Kinematics of the Fat Pad, its Central Body, and the Infrapatellar Plica, Newly Described as a Non-Isometric Ligament of the Knee

Thomas V Smallman, MD[1,2]; Amos Race, PhD[1]; Kenneth A Mann, PhD[1]
[1]Upstate Medical University [2]Auburn Community Hospital
Communication with authors: smallmat@me.com

AUBURN COMMUNITY HOSPITAL

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Arthroscopic observation of a phenomenon

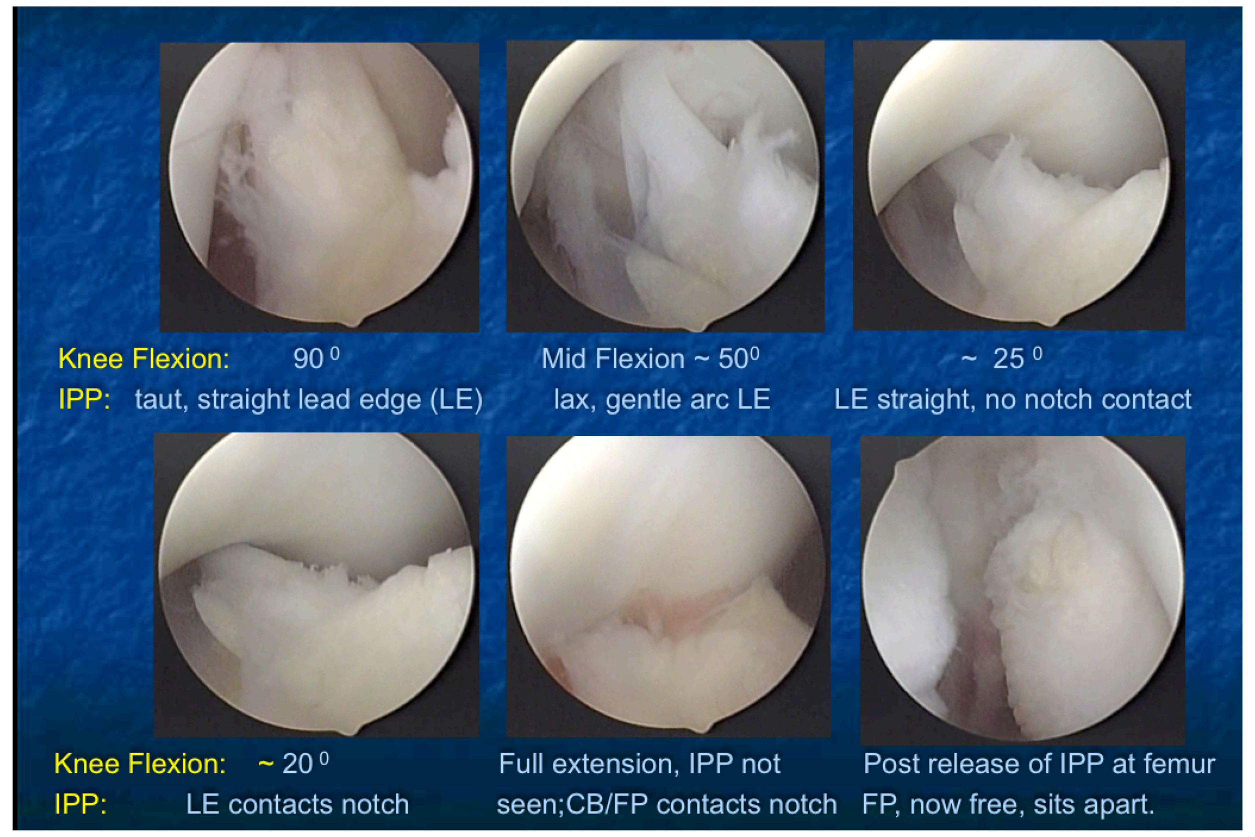


Figure 1

We observed **non-isometric mechanical behavior** of the infrapatellar plica (IPP), during arthroscopy as in figure 1. The IPP had been felt historically to be **an embryological remnant of no mechanical or clinical import, perhaps based on Wachtler's seminal article in 1979.**[1–8] We noted a dearth of basic information on this structure and no clinical studies to support this literature-based opinion. As structure and function are linked in nature, we therefore completed a preliminary review of the gross and microscopic anatomy of the IPP, the linked central body (CB), and fat pad (FP) as reported in Poster # 545.3: **The Infrapatellar Plica – a New Intra-articular Ligament of the Knee.** This current poster documents the concomitant physiologic studies performed to visualize and explain in part these observations.

Hypothesis

