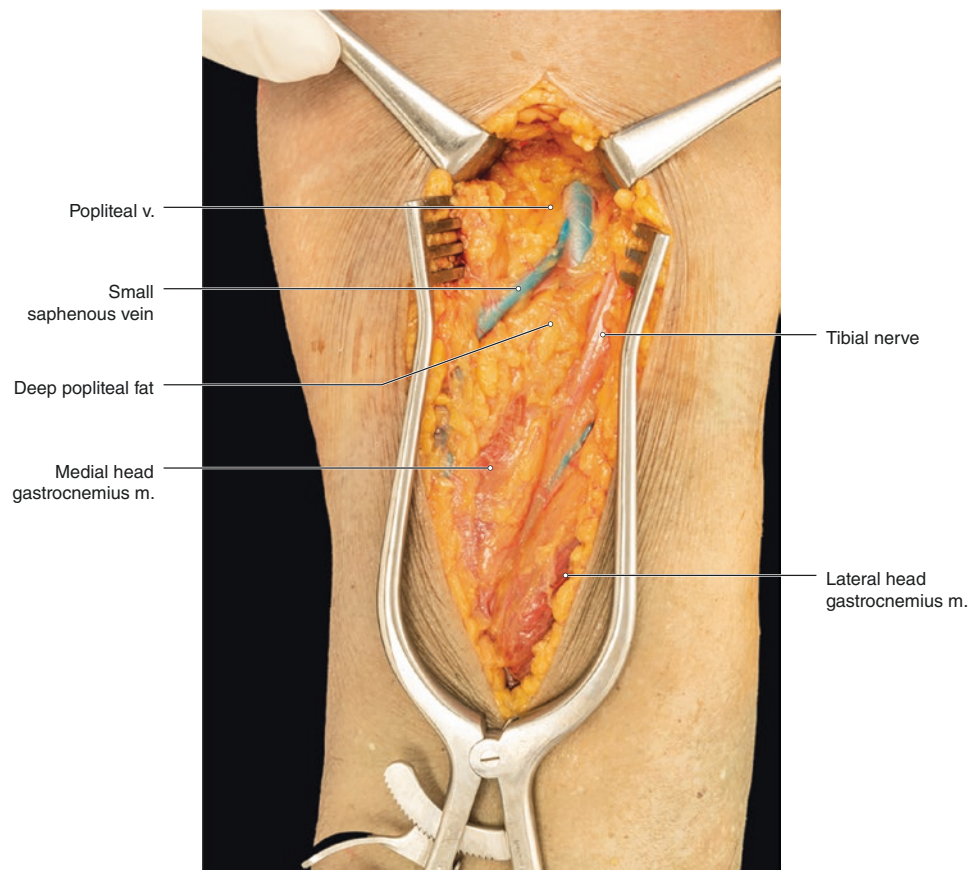


Fig. 13.8 With the deep popliteal fascia gone, the *deep popliteal fat* is exposed

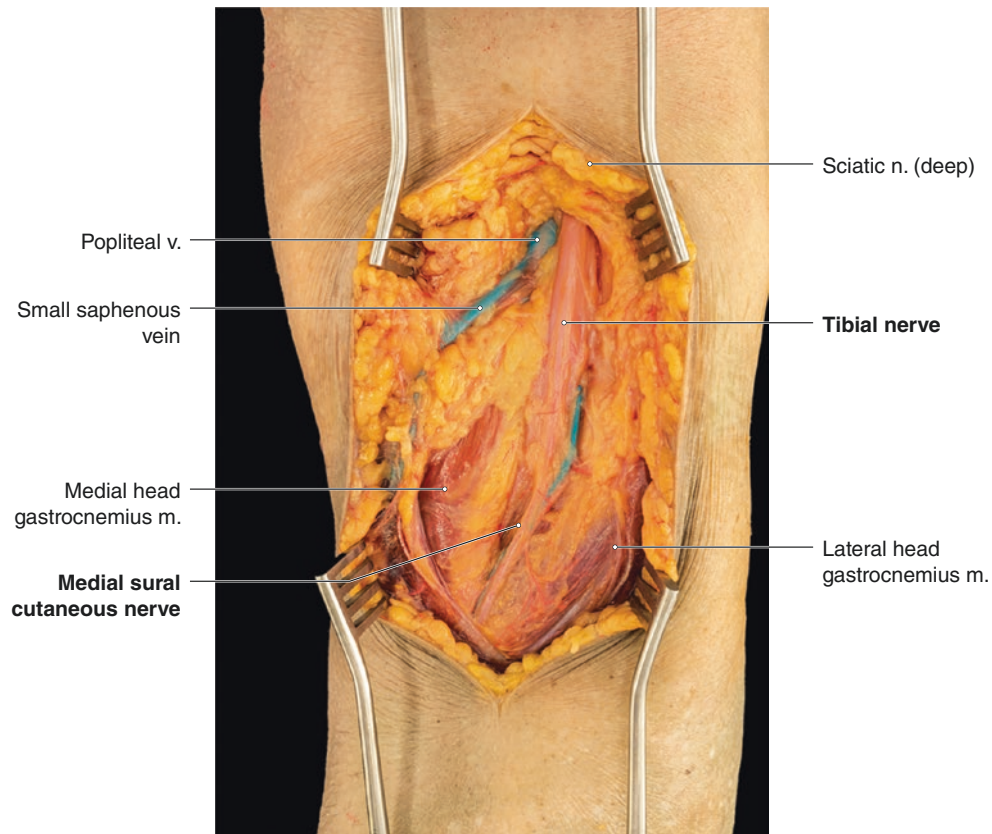


Fig. 13.9 Locate the medial *sural cutaneous* nerve. This is Henry's "white guide." It lies in the midline below the deep fascia. Trace it proximally to the *tibial* nerve

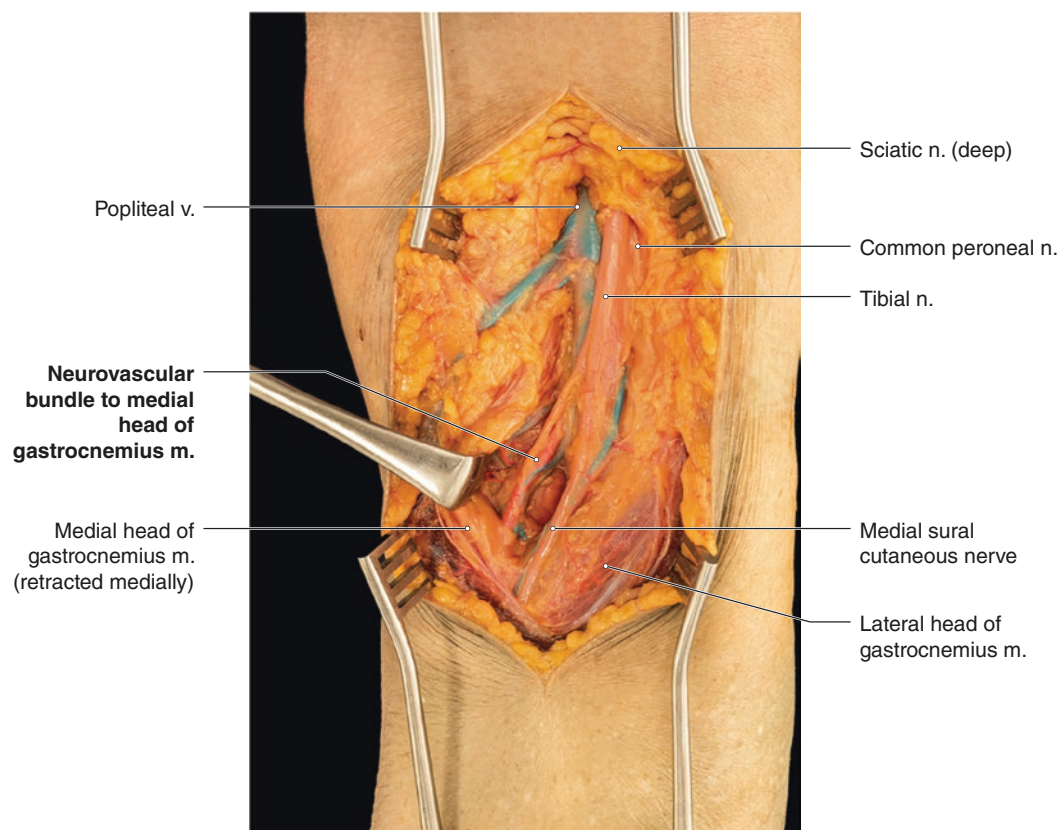


Fig. 13.10 Locate and protect the neurovascular bundle to medial head of gastrocnemius muscle

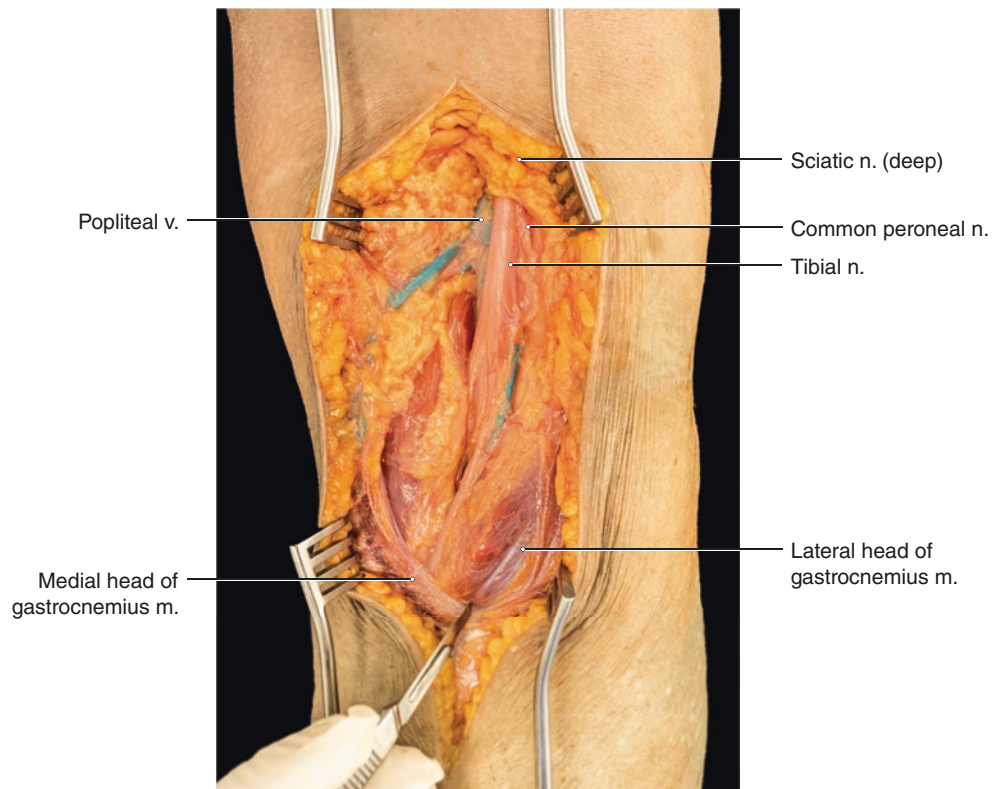


Fig. 13.11 If additional exposure is needed, extend the skin incision distally and spread seam between the medial and lateral heads of gastrocnemius muscle

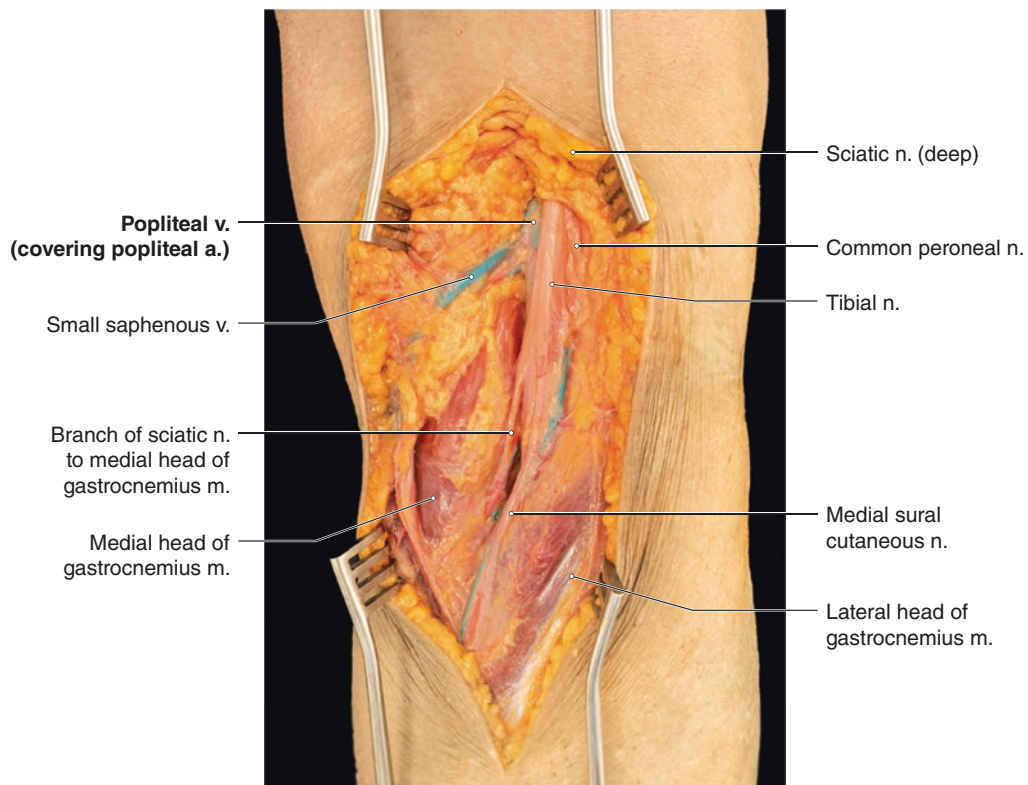


Fig. 13.12 Of the major neurovascular structures in the back of the knee, the sciatic, tibial, and common peroneal nerves are the most superficial. The popliteal vein is next, and the popliteal artery is the

deepest. The popliteal vein branches wrap around the popliteal artery, and the two are inseparable

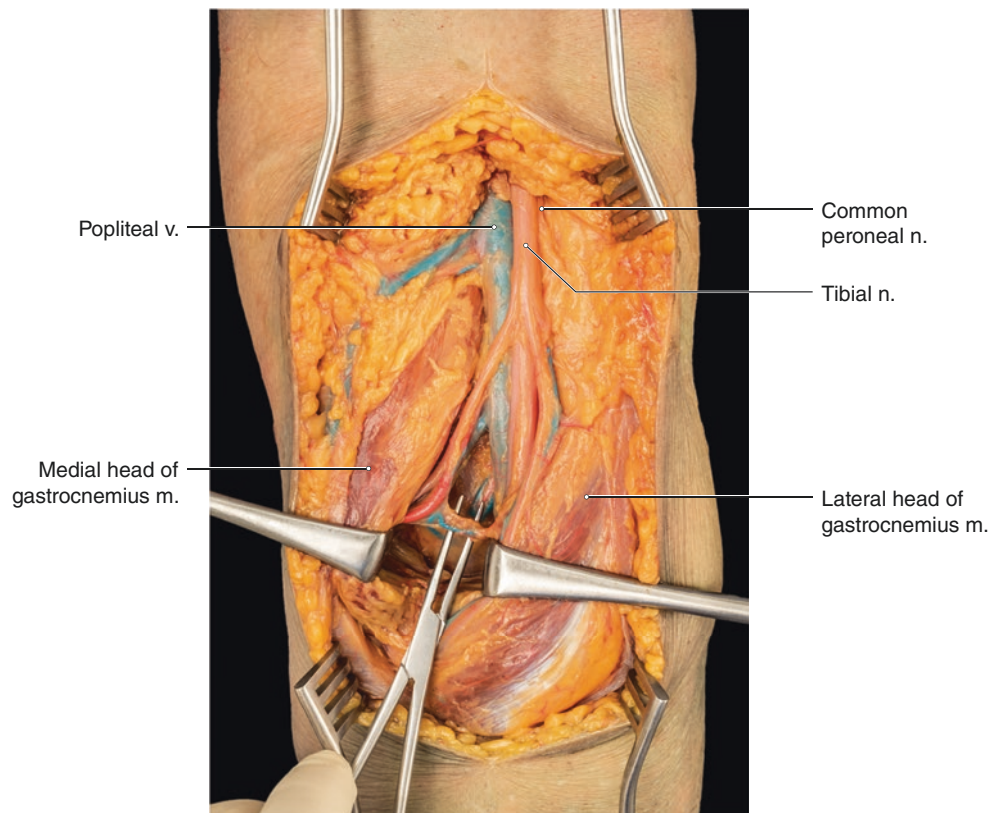


Fig. 13.13 Retract the medial and lateral heads of the gastrocnemius muscle. Isolate the arteries and veins that block further entry into the popliteal fossa

