The Infrapatellar Fat Pad and Plica: Gross Anatomy, and Histology Suggesting that the Infrapatellar Plica Functions as an Intra-articular Ligament: A Preliminary Report

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Purpose

This study seeks to demonstrate the gross anatomy and histology of the infrapatellar fat pad (FP) and infrapatellar plica (IPP) with a view to emphasizing that they are part of a structural and biomechanical continuum one function of which is to transmit force. The histology of these structures has not been reported in the orthopaedic literature.

Background

Anatomy: The FP and IPP are viewed in isolation with respect to the rest of the synovial membrane in standard texts and in the arthroscopic literature (Figures 1 and 2). Gallagher provided a complete review of the gross anatomy of the FP (3 Gallagher,J. 2005) the study was deficient in that no specimen was without an IPP, and there was no histology performed.

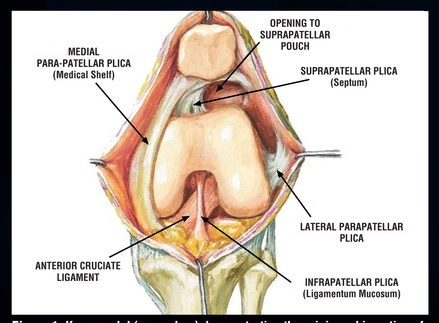


Figure 1: Knee model (opened up) demonstrating the origin and insertion of common synovial plicae. For better visualisation patellar tendon detached from the tibial tuberosity and patella reflected superiorly. 'Reproduced by kind permission of Icon Learning Systems LLC, Yardley/Pennsylvania, a division of MediMedia USA Inc. (copyright holder), from the Netter Collection of Medical Illustrations, Volume 8: Musculoskeletal System, Part 11'.

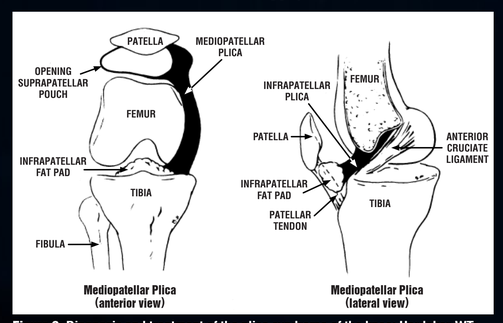


Figure 2: Diagnosis and treatment of the plica syndrome of the knee: Hardaker,WT; Whipple,TL; Bassett,FH:J.Bone Joint Surg.Am., 1980, 62, 2, 221-225.

The typical descriptions of the IPP would be as follows: it is a synovial fold that originates from the inter-condylar notch of the femur, runs parallel to and above the anterior cruciate ligament, and attaches to the infrapatellar fat pad. (1 Boyd, C.R. 2005; 6 Kim, S.J.; 7 Kim,S.J. 1996; 5 Hardaker,WT 1980). These descriptions suggest that the IPP ends at the FP. They do not take into account historic anatomic descriptions: "…On either side of the patella, the synovial membrane extends beneath the aponeuroses of the Vasti, and more especially beneath that of the Vastus medialis. Below the patella it is separated from the ligamentum patellæ by a considerable quantity of fat, known as the infrapatellar fat pad. From the medial and lateral borders of the articular surface of the patella, reduplications of the synovial membrane project into the interior of the joint. "These form two fringe-like folds termed the **alar folds**; below, these folds converge and are continued as a single band, the patellar fold *(ligamentum mucosum)*, to the front of the intercondyloid fossa of the femur…"(4 Gray, H. 2005) The ligamentum mucosum is the IPP.

Anatomical Summary: Inherent in this historical description is the implication that synovial membrane is continuous from the undersurface of the vasti to the distal femur, and distally. By contrast, in both figures 1 and 2, the IPP is shown as simply ending in the FP. The mediopatellar plica is also shown in figure 2 to end in the FP.

Histology: Fat Pad – No overview in the current literature.