- **The infrapatellar plica (IPP), central body (CB), and fat pad (FP) collectively are a highly innervated and sensate enthesis organ[9] whose mechanical function is stress attenuation.**
- **The enthesis[9] is the femoral attachment (see figure 2) of the IPP.**
- **The IPP is an intra-articular, non-isometric ligament.**
- **Knee motion therefore perturbs the IPP and CB, and FP.**

Objective

Figure 2. Anatomic Orientation: Contents of the Anterior Compartment of the Knee

- **IPP: femoral attachment (FA), and central zone (CZ)**
  - **Tissue make up -- connective tissue (loose and dense), fat, and nerves**
- **Fat Pad: medial and lateral extensions (ME, LE); alar folds (AF); central body (CB)** as described by Gallagher.[10]

Our anatomic studies show that **the enthesis is the FA,** which acts as the center of rotation for the enthesis organ (IPP/CB/FP)[9]. The FA is not the axis of rotation of the knee, and the IPP, CB, and FP must stretch and relax with knee motion.

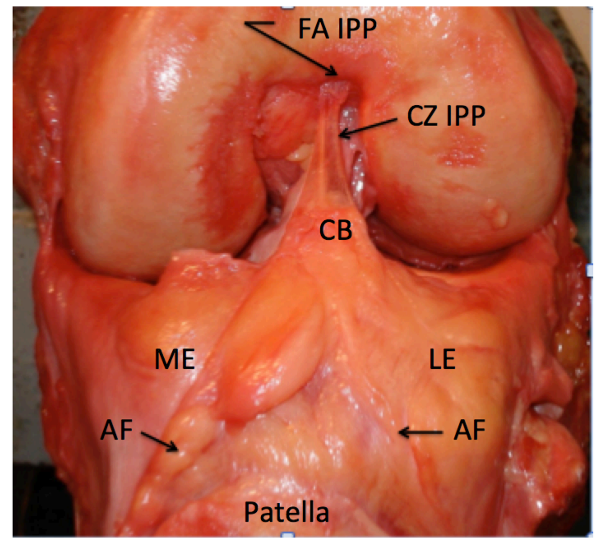


Figure 2

We sought to **visualize the kinematics of the contents of the anterior compartment of the knee (IPP, CB, and FP)**,a potential space whose geometry changes with knee motion (see Poster 545.3).

Materials & Methods

Using lateral fluoroscopy throughout, we studied **2 cadavers**, and **9 human volunteers undergoing arthroscopy** in an Institutional Review Board approved study:

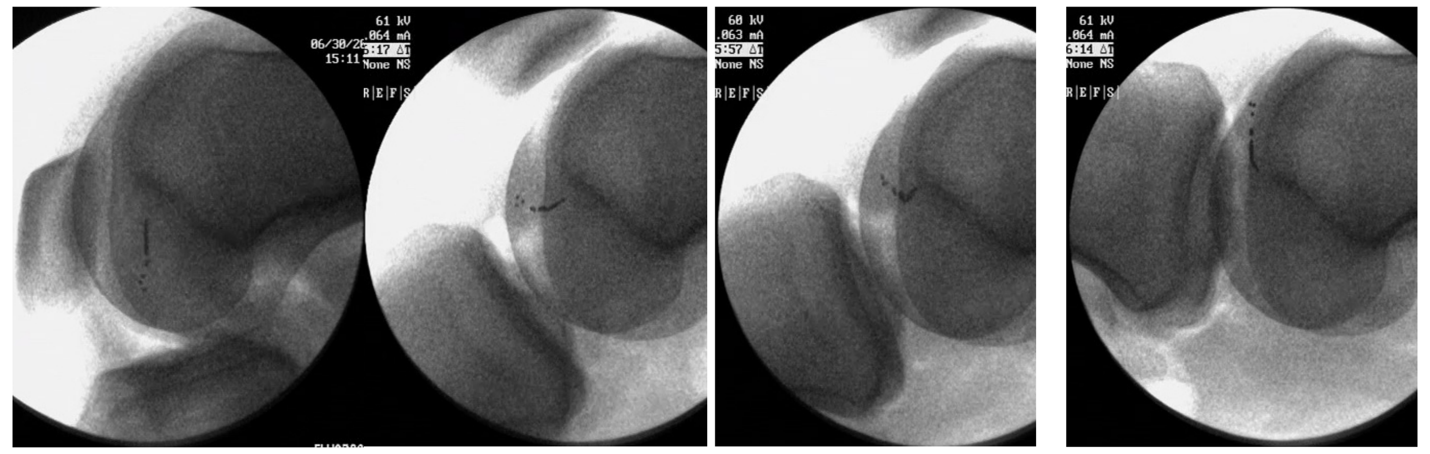
•Cadaver experiment # 1 – tantalum beads implanted via needle in IPP

•Cadaver experiment # 2 -- radiographic contrast implanted via needle into the IPP/CB/FP, visualizing arthroscopically, recording pre- and post resection of the IPP femoral attachment.

•IRB study – repeated experiment # 2, adding active motion/quads set.

Results

Cadaver Experiment # 1: Figure 3. Tantalum beads



Beads: inferior, lengthened — Oblique, relaxed arc — Oblique, relaxed arc — Lengthened, anterior orientation

Results (continued)

Cadaver Experiment # 1: Bead "movie" shows selected frames from flexion to extension: the bead column changed length and orientation:
•IPP stretches and is inferiorly oriented in full flexion
•IPP shows a relaxed arc through **mid-flexion**
•IPP stretches and is anteriorly oriented in full extension.