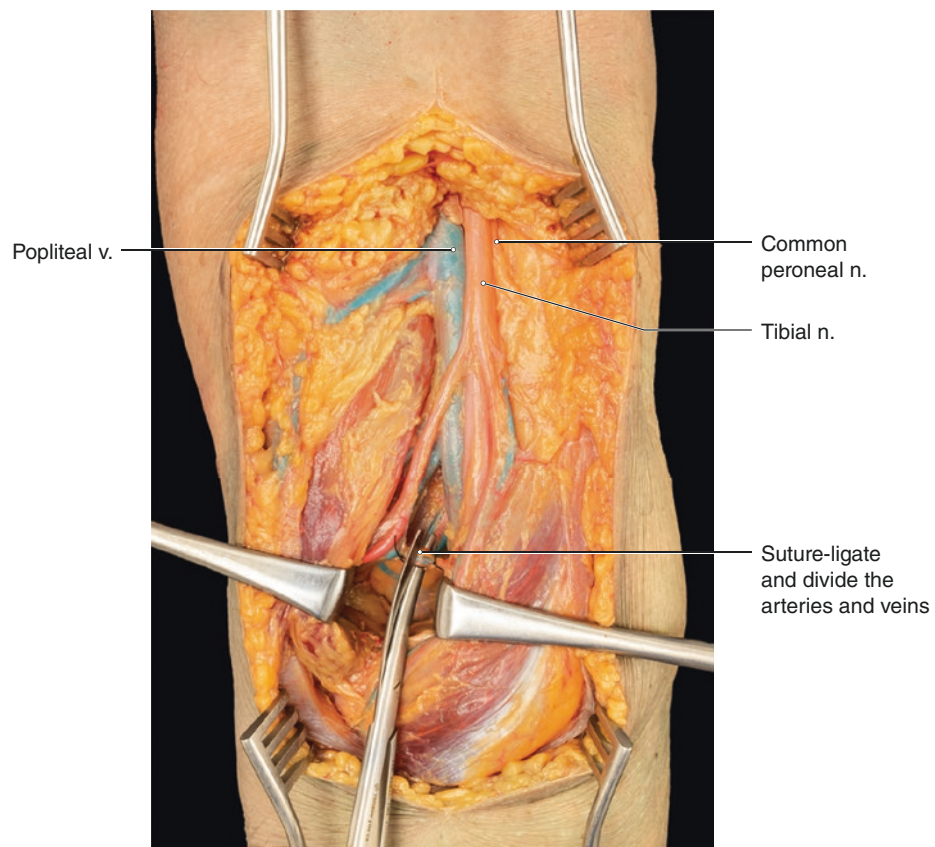


Fig. 13.14 Suture-ligate and divide the vessels

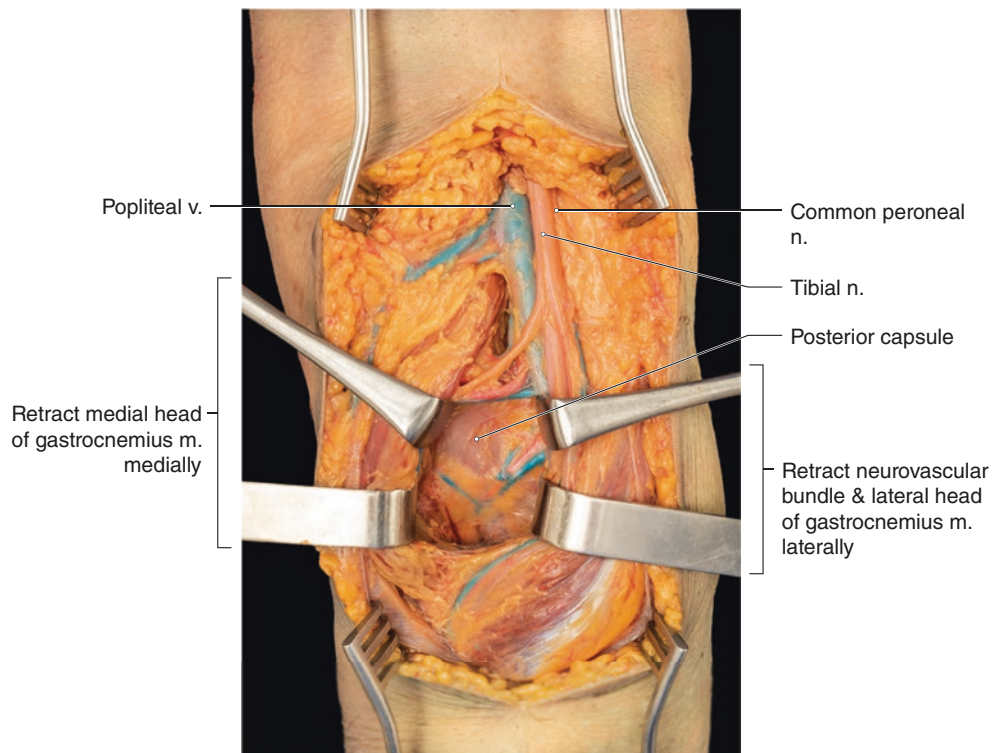


Fig. 13.15 The lower part of the posterior knee capsule has been exposed

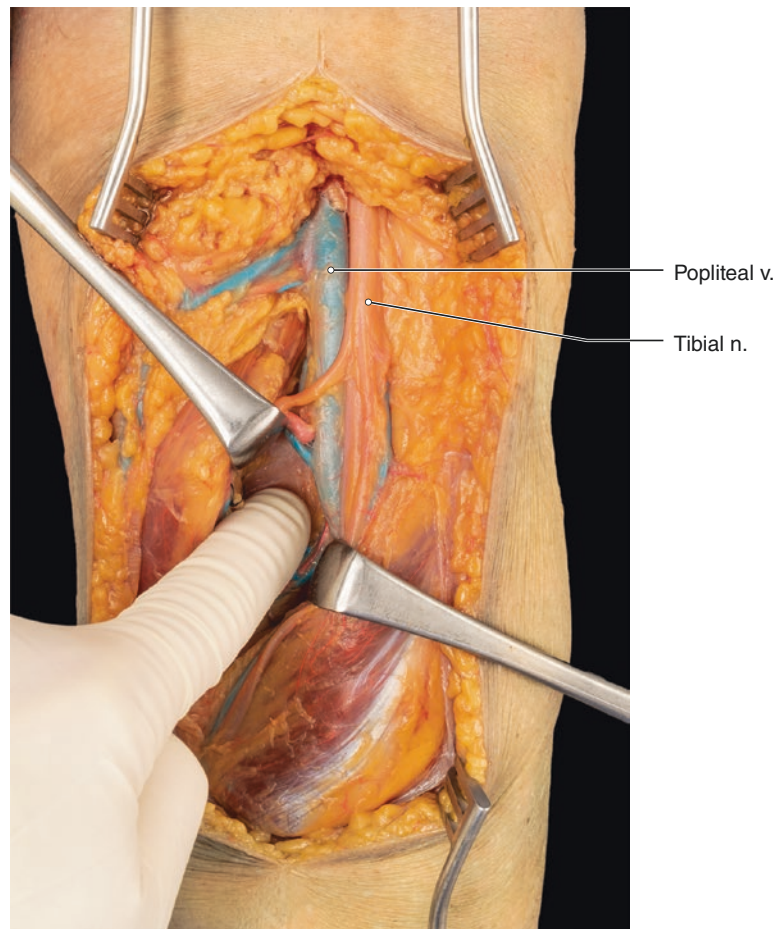


Fig. 13.16 Palpate the posterior capsule to confirm location

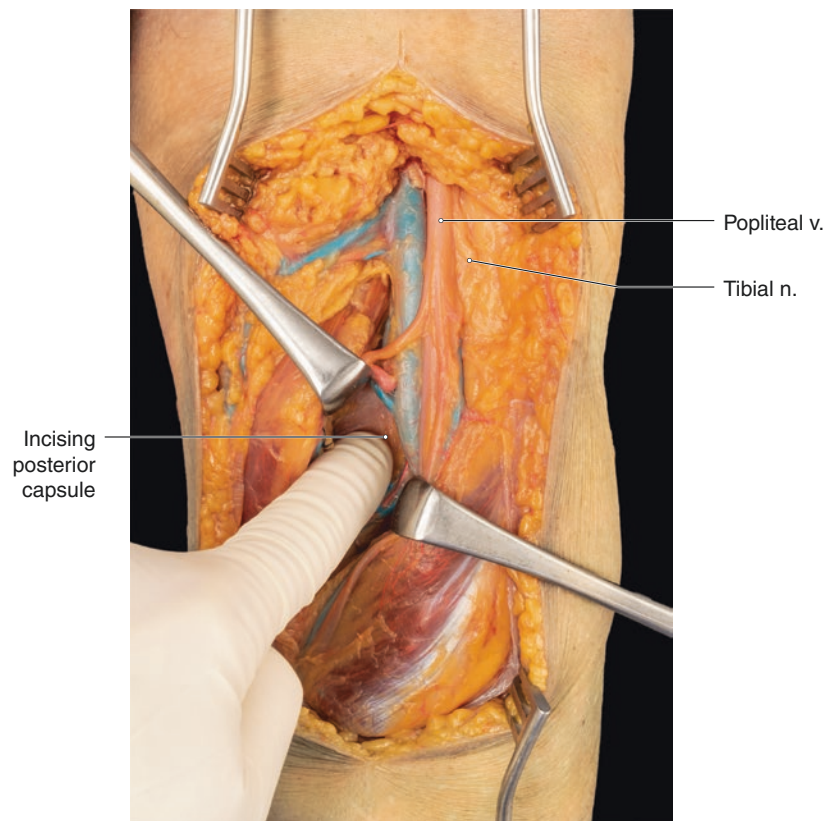


Fig. 13.17 Incise the posterior capsule lengthwise

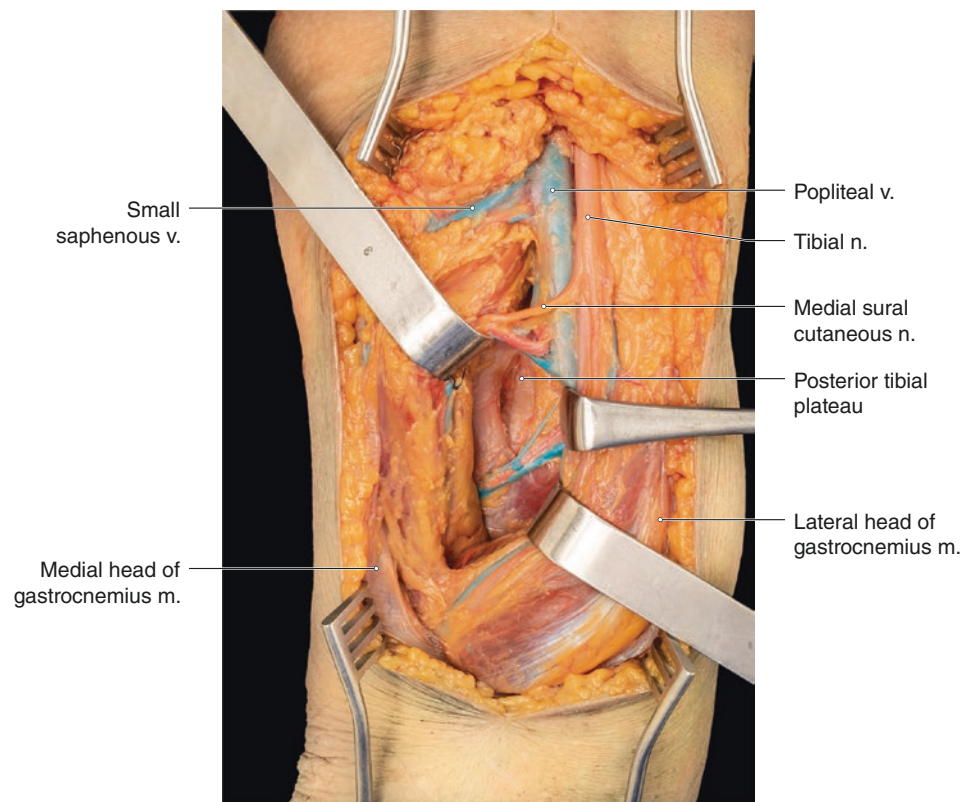


Fig. 13.18 The posterior upper edge of the tibial plateau has been exposed. This exposure allows internal screw fixation of an avulsion fracture of the posterior cruciate ligament

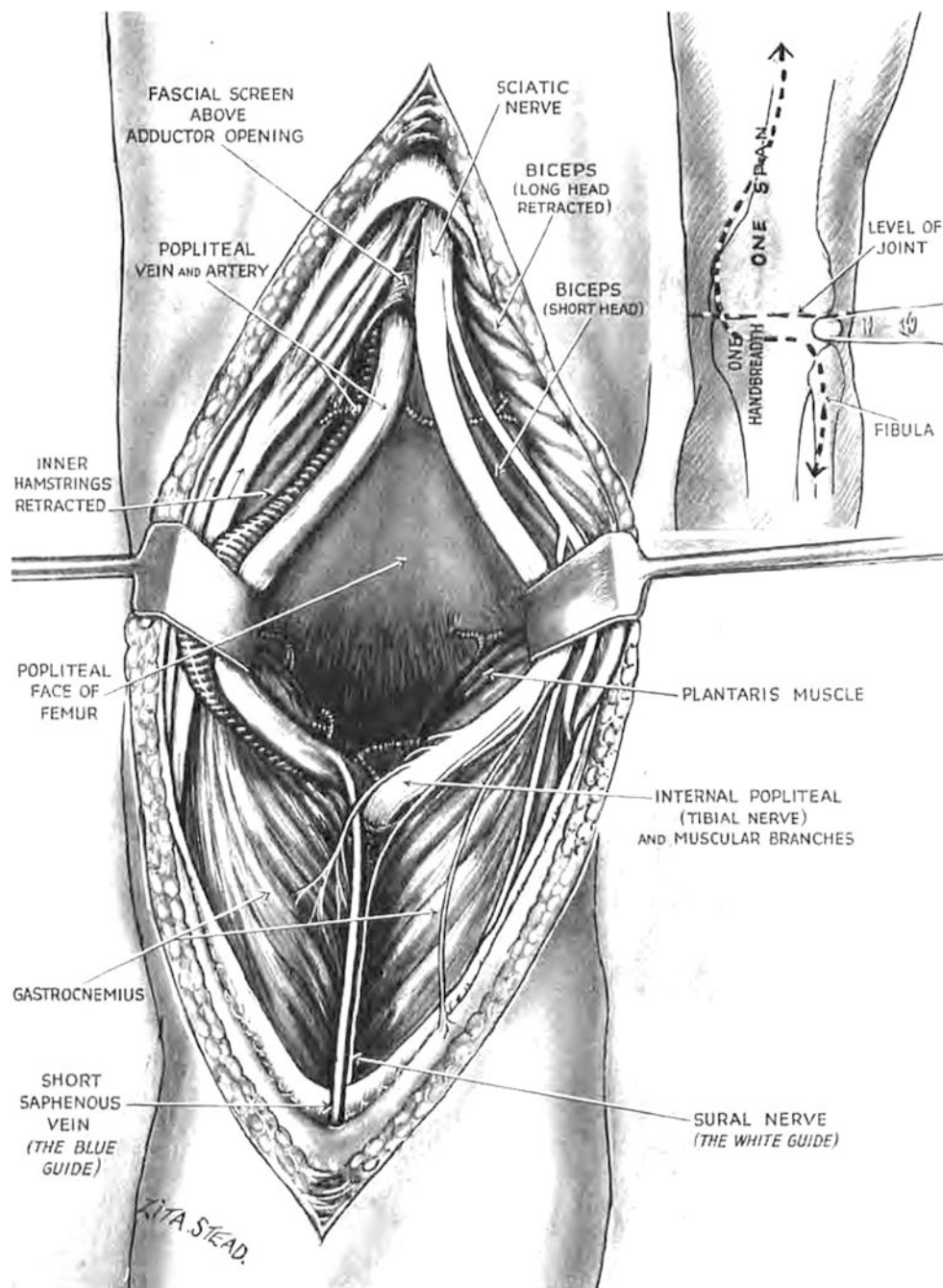
13.2 Posterior Knee: To Expose Distal Femur

The midline popliteal approach that Henry described exposes the posterior surface of the distal femur (see Fig. 13.19) [1]. It is very difficult to expose the posterior knee capsule between the distal femur and proximal tibia without sacrificing major anatomical structures.

13.2.1 Technique

To extend the exposure higher up the back of the knee, lengthen the skin incision proximally. The upper end of the incision should end at about 10 cm proximal to the popliteal skin crease (see Fig. 13.20). Expand the dissection (see Fig. 13.21). Retract the tibial and common peroneal nerves laterally (see Fig. 13.22). Retract the popliteal vein and artery medially. This exposes the popliteal surface of the distal femur (see Fig. 13.23).