Infrapatellar Plica –In 1978 Wachtler (10 Wachtler, F. 1979) described the histology of the IPP, but did not show it. His view of the IPP – *an embryological remnant of a septum separating the medial and lateral femoro-tibial compartments of no mechanical importance*. The IPP is considered not be of clinical importance (5 Hardaker,WT 1980; 8 Kim,S.J. 2002; 9 O'Dwyer, KJ 1988). Other authors (1 Boyd,C.R. 2005; 2 Demirag, B. 2006) have noted that arthroscopic release of the IPP successfully (in 90%) relieves anterior knee pain.

Histological Summary: *There is an absence of data on the histology of the FP and IPP. As structure and function are irrevocably linked in biology, the objective of this study was to review this basic anatomical and histologic information and determine the potential biomechanical function of these structures.*

Method

Twelve fresh-frozen cadaver knees (8 with IPPs and 4 without) were dissected, lifting the extensor apparatus from the femur and reflecting it 180º. Synovial relationships relationships were examined, recorded, and compared to historical descriptions and current literature. Histological study of the FP and IPP was performed using hematoxylin and eosin, elastin, and trichrome stains.

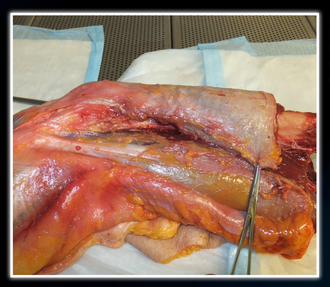


Figure 3: (Left) Instrument at intermuscular septum, poised to flip the extensor apparatus.

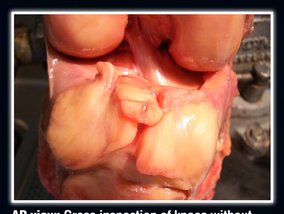
Figure 4: (Left) View from Lateral Side: Extensor apparatus flipped 180º: femur on R, patella above, lateral fibrous synovium below, lateral extension of FP merging with meniscus on R. Lateral alar fold crosses FP to become IPP.

Figure 5: (Left) View from above: notch below, FP between, lateral extension on L, medial extension on R, central body in notch, plica (not seen), alar folds wrap around patella through central body to become IPP.

Figure 6: (Left) View from medial side: Patella above, fibrous synovium under vasti passes distally to meniscus, wraps around patella to cross medial extension and become the IPP.

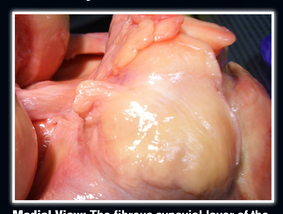
Results: Gross Anatomy

Fat Pad without Infrapatellar plica (4): *the 180º flip of the vasti shows the fibrous synovium bypassing the FP to the upper surface of the menisci; there is no constraint on the central body; no potential distortion of central body and FP other than compression and shear.*



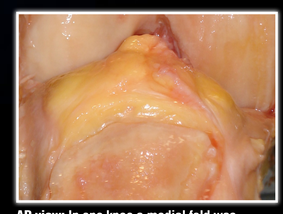
AP view: Gross inspection of knees without IPP (4) demonstrated FPs that were lobular, with medial lateral extensions, and a lobulated central body.

Lateral View: The fibrous synovial layer of the capsule bypassed the FP, inserting on either side to the superior aspect of the menisci.



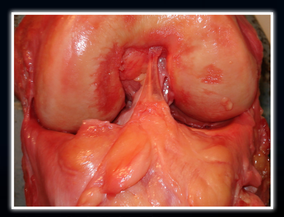
Medial View: The fibrous synovial layer of the capsule bypassed the FP, inserting on either side to the superior aspect of the menisci.

With motion the semi-fluid medial and lateral extensions intimately apposed the adjacent condyles, and the central body interdigitated with the notch.

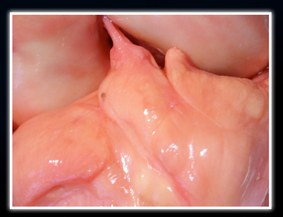


AP view: In one knee a medial fold was present. This extended into and coalesced with the medial extension. This replicates the literature viewpoint on the medial inferior extent of the medial fold and plica.