Fig. 13.19 Illustration of the midline popliteal approach. This original description exposes the distal femur and is more proximal than the one described in Sect. 13.1. (From Henry [1]; with permission)



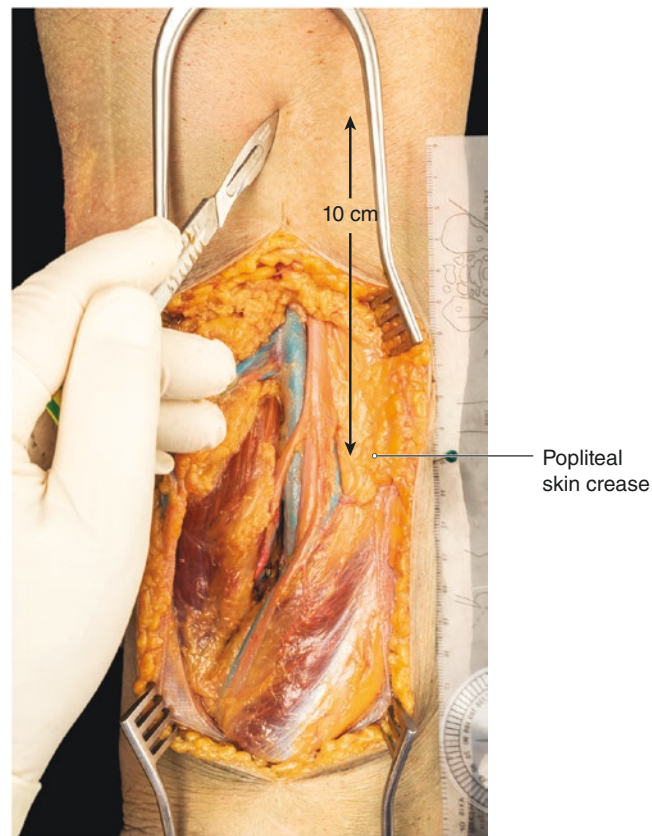


Fig. 13.20 To gain access to the distal femur posteriorly, extend the skin incision proximally to about 10 cm proximal to the popliteal skin crease

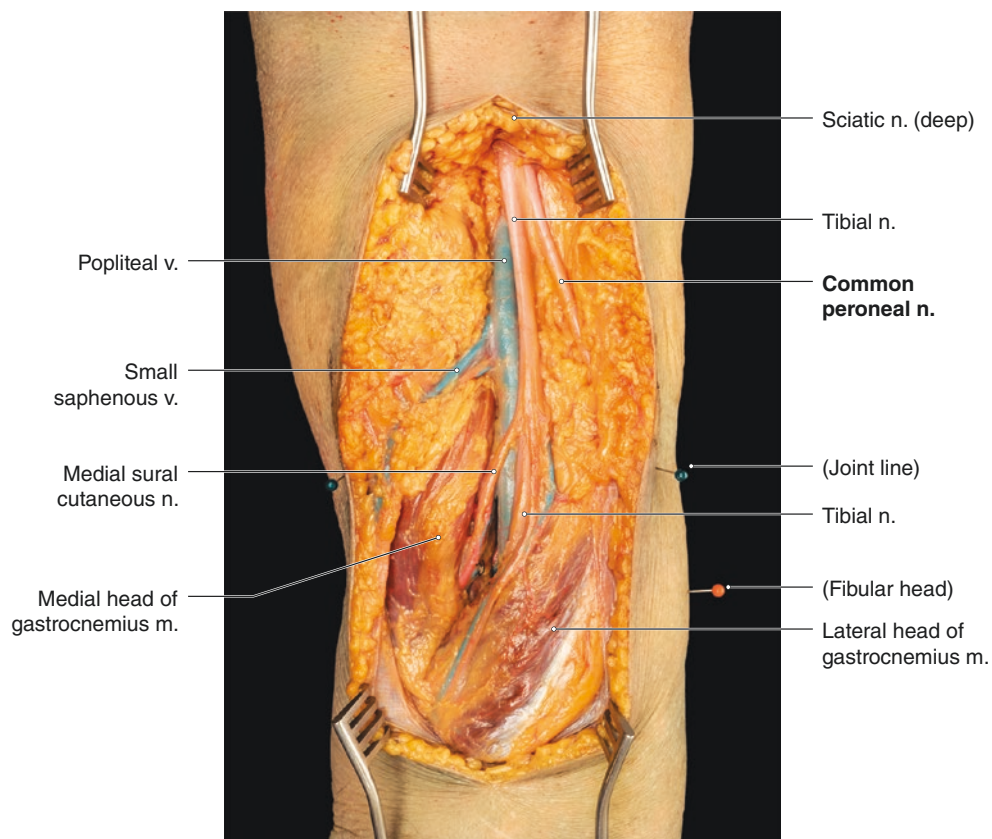


Fig. 13.21 Wide exposure of the popliteal fossa. Note the common peroneal nerve coursing laterally

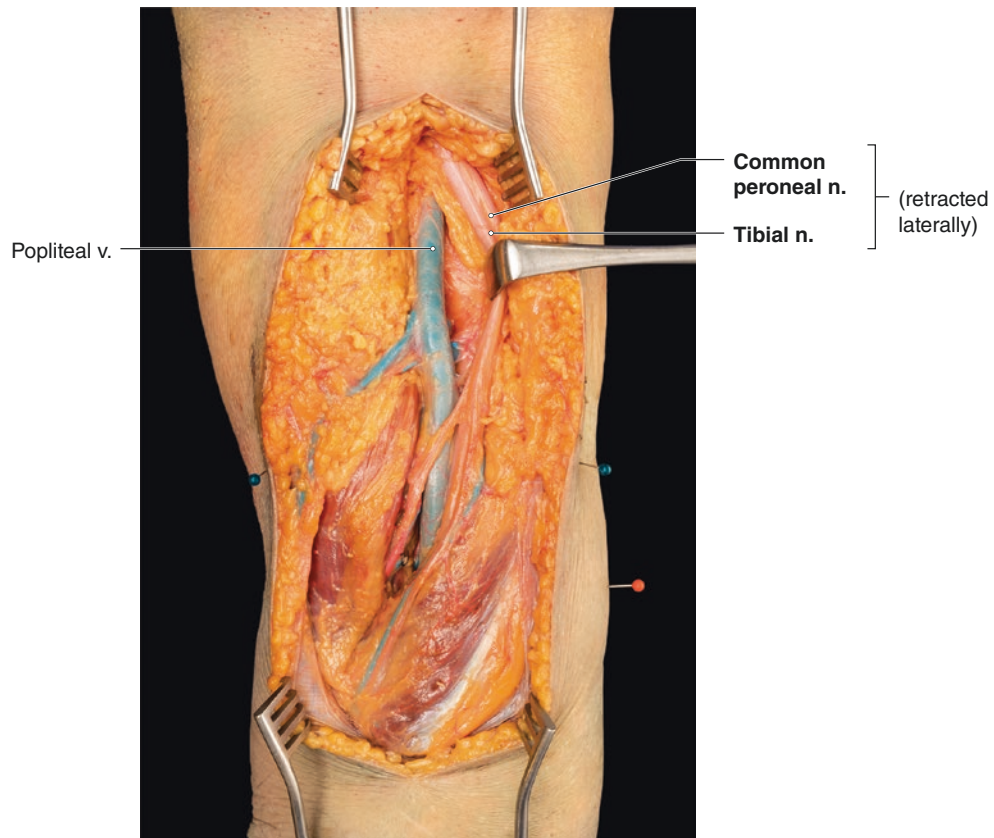


Fig. 13.22 Retract the tibial and peroneal nerves laterally

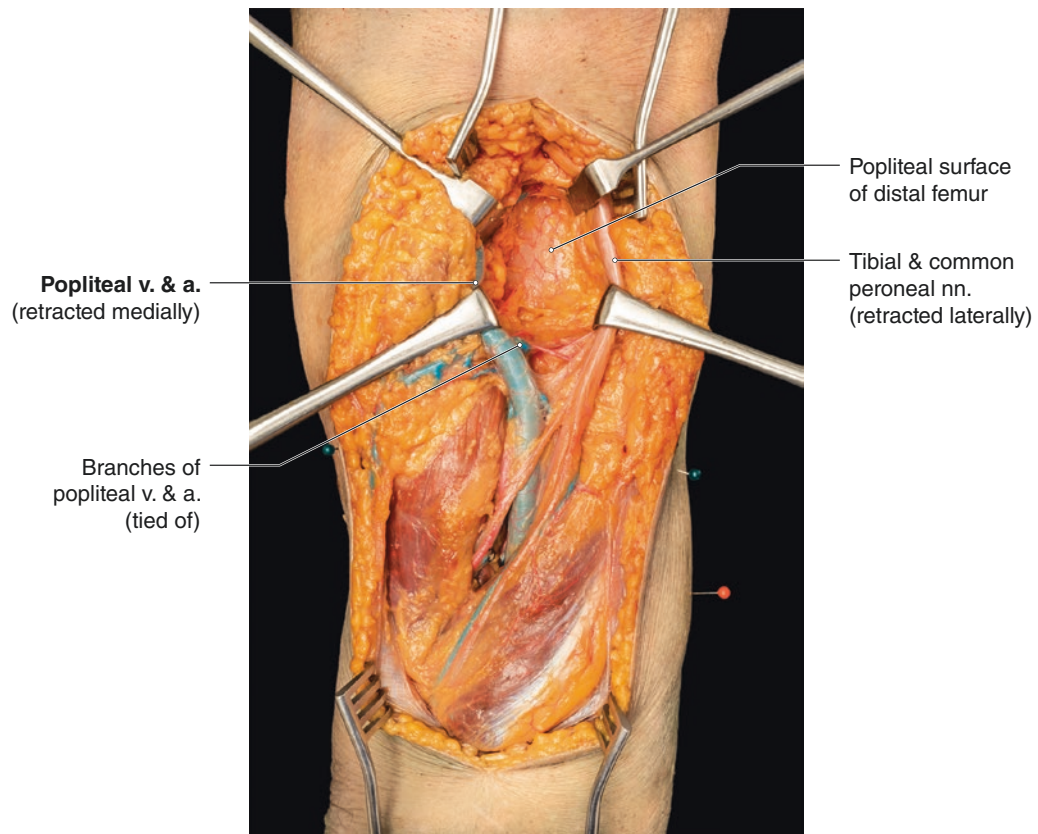


Fig. 13.23 Retract the popliteal vein and artery medially. The popliteal surface of distal femur has been exposed

13.3 Posteromedial Knee: To Approach Popliteal Cyst

13.3.1 Technique

Make a gentle S-shaped incision over the cyst in the back of the medial knee. Carry the dissection down to the cyst and continue to dissect around the edges of the cyst toward its

base. Retract the semimembranosus tendon medially and the medial head of the gastrocnemius laterally. If the cyst is excessively large, decompress the cyst to make it easier to go further. Trace the stalk of the cyst to its opening high in the posteromedial capsule beneath the medial head of gastrocnemius. Excise the cyst. Securely close the opening in the posterior capsule, taking down the upper part of the medial head of gastrocnemius tendon to the upper capsule (*see* Fig. 13.24).

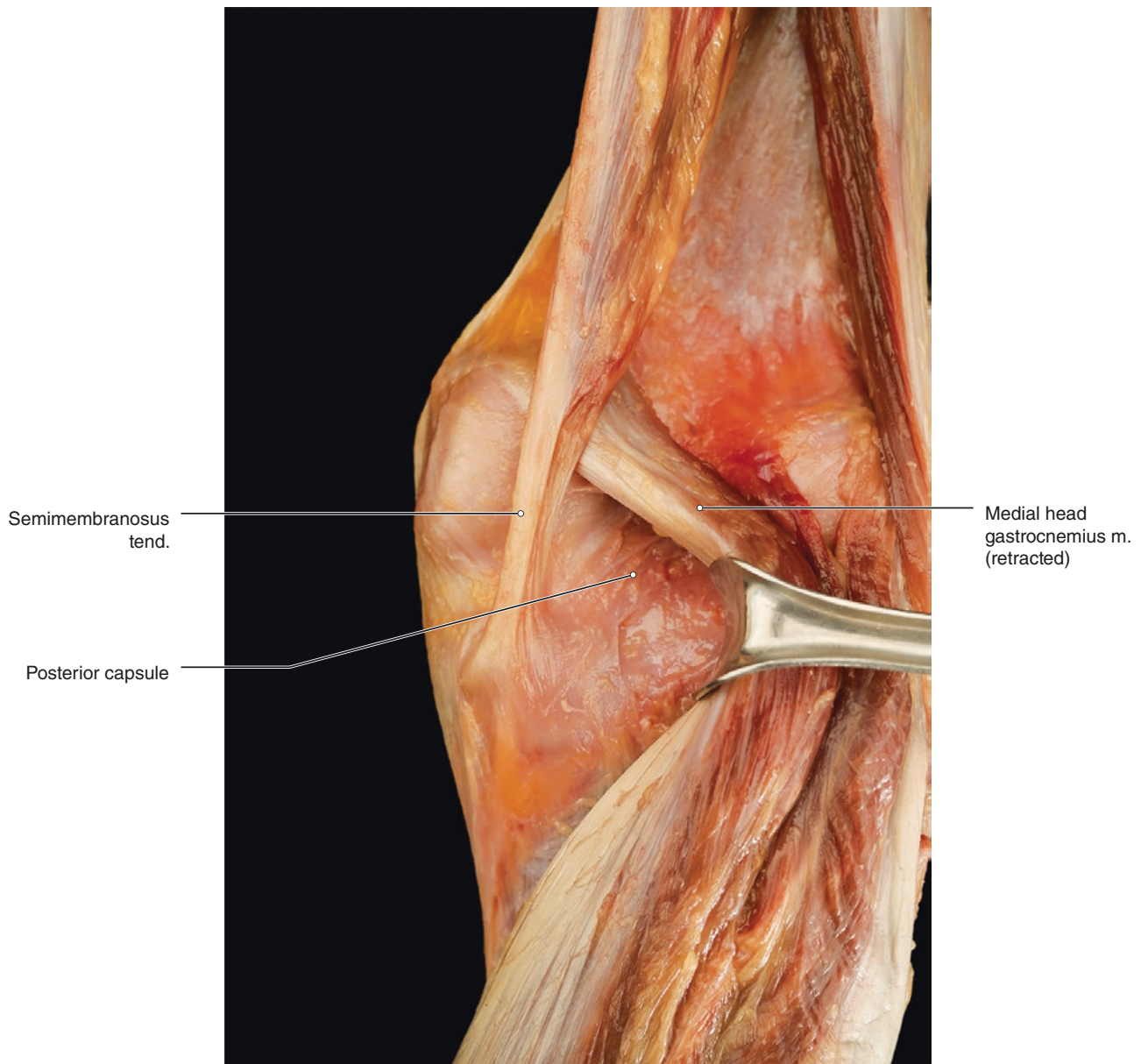


Fig. 13.24 To approach a popliteal cyst through a posterior approach, make a gentle S-shaped incision over the cyst in the back of the knee. Trace the cyst to its connection to the posterior capsule. Retract the

semimembranosus tendon medially and the medial head of gastrocnemius muscle laterally

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Knee Arthroplasty Exposures

14

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14.1 Medial Exposures

The *medial approach* is the most used exposure for total knee arthroplasty (TKA). There are several variations of the approach that differ with respect to the proximal portion of the arthrotomy (*see* Fig. 14.1). The three main approaches are the medial parapatellar approach, subvastus approach, and midvastus approach. The patient positioning, knee position, and skin incisions are similar for all three approaches.

14.1.1 Patient Positioning

The patient is positioned supine on a standard operating table or a special table that allows the surgeon to drop the contralateral leg. If a tourniquet is to be used, it should be placed as proximal as possible on the thigh (*see* Fig. 14.2).

14.1.2 Knee Position

The leg should be free so that the knee can be flexed and extended throughout the case. Foot bumps can be placed to

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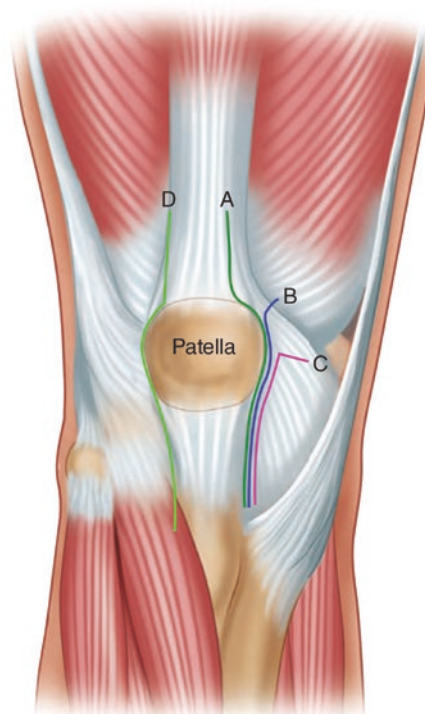


Fig. 14.1 Arthrotomies for total knee arthroplasty: (a) Medial parapatellar, (b) midvastus, (c) subvastus, and (d) lateral parapatellar



Fig. 14.2 A special knee holder with foot bumps that can hold the leg at 30° and 100° flexion. This table allows the surgeon to drop the contralateral leg. The tourniquet has been placed as proximal as possible on the thigh



Fig. 14.3 The knee has been prepped and draped. Transverse lines have been drawn on the skin to help align skin edges during closure. A sterile adhesive drape has been applied with the knee in flexion to seal off the skin. This is a sterile surgical field

hold the leg at 30° and 100° of knee flexion. If the knee has a contracture or limited motion, one must estimate the positions of the bumps. This can be done by comparing it to the contralateral limb. To ensure that the knee is not externally rotated, place a bump under the ipsilateral hip or a post at the level of the tourniquet (see Fig. 14.2).

14.1.3 Skin Incision

Apply a sterile adhesive drape with the knee in flexion (see Fig. 14.3). There are variations in the placement of the anterior skin incision, but a longitudinal, straight, midline skin incision is commonly used for knee arthroplasty (see Fig. 14.4). Mark the inferior, superior, medial, and lateral borders of the patella, the joint line, and the tibial tuberosity.

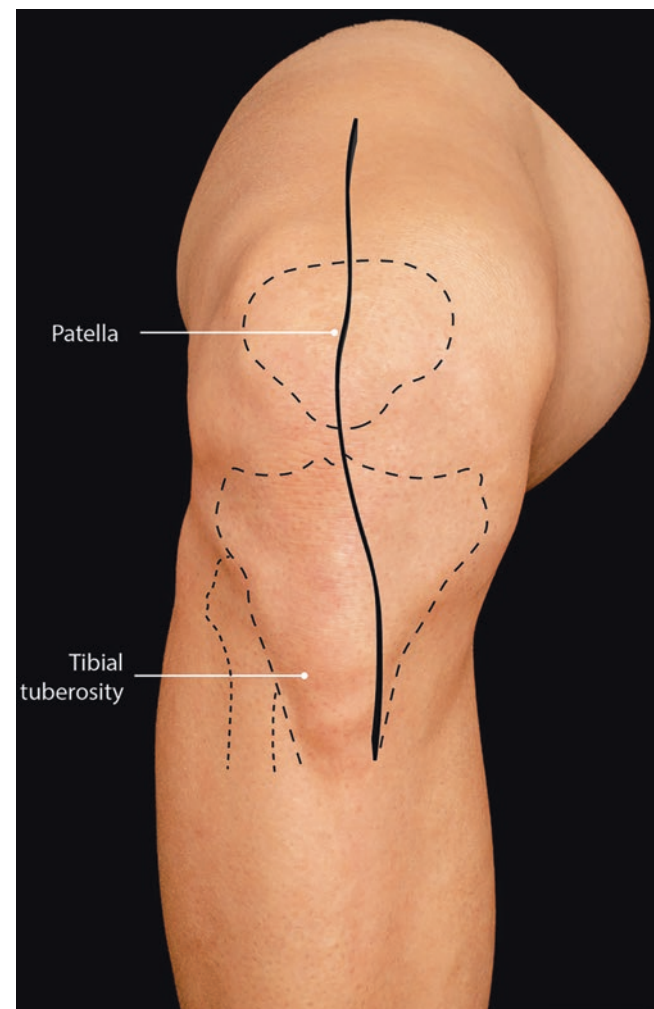


Fig. 14.4 A longitudinal, straight, midline skin incision is commonly used for knee arthroplasty

Make a vertical skin incision on the anterior knee. Start the incision 3 cm proximal to the superior pole of the patella and center it over the quadriceps tendon. Extend the incision distally to 3 cm distal to the joint line.

14.2 Medial Parapatellar Approach

The medial parapatellar approach is the commonly used exposure for knee arthroplasty (*see* Fig. 14.1). It allows excellent exposure of all knee compartments [1]. It can be used for medial and lateral unicompartamental knee arthroplasties (UKA) as well as minimally invasive TKA [2]. It can be extended for revisions procedures, stiff knees, and knees with patellar baja, or other deformities [3, 4].

14.2.1 Technique

With the knee in flexion, incise the skin and subcutaneous tissues down to the deep fascia. Make full-thickness skin flaps. Identify the quadriceps tendon, medial edge of patella and patellar tendon. Leave intact the deep fascia that overlies the vastus medialis muscle. Do not develop the skin flap later-

ally at this point; this can be a useful step at the end of the procedure if patellar tracking is to be addressed (*see* Fig. 14.5).

Begin the full-thickness arthrotomy 3 cm proximal to the superior pole of the patella and 2 or 3 cm lateral to the vastus medialis muscle at the junction of the medial and central thirds of the quadriceps tendon (*see* Fig. 14.6). Cut through the medial edge of the quadriceps tendon near its insertion to the patella and make a full-thickness incision into the joint. At the medial edge of the quadriceps tendon, leave enough tissue to allow side to side repair for closure (*see* Fig. 14.7). Extend the arthrotomy distally along the edge of the vastus medialis and the medial border of the patella. Leave 2–3 mm of tissue intact along the medial edge of the patella to allow closure. Continue to incise distally along the medial edge of the patellar tendon, taking care not to incise the tendon (*see* Fig. 14.8). A small perforating branch of the inferior medial geniculate artery often marks the medial edge of the patellar tendon. Extend the incision distally until the joint line (*see* Fig. 14.9). Extend the arthrotomy to the anterior horn of medial meniscus and the medial slope of the tibial tuberosity, ending 2 cm distal to the joint line. The patella can now be elevated (*see* Fig. 14.10).

Flex the knee to 30°. Excise the infrapatellar fat pat and synovium but leave the capsule in place (*see* Fig. 14.11).

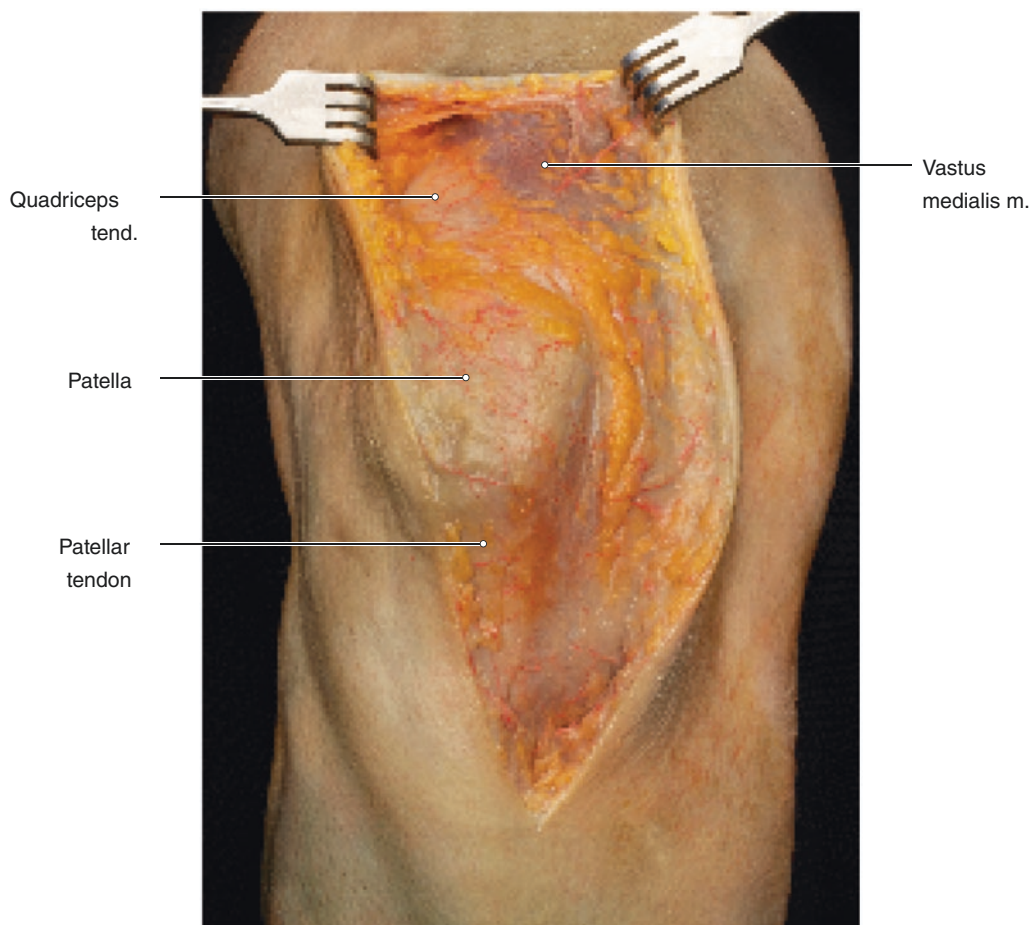


Fig. 14.5 Incise the skin in front of the knee and expose the deep fascial layer

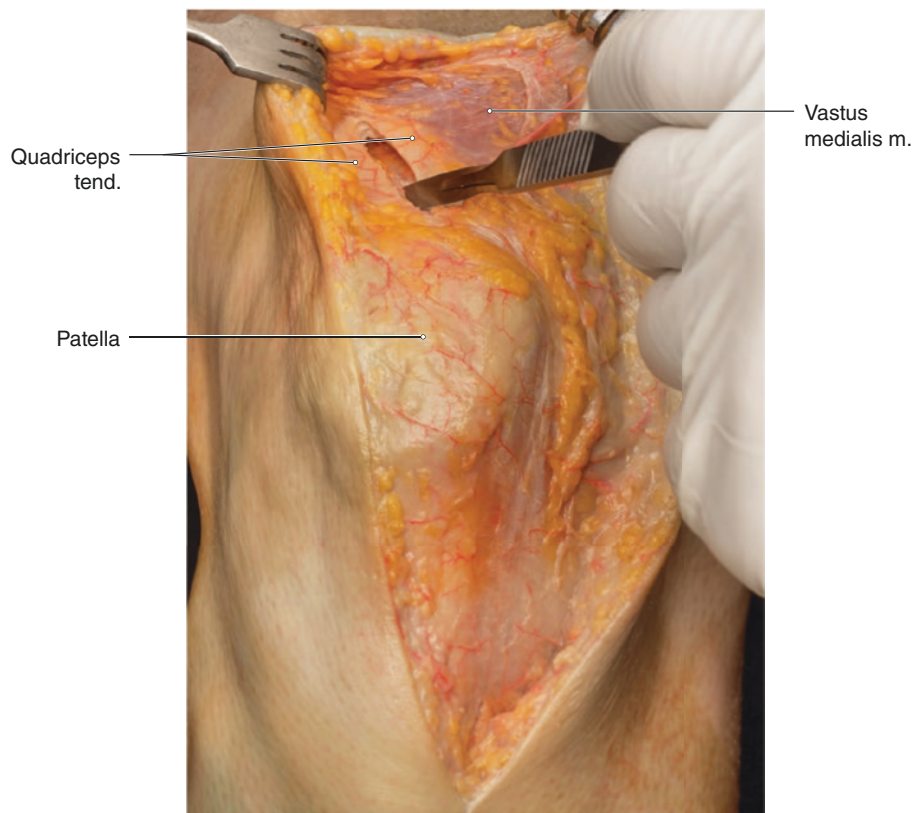


Fig. 14.6 Begin the full-thickness arthrotomy 3 cm proximal to the superior pole of the patella and 2–3 cm lateral to the vastus medialis muscle at the junction of the medial and central thirds of the quadriceps tendon

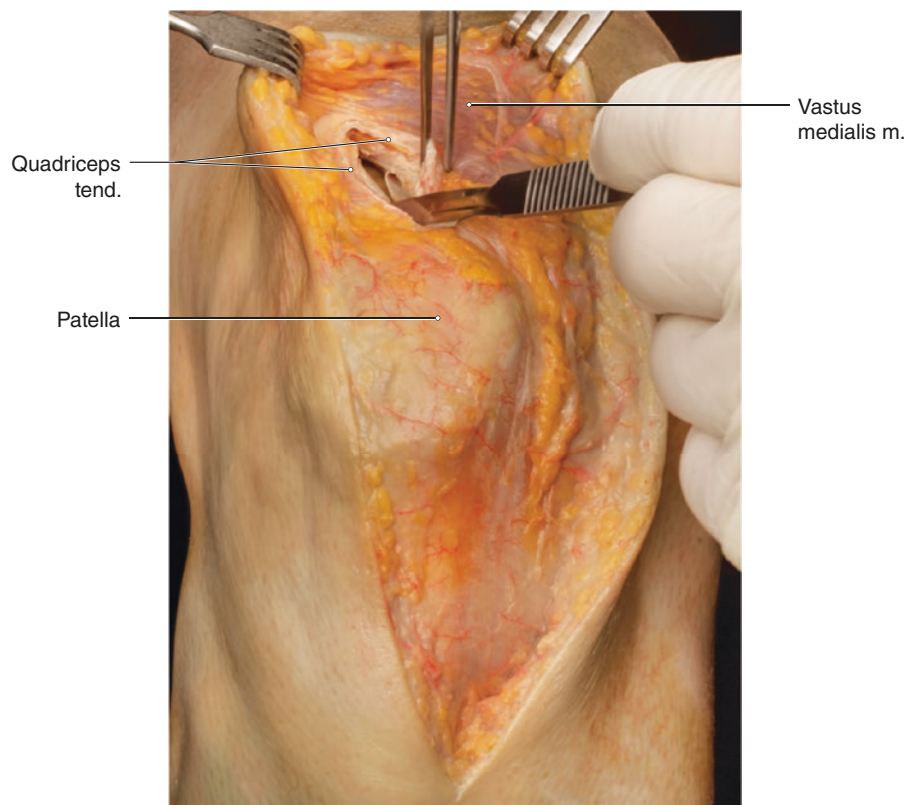


Fig. 14.7 Cut through the medial edge of the quadriceps tendon near its insertion to the patella and make a full-thickness incision into the joint. At the medial edge of the quadriceps tendon, leave enough tissue to allow side to side repair for closure

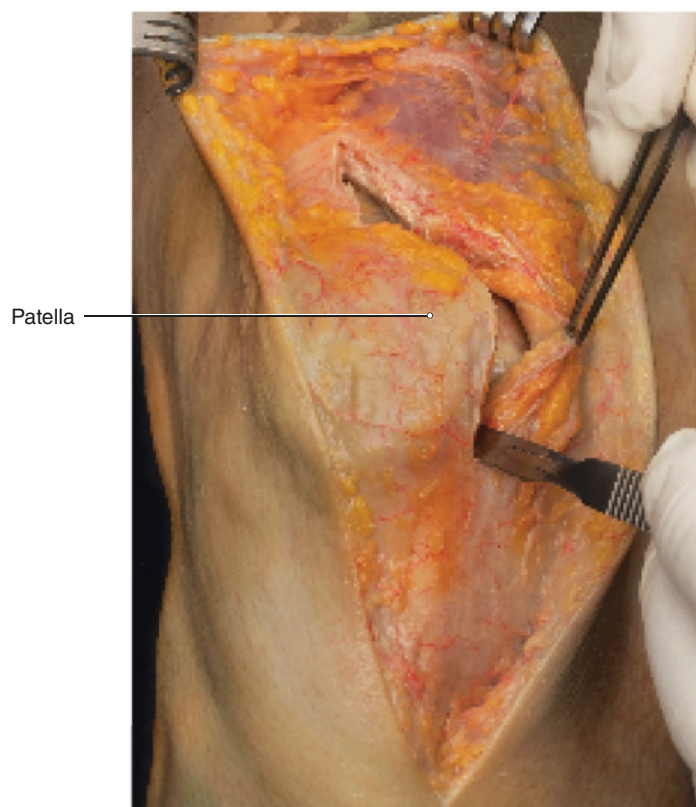


Fig. 14.8 Extend the arthrotomy along the medial edge of the patella, leaving enough strong tissue for closure

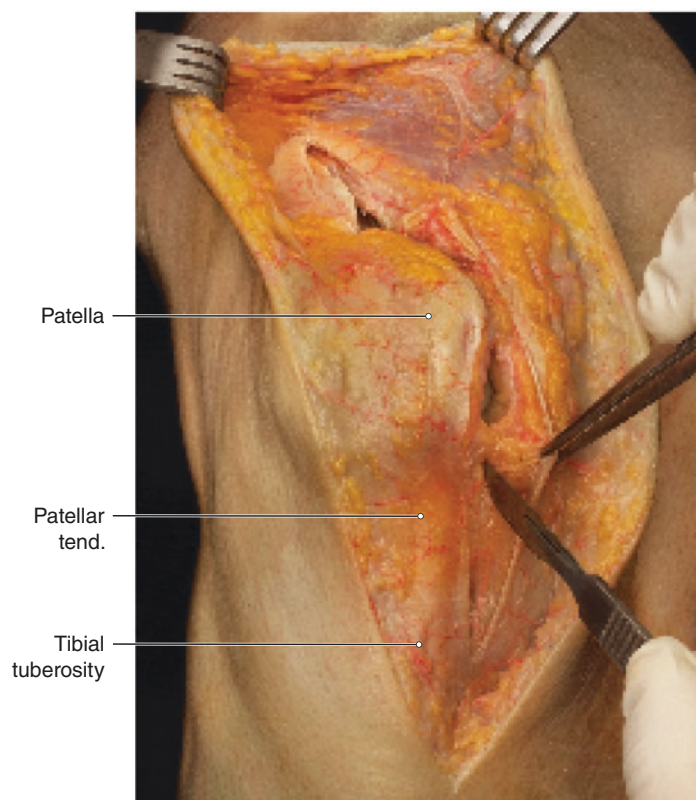


Fig. 14.9 Extend the incision distally until the joint line

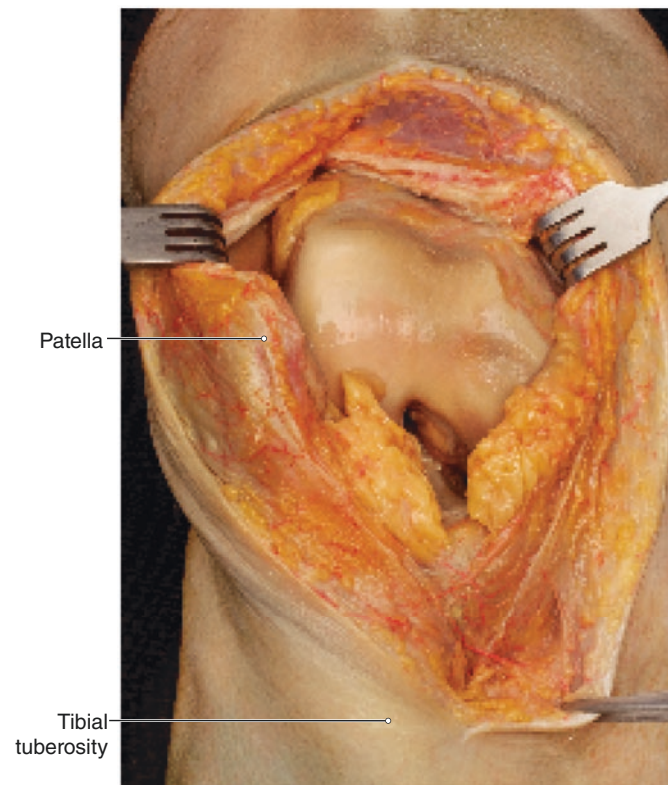


Fig. 14.10 Extend the arthrotomy to the anterior horn of the medial meniscus and the medial slope of the tibial tuberosity, ending 2 cm distal to the joint line. The patella can now be sublaxed