FP with IPP (8): Central body is constrained by attachment to notch. FP is crossed by fibrous synovial elements. These fibrous elements, termed alar folds, ramify over and through the FP and are continuous with the upper portion of the IPP medially and laterally. Inferiorly the lower portion of the IPP merges with fibrous synovium that is attached to the superior aspect of the menisci and the inter-meniscal ligament. Arthroscopic observation of the IPP shows that it demonstrates non-isometric behavior tightening as the knee approaches full extension and flexion. In the cadaver knees, traction on the vasti perturbs the FP and IPP.



AP view: Centrally the FP is crossed and intermingled with fibrous elements that include the alar folds, the medial plica, contributions from below the patella.



AP view: the specimen has much more fat, showing tongue-like projections inferiorly and superiorly.

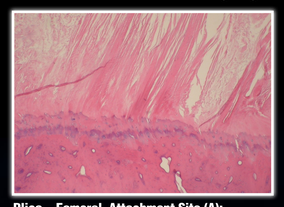
AP view: almost no fat in FP, suggests extreme emaciation. However, the pattern of collagenous elements, all focusing on the IPP is evidence of force transmission from the extensor apparatus.

Clip from action shot: The direct connection from the medial plica to the IPP is apparent. This is a new finding and has major implications for the interpretation on the literature relevant to the medial plica and shelf.

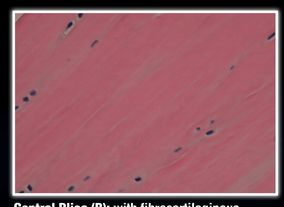
Clip from action shot: The direct connection from the medial shelf is apparent. This is a new finding and has major implications for the interpretation on the literature relevant to the medial plica and shelf.

Results: Histology

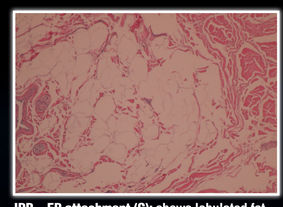
Infrapatellar Plica: *Displays a transition zone between the dense fibrillar collagen of the plica, then a buffer of fibrocartilage completing the attachment to bone similar to a ligament attachment site. The central plica is composed chiefly of dense regular connective tissue with focal fat interspersed between the fibrous tissue in some plicae. The PP – FP attachment shows undulating lobules of fat with neurovascular bundles and loose fibrous connective tissue merging with the dense fibrous connective tissue of the IPP.*



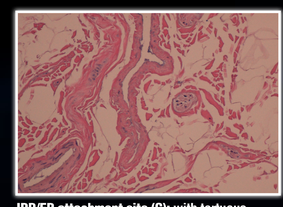
Plica – Femoral Attachment Site (A): collagen above, cartilage cells in lacunae in the lower middle, and bone below.



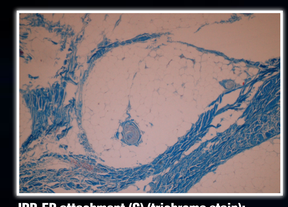
Central Plica (B): with fibrocartilaginous differentiation in background collagen.



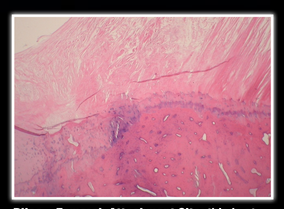
IPP – FP attachment (C): shows lobulated fat with neurovascular bundle in lower left of field.



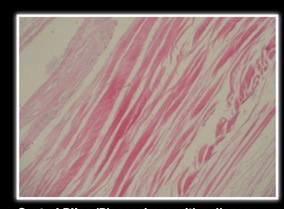
IPP/FP attachment site (C): with tortuous neurovascular bundle.



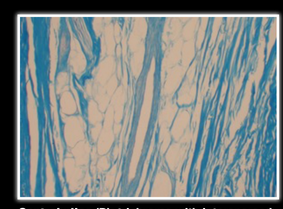
IPP-FP attachment (C) (trichrome stain): The lobular architecture is highlighted by this connective tissue stain. Thick blue staining fibrous septa separate the fat lobules.



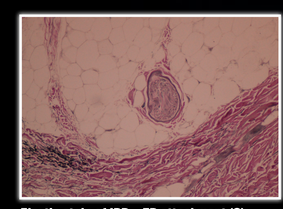
Plica – Femoral Attachment Site: this is at the junction with articular cartilage and subchondral bone of notch.