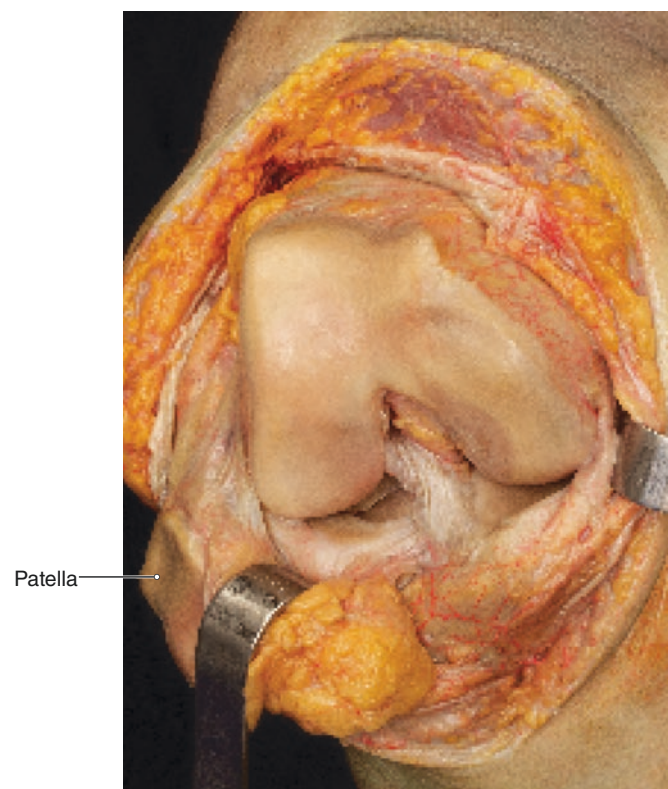


Fig. 14.11 Flex the knee to 30°. Excise the infrapatellar fat pad and synovium but leave the capsule in place

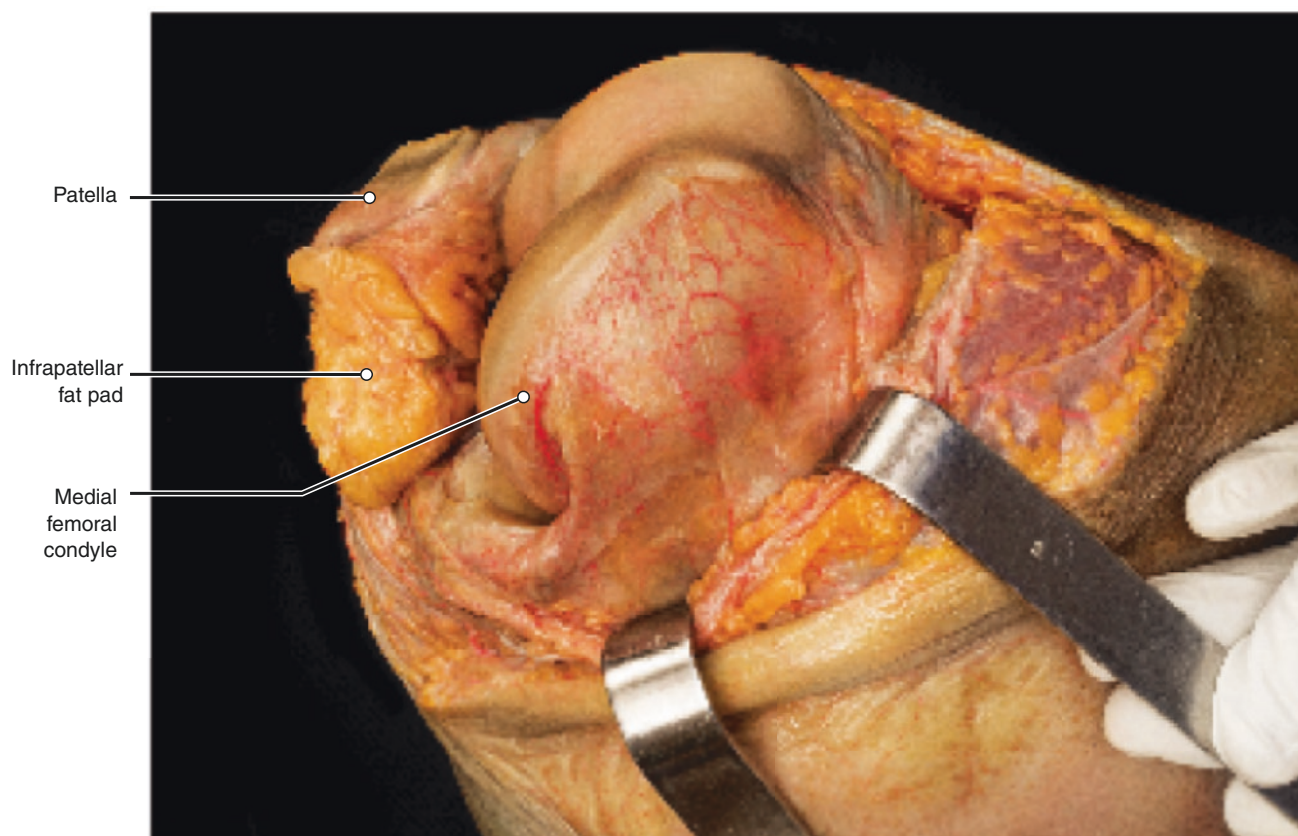


Fig. 14.12 Hyperflex the knee and subluxate the patella laterally to expose the distal femur and tibial plateau

Expose the proximal tibia medially. Elevate the medial joint capsule subperiosteally, creating an inverted triangle. Externally rotate the tibia to maintain tension on the medial joint capsule and facilitate dissection.

Extend the knee and continue to elevate the medial capsule. Take care to not release the mid-third medial capsule (deep medial collateral ligament) from its attachment to the tibia. Expose the anterior surface of the distal femur by excising synovium and fat from the superior patellar pouch. Retract the patella laterally and anteriorly to expose lateral synovium.

Hyperflex the knee and subluxate the patella laterally to expose the distal femur and tibial plateau (*see* Fig. 14.12).

Excise the anterior cruciate ligament (ACL) and excise the posterior horn of the medial meniscus, taking care to preserve the posterior cruciate ligament if a cruciate-retaining knee implant is to be used. The tibia can then be externally rotated and translated anteriorly to expose the tibial plateau.

14.3 Midvastus Approach

The *midvastus approach* is a medial exposure that preserves the vastus medialis muscle insertion (*see* Fig. 14.1). It can be used for primary TKA and medial UKA but is usually used for minimally invasive TKA. The exposure is contraindicated and is difficult in muscular and obese patients, knees

that have limited motion, patellar baja, large deformities, and knees that have had prior surgery.

Reported advantages of this approach are preservation of the extensor mechanism and maintenance of patellar stability [5–7]. However, studies have not shown any difference between the midvastus and medial parapatellar approaches in post-operative strength [8, 9]. If care is taken at the proximal extent of the approach, the patellar blood supply can be preserved, as with the subvastus approach.

14.3.1 Technique

Incise the skin as shown in Fig. 14.3. Develop a full-thickness skin flap dissecting to 1 cm medial to the medial edge of the patella. Do not incise the fascia that overlies the vastus medialis muscle and do not develop the skin flap laterally.

Begin the arthrotomy along the medial edge of the patella and the patellar tendon leaving 2–3 mm of capsule along the medial edge of the patella to allow repair. Extend the arthrotomy to the medial slope of the tibial tuberosity, which is about 2 cm distal to the joint line. Excise the synovium, infrapatellar fat pad, and anterior third of medial meniscus. Proximally extend the arthrotomy to several centimeters above the patella.

Expose the proximal tibia medially by elevating the medial joint capsule from the bone in an inverted triangle.

Extend the knee and continue to elevate medial capsule but do not release the mid-third medial capsule (deep medial collateral ligament) attachment to the proximal tibia. With the knee in extension, expose the anterior surface of the distal femur by excising synovium and fat from the suprapatellar pouch. Retract the patella laterally.

Hyperflex the knee and subluxate the patella laterally to expose the distal femur and tibial plateau. Excise the ACL and transect the posterior horn of the medial meniscus. Preserve the posterior cruciate ligament (PCL) if a cruciate-retaining knee implant is to be used. The tibia can then be externally rotated and translated anteriorly to expose the tibial plateau.

14.4 Subvastus Approach

The *subvastus approach* is a medially based exposure that preserves the vastus medialis insertion (see Fig. 14.1). It can be used for primary TKA and for medial UKA. Proponents of the approach point out that preservation of the extensor mechanism improves patellar stability [10], allows early return of quadriceps function [11–13], and preserves quadriceps strength [2, 11, 14]. If care is taken at the proximal extent of the exposure, the patellar blood supply can be preserved [15]. Disadvantages of the approach include its technically difficult and the limited exposure it gives. This is a problem in muscular and obese patients, and those who have limited knee motion or have had prior knee surgery [2, 11, 14]. There is also concern for additional complications, such as less accurate prosthesis placement and resultant component loosening or failure [14, 16, 17].

Contraindications for this approach include muscular patients, patients who have limited knee motion, patellar baja, large deformities, and revision surgery [2, 15].

14.4.1 Technique

Incise the skin as shown in Fig. 14.4. Develop a full-thickness skin flap dissecting to 1 cm medial to the medial edge of the patella. Incise the deep fascia along the medial edge of the patella and patellar tendon but not at the vastus medialis. Do not develop the skin flap laterally.

Incise along the medial edge of the patella leaving 2–3 mm of capsule along the medial border of the patella to allow repair. Extend the arthrotomy distally along the medial edge of the patellar tendon being careful of the tendon. A small perforating branch of the inferior medial genicular artery often marks the medial edge of the patellar tendon.

Extend the arthrotomy distally to the medial slope of the tibial tuberosity, ending 2 cm distal to the joint line. Excise

the infrapatellar fat pad and anterior third of medial meniscus. Extend the arthrotomy proximally to the insertion of the vastus medialis. Continue the incision along the medial border of the vastus medialis at an angle of about 50° for 10 cm but do not enter Hunter's canal. Carefully elevate the vastus medialis from the medial intermuscular septum. Distally expose the medial proximal tibia by subperiosteally elevating the medial joint capsule in an inverted triangle. Rotate the tibia externally to relax the tissues.

Extend the knee and continue to elevate the medial capsule from just below the tibial plateau but do not release the mid-third medial capsule (deep medial collateral ligament) from the tibia. With the knee in extension, expose the anterior surface of the distal femur by excising synovium and fat from the superior patellar pouch.

Hyperflex the knee and subluxate the patella laterally to expose the distal femur and tibial plateau. Excise the ACL and excise the posterior horn of the medial meniscus, taking care to preserve the posterior cruciate ligament if a cruciate-retaining knee implant is to be used. Externally rotate the tibia to expose the tibial plateau.

14.5 Lateral Parapatellar Approach

The *lateral parapatellar approach* was initially described for knees that have valgus deformities [18, 19] (see Fig. 14.1). This approach allows easy access to tight lateral structures and gives access to all compartments of the knee. It can be used for TKA and lateral UKA [19, 20] and can be modified for a minimally invasive surgical approach [21, 22]. If a lateral UKA is converted to a TKA, there is concern for devascularization of the patella if the second surgery is done through a medial parapatellar approach. Closure can be difficult after tight lateral tissues have been released and the valgus knee has been straightened [18, 22]. Additionally, most TKA surgical instrumentation is designed for medial approaches which makes this approach technically challenging [22].

14.5.1 Technique

Incise the skin as shown in Fig. 14.4 or move the skin incision laterally to limit the need to elevate a large skin flap. With the knee in flexion, develop a full-thickness skin flap dissecting to 1 cm lateral to the lateral edge of the patella.

Starting 3 cm proximal to the superior pole of the patella, perform the arthrotomy along the lateral border of the quadriceps tendon and lateral border of the patella, leaving enough strong tissue to allow repair. Extend the arthrotomy distally along the lateral edge of the patellar tendon and continue lateral to the tibial tubercle for about 2 cm. Expose the lateral tibia by subperiosteally elevating the lateral joint

capsule in an inverted triangle. Externally rotate the tibia to relax the tissues. Expose the anterior surface of the distal femur by excising the synovium and fat from the suprapatellar pouch.

Hyperflex the knee and subluxate the patella medially to expose the knee. Excise the ACL and transect the posterior lateral meniscus. Preserve the PCL if cruciate-retaining knee implant is to be used.

14.6 Extensile Approaches

The following extensile approaches are often used for revision arthroplasty or complex TKA for knees that have severe deformities. The quadriceps snip and V-Y turn down are extensions of the commonly used medial parapatellar approach (q.v.).

14.6.1 Quadriceps Snip

If adequate exposure cannot be achieved with a medial parapatellar approach, a “quadriceps snip” can be added. This involves extending the superior incision at the apex of quadriceps tendon obliquely across quadriceps tendon at a 45° angle into vastus lateralis muscle (see Fig. 14.13).

Most revision TKAs can be performed with good soft tissue release and quadriceps snip. In a study of 121 revisions arthroplasties with intact extensor mechanisms, adequate exposure was achieved in 91.7% of knees in the study but the complication rate was 23% [4].

The quadriceps snip does not give as much exposure as can be achieved with a V-Y turn down or tibial tuberosity osteotomy. In very stiff knees, the quadriceps snip may not be enough.

The benefit of the quadriceps snip is that the post-operative rehabilitation protocol and the outcomes are similar compared to knees that have had a standard medial parapatellar approach [16, 23].

14.6.1.1 Technique

This exposure is a proximal and lateral extension of medial parapatellar approach. Extend the incision proximally through the quadriceps tendon until the apex of the quadriceps tendon. Then continue to cut laterally in a 45° oblique angle in line with the fibers of the vastus lateralis muscle, leaving 2–3 mm of the tendon intact for later closure.

14.6.2 V-Y Turn Down

In the V-Y turndown approach, the incision in the quadriceps tendon is extended proximally and then turned down toward the lateral retinaculum. It provides excellent exposure. In

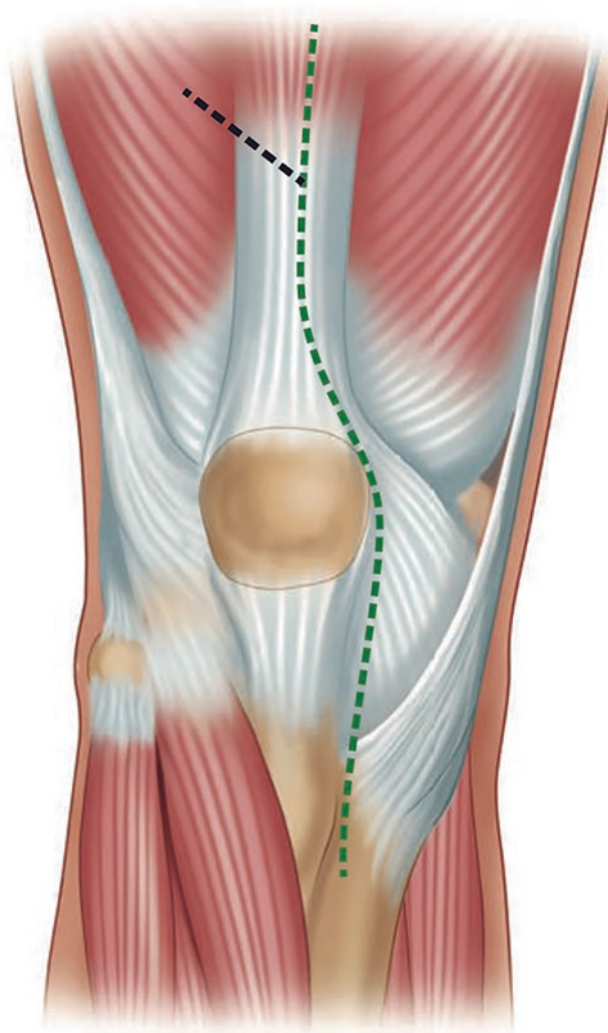


Fig. 14.13 Medial parapatellar approach (green dotted line) with quadriceps snip (black line) extensile approach for knee arthroplasty

knees in which the extensor mechanism is severely shortened, the V-Y turn down has the added advantage of allowing the extensor mechanism to be lengthened. The V-Y turn down should be done carefully to preserve the lateral superior genicular artery. Post-operatively, the patient should wear a knee brace locked in extension for 6 weeks when ambulating [24] (see Fig. 14.14).