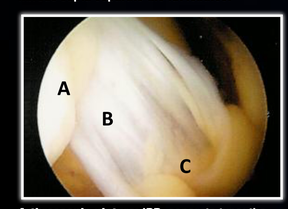
Central Plica (B): specimen with collagen bundles less compacted.



Central plica (B): trichrome with interspersed fat between some of the collagen bundle.

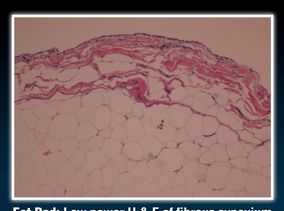


Elastic stain of IPP – FP attachment (C): abundant elastin implies structure capable of stretch.

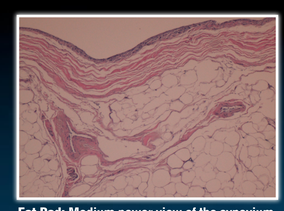


Arthroscopic picture: IPP, separate type; the sections to the left and above are samples taken at these approximate levels in the specimens.

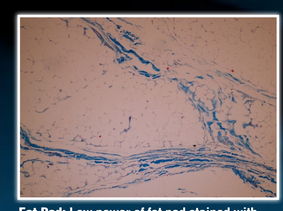
Fat Pad: *A semi-fluid, conformable structure whose medial and lateral extensions perfectly match the femoral condyles. The fat is divided in lobules by fibro-elastic septa; vessels and nerves follow the septa. Centrally, in the absence of an IPP, the central body conforms to the notch. This is the non-constrained FP. With an IPP present, the FP is captured by its attachment to the apex of the notch. The IPP is non-isometric and stretches at the extremes of motion. In full extension the FP is held captive against the distal femur. We have shown in a separate IRB-approved study in volunteers undergoing arthroscopy, that a quads set manoeuvre stretches the IPP and central body. Wolff's law applies to the capsule and force transmitting elements of the synovial layer. Force is thus constantly being transmitted through the synovial layer to the FP and IPP with every knee motion. One can expect a robust IPP in the athletic individuals.*



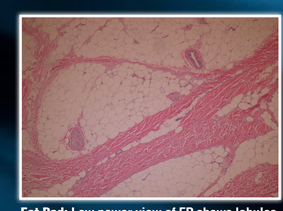
Fat Pad: Low power H & E of fibrous synovium on the free surface of the fat pad.



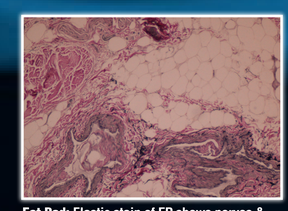
Fat Pad: Medium power view of the synovium covering the intra-articular surface of FP.



Fat Pad: Low power of fat pad stained with trichrome highlights lobular pattern.



Fat Pad: Low power view of FP shows lobules of fat and fibrous septa. Small nerve is seen in one of the lobules and gaping blood vessel is evident in another.



Fat Pad: Elastic stain of FP shows nerves & tortuous blood vessels and septa.

Conclusion

Gross Anatomy: There is a wide variation in appearance of the FP. A 180º flip of the extensor apparatus allows the continuum of the synovial layer of the knee to be appreciated. The FP can be unconstrained (no IPP) in which case the linked fibrous elements bypass the FP to attach to the mensici and tibia. The semi-fluid FP mechanically conforms to the condyles as the knee moves. The constrained FP is crossed by fibrous elements arising from alar folds linked to the vasti. These fibrous elements are joined by a medial shelf or plica if one is present and are continuous with the IPP. Attached to the central body of the FP, the IPP holds the FP captive against the end of the femur. Activation of the vasti perturbs the IPP and FP as they are linked structures.

Histology: This is the first report showing the entire structure of the IPP. It is a preliminary report because histological study was performed only on one FP without an IPP, and on 5 FP with IPPs. The IPP shows the structure of an intra-articular ligament: fibrocartilagenous transition at femoral insertion, dense connective tissue basic structure, specialized structural insertion to the FP with finger-like fibro-elastic connections wrapped around tortuous nerves and vessels. The basic structure of the FP is of a conformable pad of fibro-elastic septa, dividing lobules of fat with nerves and vessels following the septa.

References: Handout list available below.