14.6.2.1 Technique

This exposure is an extension of medial parapatellar approach.

Extend the incision in the quadriceps tendon proximally at a 45° angle toward the vastus lateralis muscle. The length of this portion can be extended as much as necessary. Then make a sharp turn down toward the superior lateral part of

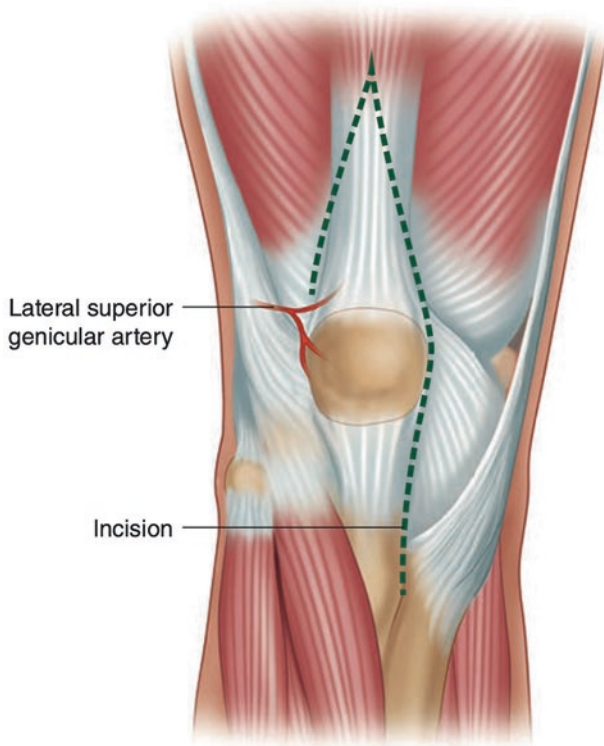


Fig. 14.14 V-Y turn down arthrotomy. Avoid extending the lateral arthrotomy past the superior pole of the patella to avoid compromising the lateral superior genicular artery

the patella. Do not extend this incision past the superior pole of the patella to avoid injury the lateral superior genicular artery. Cutting the lateral superior genicular artery would devascularize the patella.

14.6.3 Tibial Tuberosity Osteotomy

Detaching the tibial tuberosity and retracting it proximally together with the patellar tendon and patella gives excellent exposure of the knee. This approach is useful to remove a cemented tibial implant. However, the operation is difficult to perform and is fraught with potential complications, especially failure of the tibia tuberosity to reunite. Reported complications rates range from 7 to 23% and include extensor lag, wound healing problems, and tibial fractures [25, 26]. It is very helpful in the setting of patellar baja (see Fig. 14.15).

14.6.3.1 Technique

Extend the standard TKA skin incision distally for about 8–10 cm toward the medial slope of the proximal tibia. Using a small oscillating saw, make two lengthwise cuts in the anterior tibial crest 2 cm wide and 6–8 cm long.

Taper the cuts to make a triangular bone wedge that is 8–10 mm deep proximally and 5–7 mm deep distally. Cut the

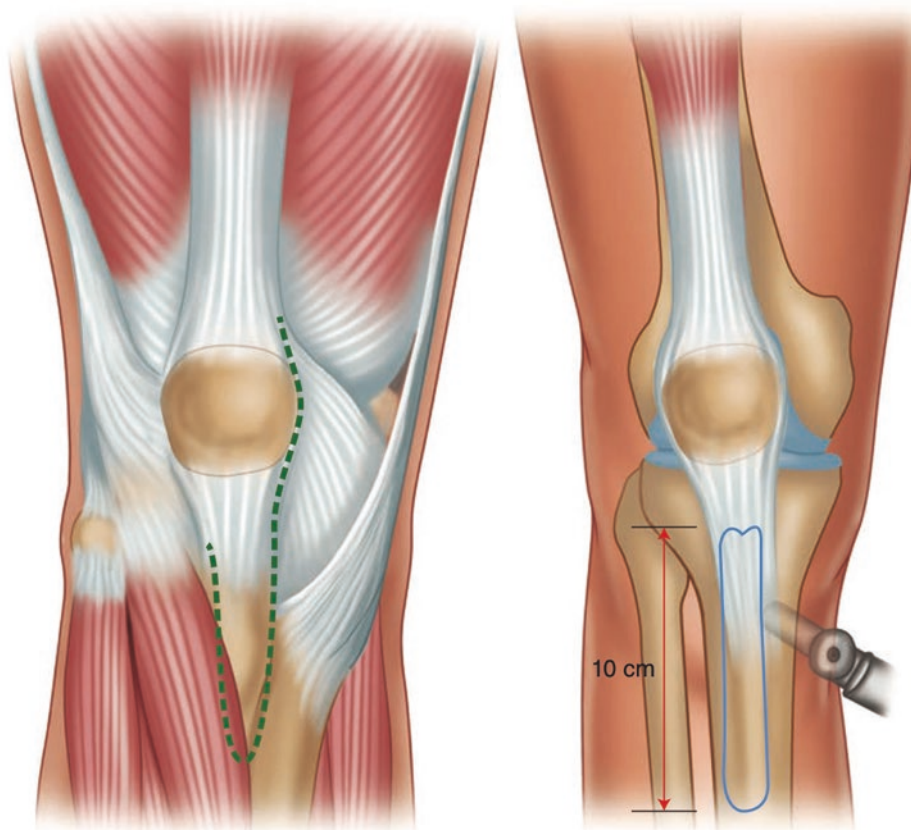


Fig. 14.15 Tibial tuberosity osteotomy with medial parapatellar arthrotomy. The osteotomy of tibial tuberosity is 10 cm long. Used in revision arthroplasty for improved knee exposure

bone block transversely at its distal end using the saw or a pencil tip burr. Use an osteotome to cut the bone block proximally parallel to the joint line. Use very wide osteotomes to elevate the tibial tuberosity, being careful not to fracture the bone.

The soft tissues can be released from the anterior lateral tibia to gain additional exposure. At the end of the procedure, the osteotomy can be repaired with cables passed posterior to the revision tibial stem or the posterior tibial cortex.

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15.1 General Technique

The placement of an arthroscopy portal is critical because it determines the view of the joint, determines the ease of introducing and maneuvering instruments, and helps to avoid critical anatomical structures.

15.1.1 The Start

Introduce a 21-gauge needle into the knee at the spot where you plan to make the portal. The angle of the needle should be the same as the angle of the proposed tunnel. If the needle does not hit an obstruction, it probably is a good location for the portal.

As you withdraw the needle, infuse the tissues with a local anesthetic plus epinephrine. The epinephrine will cause vasoconstriction and there will be less bleeding during the arthroscopy. Inject the solution even if the procedure is being performed under general anesthesia; it will give postoperative pain relief. If the procedure is done under local anesthesia, wait an appropriate length of time to achieve anesthesia and vasoconstriction.

15.1.2 Incision

There are three steps for making the incision for the portal:

1. Incise the skin (only) using a #11 surgical blade.
2. Easily glide the knife through the subcutaneous fat at the appropriate angle.

3. Cut the capsule at the angle you plan to introduce the arthroscope and instruments. For anterior knee portals, this is about 120° relative to the tibia.

Make *skin incisions* for arthroscopy portals in a vertical direction. A vertical incision can be extended in either vertical direction if the portal is misplaced. An exception is the skin incision for the anterior central (trans-patellar tendon) portal, which should follow Langer's lines in a transverse direction (skin only).

Be aware of two small neurovascular bundles that pierce the deep fascial in the anteromedial and anterolateral aspects of the knee. If cut, there will be excess bleeding during the arthroscopic procedure and residual numbness in front of the knee (*see* Figs. 15.1 and 15.2).

An #11 surgical blade cuts downward, so start the incision slightly higher than where you want to be. Memorize the angle of the tunnel—for anterior portals, it goes straight in through the subcutaneous fat and then downward to enter the joint. If you angle the instrument downward immediately under the skin, you will advance into the infrapatellar fat pad.

If there is a *critical superficial nerve* in the vicinity of the portal, such as the saphenous nerve posteromedially, make a slightly longer skin incision than usual. Do not advance the knife blade below the skin but spread the subcutaneous tissues with a fine clamp to push the tissues out of the way.

If the *length* of the tunnel is long, such as for a posterior knee portal, the procedure can be modified. Use a spinal needle to locate a spot where the needle passes freely. Leave the needle in place as a guide. Pass a #11 blade along the needle to create the tunnel. Then introduce a sheath with a blunt obturator into the joint through the tunnel and use a switching stick (also known as Wissinger rod) to guide the instruments.

At the end of the procedure, close each portal with a non-resorbable suture or use skin closure tapes to approximate the skin edges.

The commonly used portals for knee arthroscopy as well as useful accessory portals are shown in Fig. 15.3.

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Fig. 15.1 Right knee. Be aware of two small neurovascular bundles that pierce the deep fascia in the anteromedial and anterolateral aspects of the knee. If they are cut, there will be excess bleeding during the arthroscopic procedure and residual numbness in front of the knee

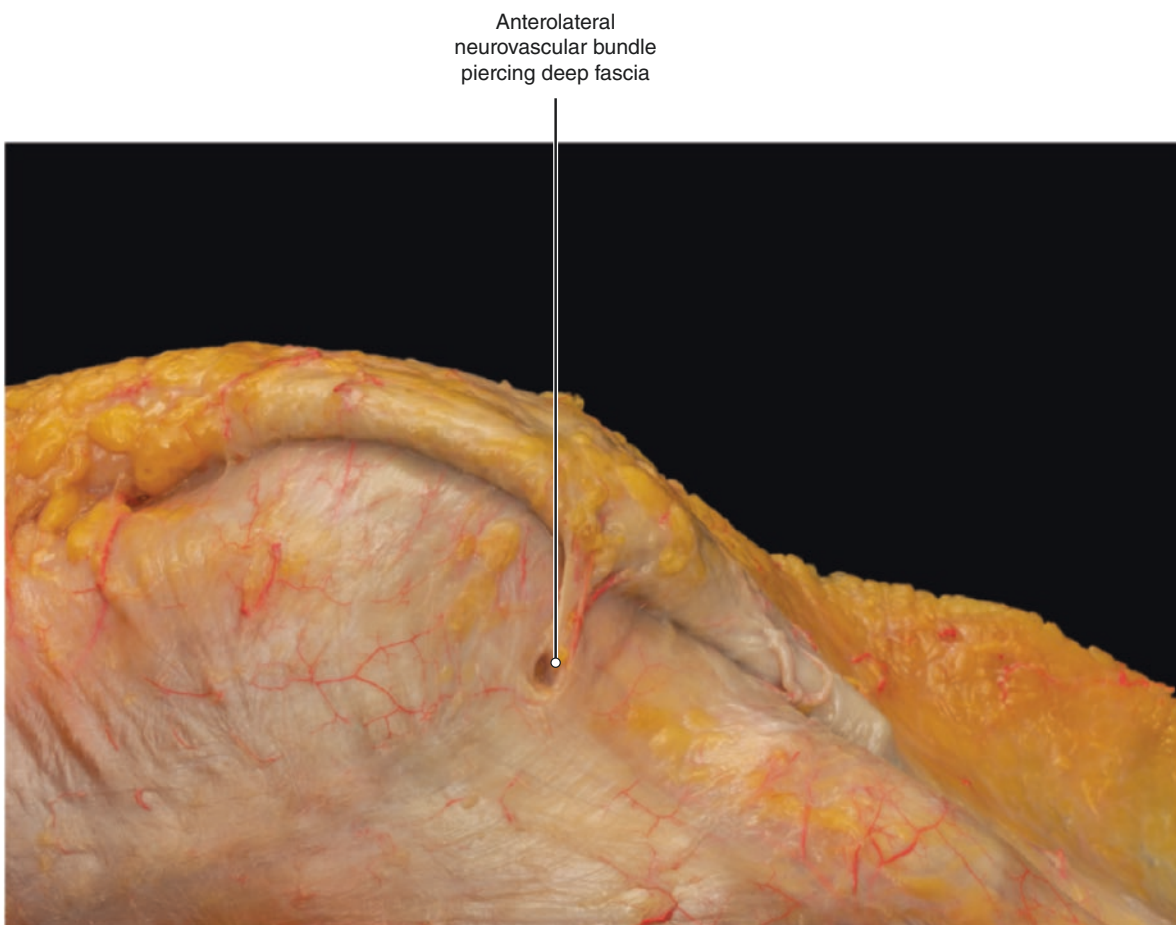


Fig. 15.2 Right knee. The skin and subcutaneous fat on the anterolateral side of the knee have been lifted. Note the superficial artery and nerve that pierce the deep fascia. This neurovascular bundle is sometimes cut when making an anterolateral arthroscopy portal

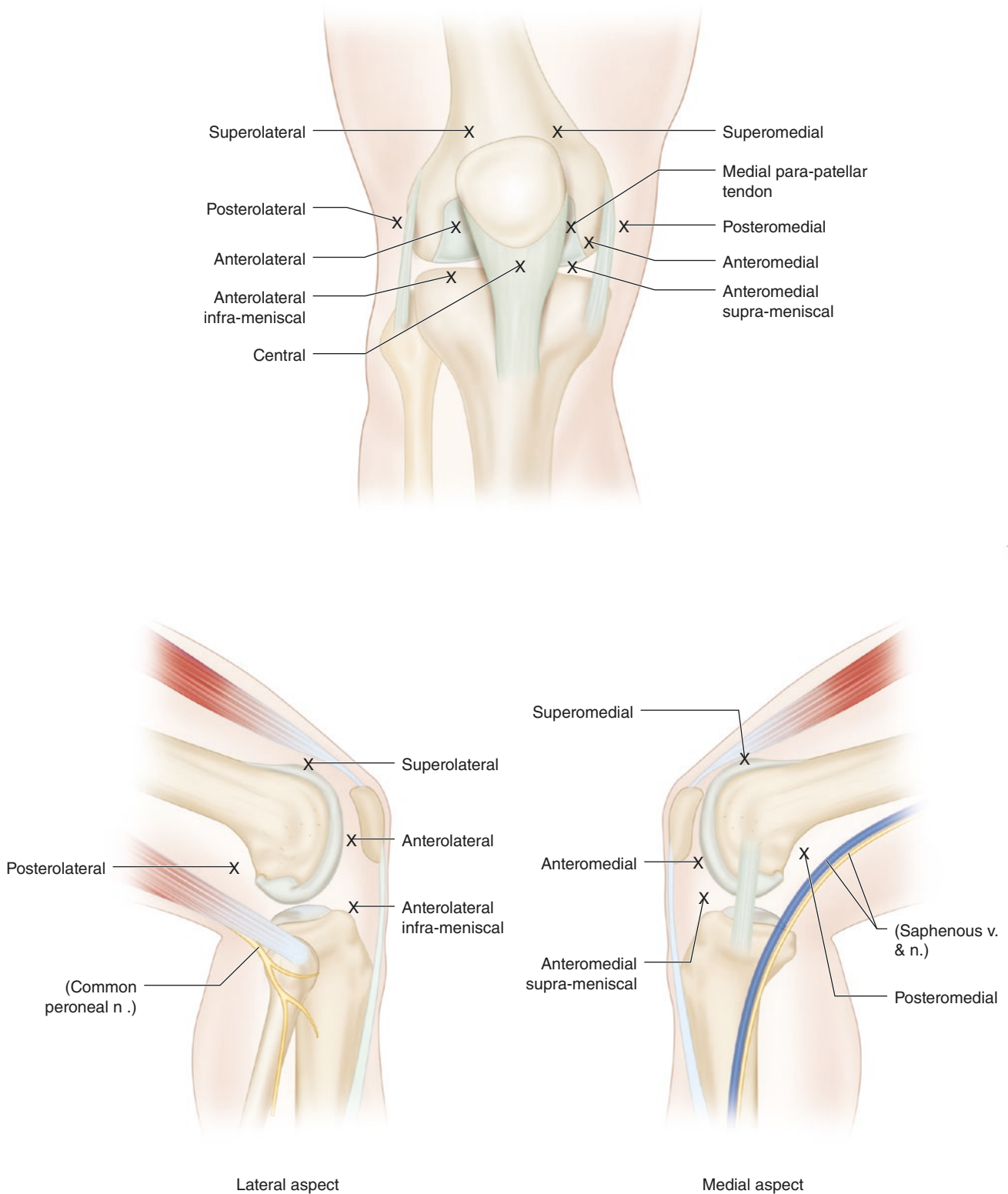


Fig. 15.3 Commonly used arthroscopy portals for the knee and accessory portals

15.2 Anterolateral Portal

The *anterolateral portal* is the standard portal for diagnostic arthroscopy. It is located toward the top of the “soft spot” on the anterolateral aspect of the knee. It is slightly proximal to the level of the inferior pole of the patella. The portal is about

2 cm above the joint line and slightly below the midline of the patella. The angle of the arthroscope in relation to the tibia upon entry is about 120° . It is important to keep the portal high to avoid the infrapatellar fat pad (see Figs. 15.4 and 15.5). Remember that the #11 blade cuts downward, so the tendency is to wind up with an anterolateral portal that is too low.

Fig. 15.4 (a) Anterior arthroscopy portals should be made high. This gives the best view of the top of the tibia. Note the angle of the arthroscope in relation to the tibia. (b) If the portal is low, the arthroscope and instruments go through the infrapatellar fat pad

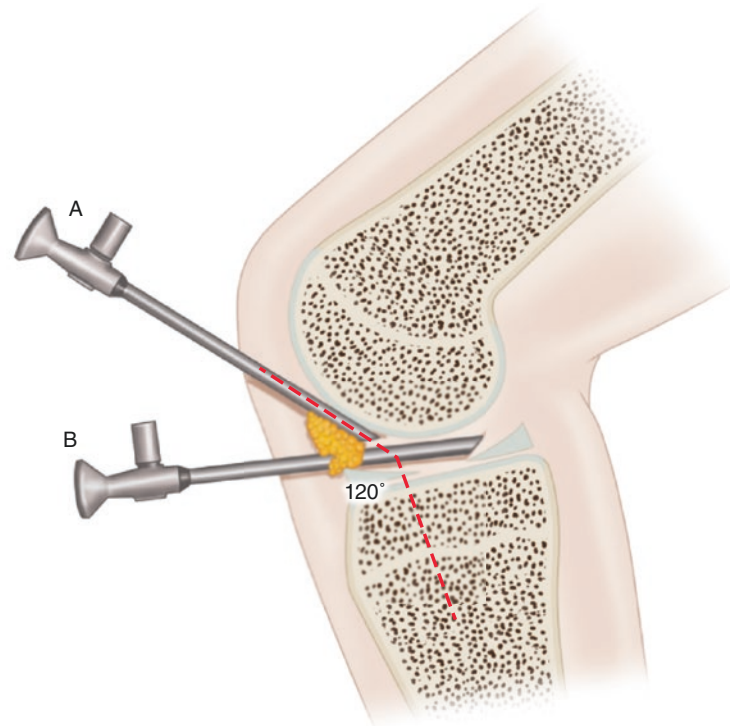
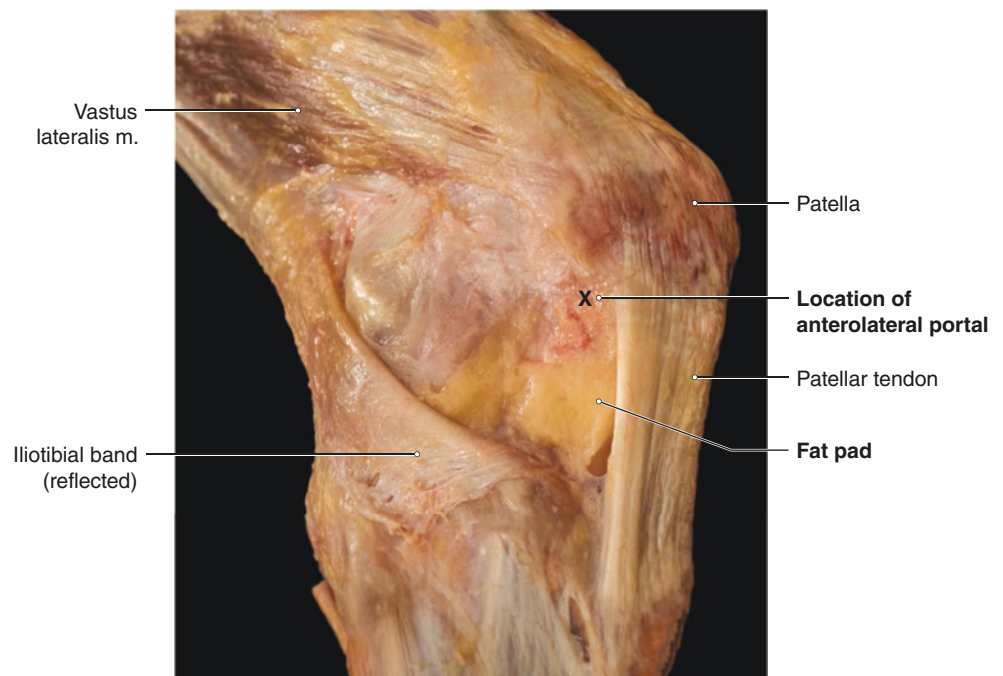


Fig. 15.5 The anterolateral portal should be located high in the “soft spot” of the anterolateral knee. The location is slightly proximal to the inferior pole of the patella and slightly below the midline of the patella. *It is important to keep the portal high to avoid the fat pad*



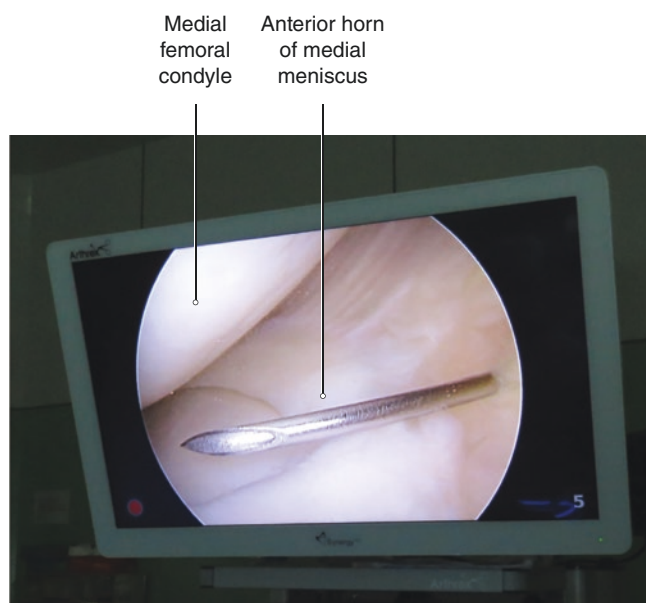


Fig. 15.6 To select a location for the anteromedial portal, view the compartment from the anterolateral portal with the arthroscope. Pass a trial needle into the joint from the anteromedial knee “soft spot.” If the portal is made too low, the incision can cut into the medial meniscus

15.3 Anteromedial Portal

The *anteromedial portal* is usually made after the diagnostic arthroscopy has been completed and a surgical plan has been made. Its location will vary depending on the procedure to be performed. While viewing from the anterolateral portal, pass a needle into the anteromedial joint to select the best location (see Fig. 15.6). To avoid cutting the medial meniscus do not make the portal too low.

15.4 Superior Portals

Superomedial and superolateral portals are routinely used to deliver irrigating fluid to distend the joint for arthroscopy (see Fig. 15.3). Operating and inflow portals can be made superomedially and superolaterally about 1 cm from the edges of the patella, respectively.

A problem with a superior portal that is used to deliver fluid is that it shuts down when the knee is flexed. A central (trans-patellar tendon) portal provides better inflow when working in the anterior aspect of the flexed knee.

15.5 Anterior Central Portal (Trans-Patellar Tendon)

The *central portal* is the best portal for inflow when operating in the anterior knee in flexion. It can also be used as an operating or viewing portal when needed, but the space between the arthroscope and instruments that are in anterolateral and anteromedial portals is close and, therefore, the angles of triangulation are small.

Make a small superficial transverse incision in the skin overlying the center of the patellar tendon. Do not cut deeply into the tendon, but just pop the trocar and cannula through the tendon.

15.6 Medial Para-Patellar Tendon Portal

The *medial para-patellar tendon portal* is located next to the medial edge of the inferior pole of the patella. This portal is useful to visualize the posterior compartment and to introduce instruments for PCL reconstruction.

Direct a spinal needle toward the lateral aspect of the medial femoral condyle to confirm the location and avoid injury to the patellar tendon.

15.7 Posteromedial Portal

To find the spot for a posteromedial portal, palpate the soft area behind the medial femoral condyle. It is bordered by the semitendinosus tendon, the medial femoral condyle, and the medial head of gastrocnemius muscle. The correct spot is about 1 cm proximal to the joint line and 5 mm posterior to the posterior margin of the medial femoral condyle. To assist in locating the proper spot, pass the arthroscope through the intercondylar notch into the pos-

teromedial knee. Shine the light through the posteromedial capsule and look for the transillumination (*see* Fig. 15.7). Push on the skin and look with the arthroscope for motion of the capsule. Pass a trial needle into the joint from that location and see if it looks good (*see* Figs. 15.8 and 15.9). The postero-medial portal must be carried out under intraarticular direct vision to increase the accuracy of the procedure.

There are two important anatomical structures posteromedial that are at risk when making a posteromedial portal: the great saphenous vein, which is superficial, and the saphenous nerve, which is deeper. Stay above both the vein and the nerve (*see* Fig. 15.10).

1. The *great saphenous vein* is located posterior and inferior to the proper posteromedial portal. It is very superficial. The vein is close to the back of the knee joint when the knee is extended. When the knee flexes, the vein moves away from the joint (*see* Fig. 15.11).
2. The *saphenous nerve* is also located somewhere posterior and inferior to the portal. Its location is variable, but it is somewhere near the musculotendinous junction of the sartorius (*see* Fig. 15.12) [1].

Both the vein and the nerve are much closer to the posteromedial capsule when the knee is extended than flexed. Therefore, **make the posteromedial portal with the knee at 90° flexion** [2].

An *accessory posteromedial portal* can be added 1 cm proximal to the posteromedial portal that has been made.

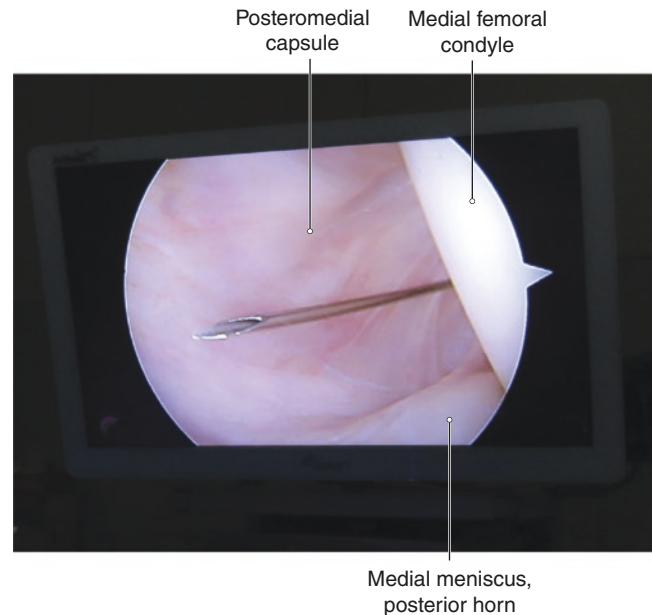


Fig. 15.8 View the location of the trial needle with the arthroscope

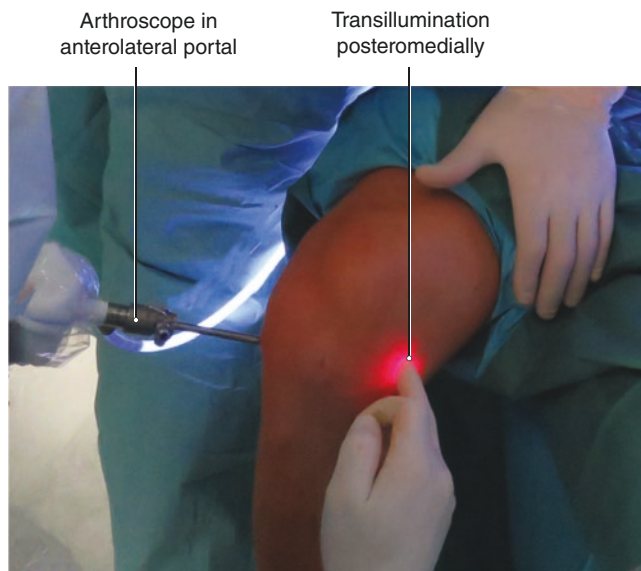


Fig. 15.7 To select the proper location for the posteromedial portal, pass the arthroscope through the intercondylar notch into the posteromedial knee. Shine the light through the skin and look for the transillumination. Push on the skin and look with the arthroscope for motion of the capsule

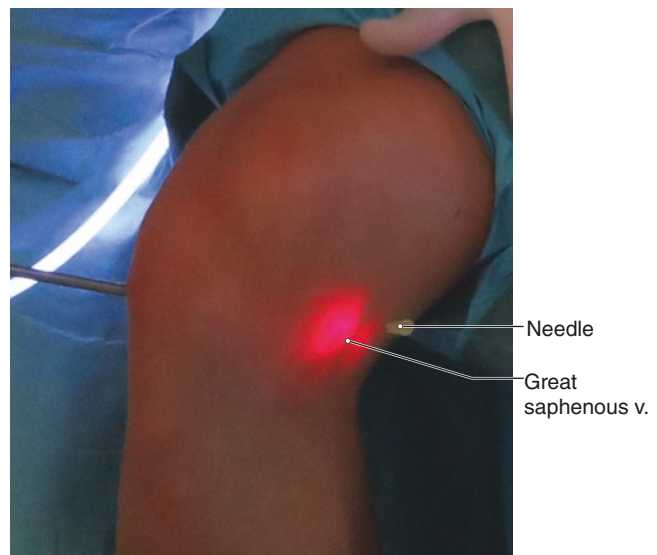


Fig. 15.9 Pass a trial needle into the posteromedial joint. Note the shadow of the great saphenous vein



Fig. 15.10 Posteromedial anatomic structures that are at risk with posteromedial portal: great saphenous vein (superficial) and saphenous nerve (deep)

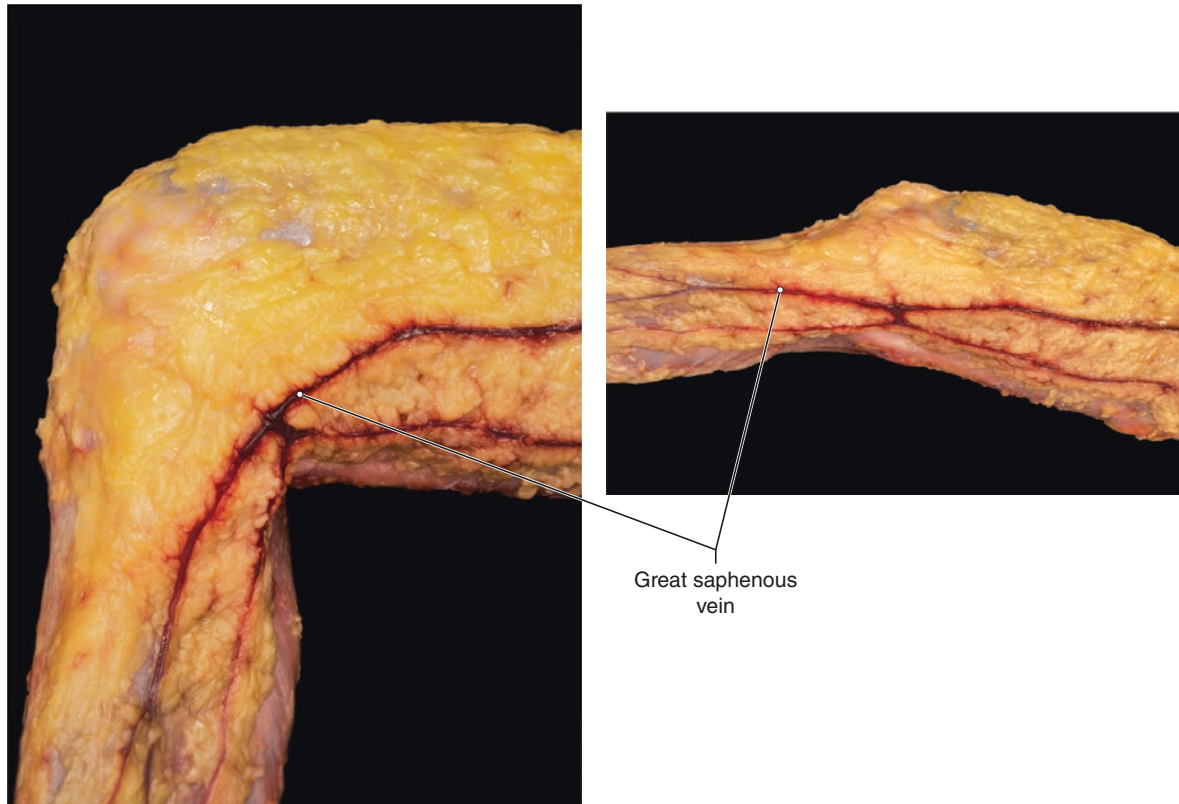


Fig. 15.11 The *great saphenous vein* is superficial. It is located further from the posterior aspect of the knee in flexion (a) compared to extension (b)

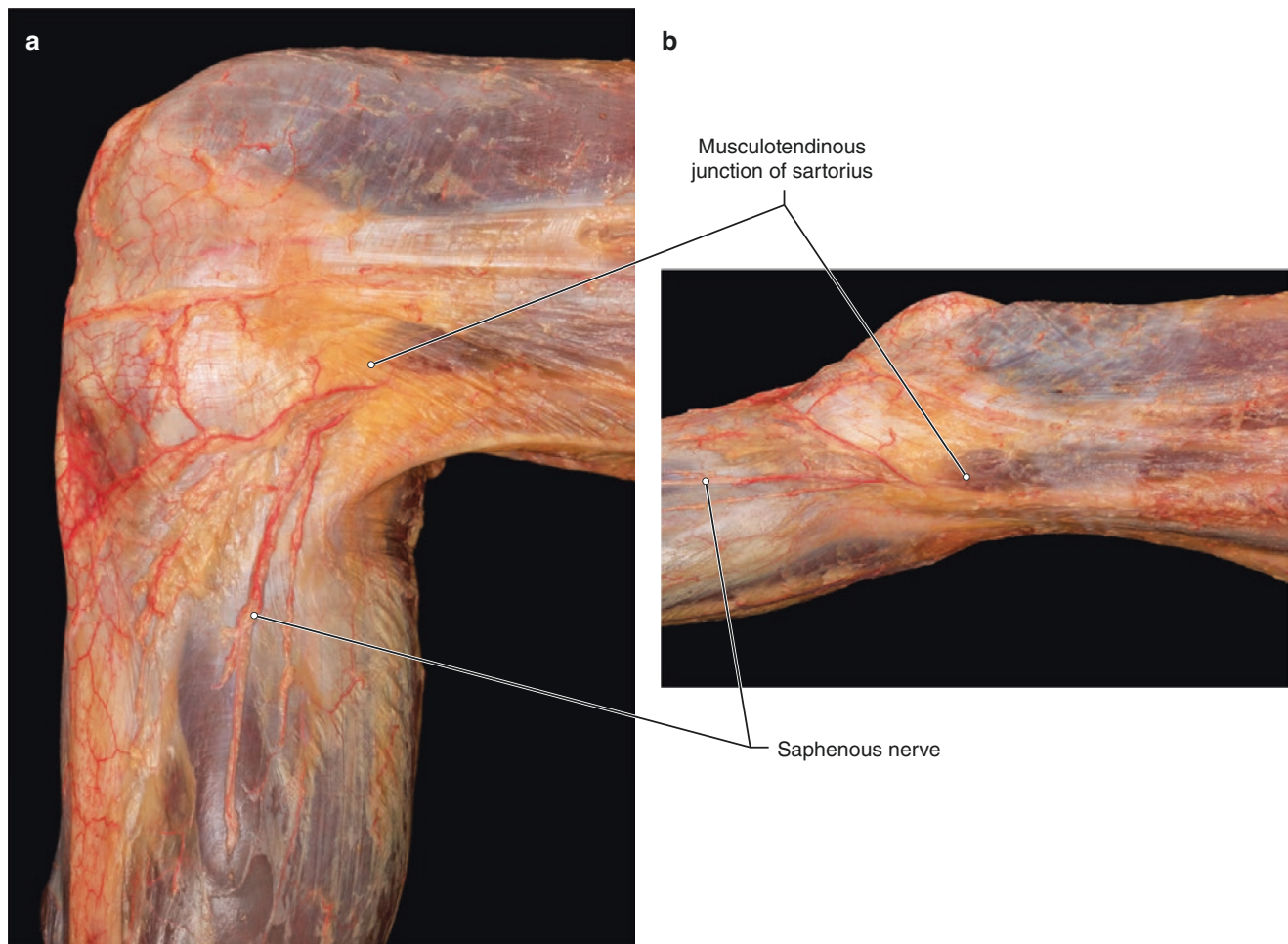


Fig. 15.12 The *saphenous nerve* becomes superficial somewhere near the musculotendinous junction of the sartorius. It is further from the posterior aspect of the knee in flexion (a) compared to extension (b)

15.8 Posterolateral Portal

With the knee at 90° flexion, the posterolateral portal should be made below the iliotibial band, above the biceps femoris tendon, and behind the lateral femoral condyle [3, 4] (see Fig. 15.13).

The common peroneal nerve is located behind and medial to the biceps femoris tendon. It is very close to the knee joint when the knee is extended. **The popliteal artery also moves away from the posterior capsule when the knee is flexed.**

The postero-lateral portal must be carried out under intraarticular direct vision to increase the accuracy of the procedure.

Precaution

Be aware of possible anatomical variations of the popliteal artery (see Fig. 1.48).

Precaution

It is critically important to keep the knee at 90° flexion when making posterior portals to reduce the risk of injuring the neurovascular structures.

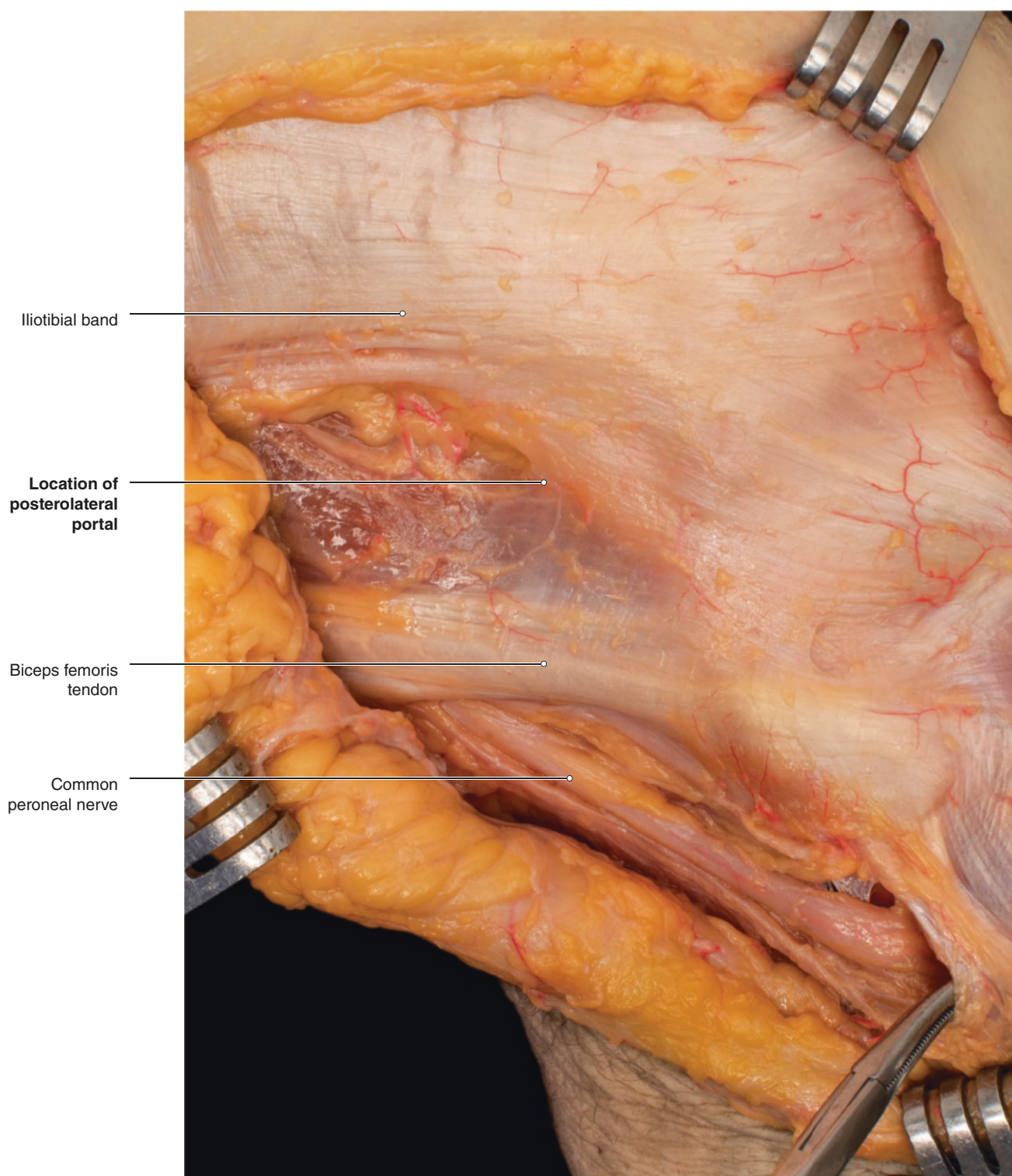


Fig. 15.13 When making a posterolateral portal, stay below the iliotibial band (tract). Stay above the biceps femoris tendon to avoid the common peroneal nerve. Aim the portal anteriorly to avoid hitting the popliteal artery

15.9 Trans-Septal Portal

There is a septum that divides the medial from the lateral posterior compartments of the knee. It is triangular, and it extends from the posterior cruciate ligament (PCL) to the posterior joint capsule (see Fig. 15.14). This septum can be removed to increase the field of view.

When viewing from the postero-medial portal, it is possible to visualize the posterior and postero-superior parts of the lateral femoral condyle, the posterior horn of the lateral

meniscus, the posterior aspect of the popliteal tendon, the posterior and inferior portions of the PCL and the posterior meniscofemoral ligament (ligament of Wrisberg), and the posterior capsule.

When viewing from the postero-lateral side of the joint, it is possible to visualize the posterior and postero-superior parts of the medial femoral condyle, the posterior horn of the medial meniscus, the posterior and inferior portion of the posterior cruciate ligament, the posterior meniscofemoral ligament (ligament of Wrisberg), and the posterior capsule [4].

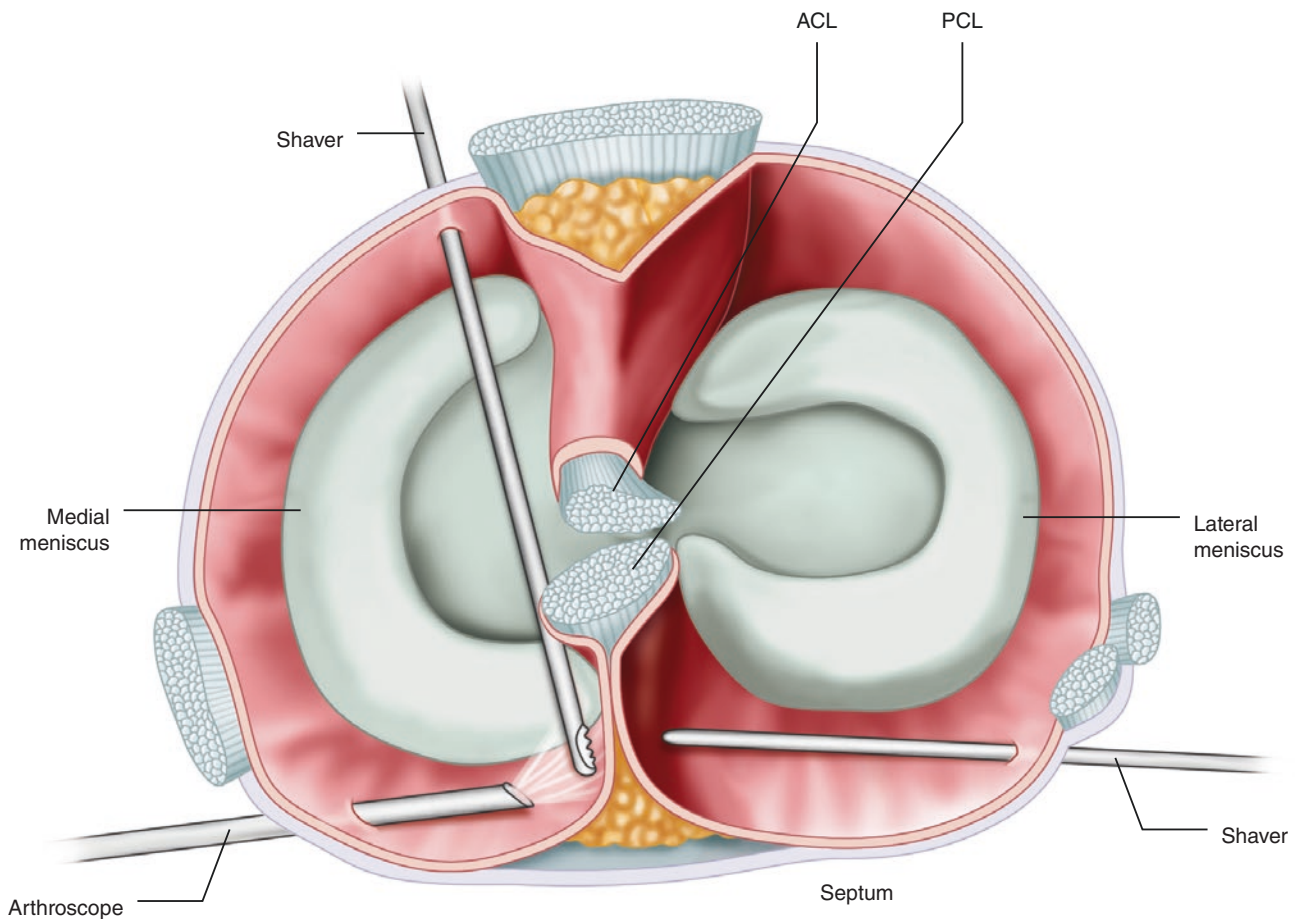
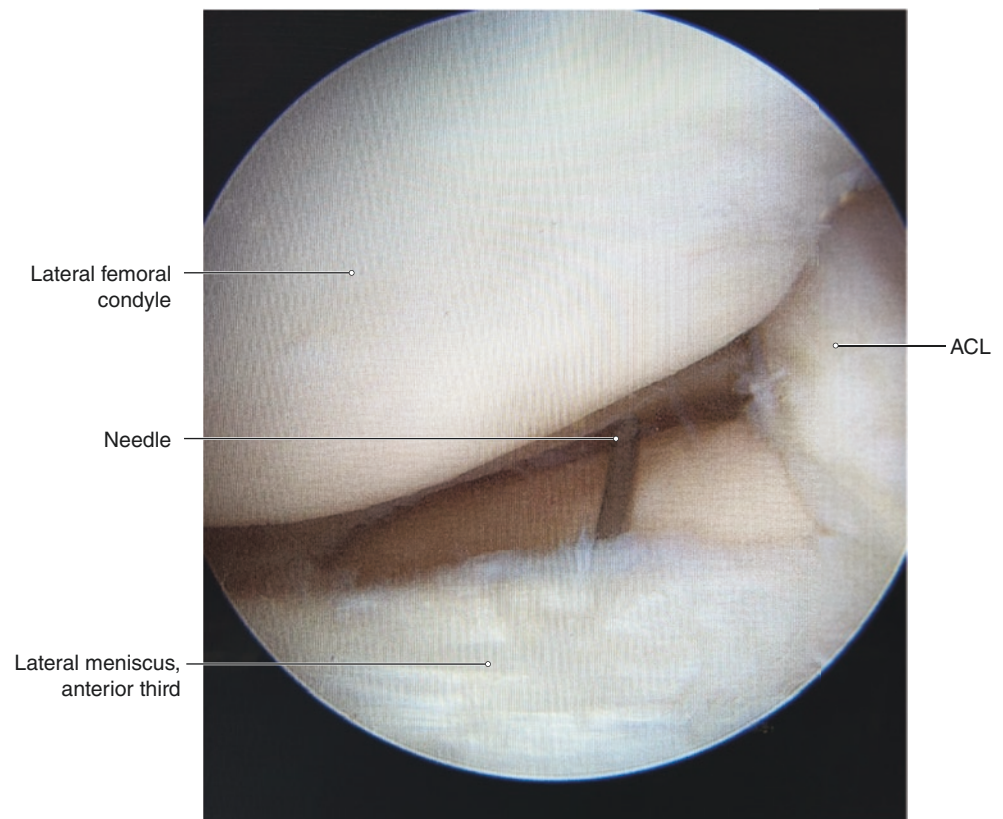


Fig. 15.14 Posterior *transseptal* portal for arthroscopic knee surgery

Fig. 15.15 An accessory anterolateral infra-meniscal portal directly above the tibial plateau is useful to access and work on the anterior horn of the lateral meniscus



15.10 Anterolateral Infra-Meniscal Portal

An accessory anterolateral infra-meniscal portal directly above the tibial plateau is useful to access and work on the anterior horn of the lateral meniscus. It is performed under direct arthroscopic visualization with the arthroscope in the anteromedial portal (*see* Fig. 15.15).

15.11 Anteromedial Supra-Meniscal Portal

An accessory anteromedial supra-meniscal portal is useful for working on the posterior third of the medial meniscus (*see* Fig. 15.3). To find the best location, pass spinal needle just above the anterior third of the medial meniscus while viewing from the anterolateral portal.

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