Cadaver Experiment # 2: Radiographic Contrast Filling IPP and CB

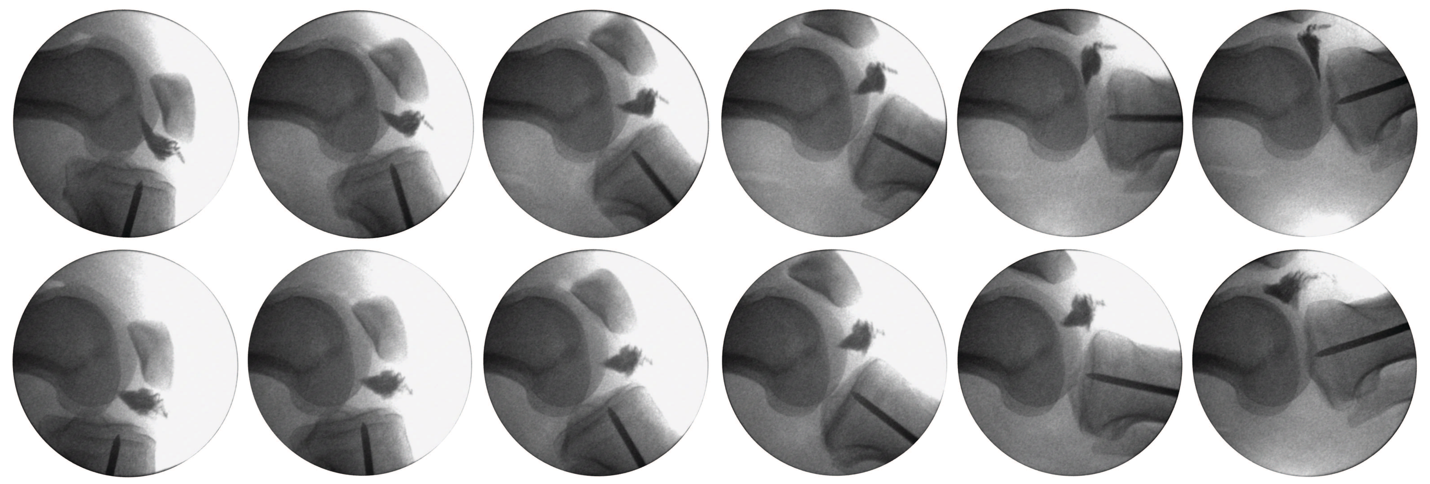


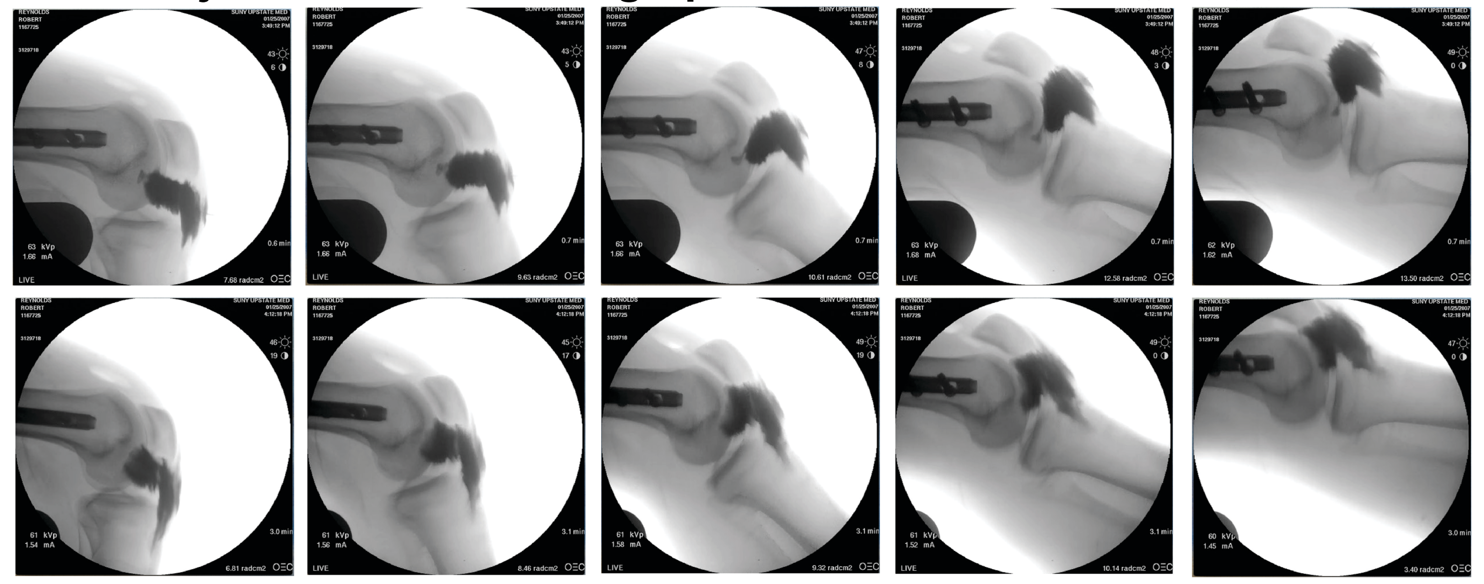
Figure 4. Cadaver knee, radiographic contrast pre and post resection of FA of IPP

EXPERIMENT ISOLATES THE MECHANICAL BEHAVIOR OF THE IPP AND CB
•TOP ROW:
- **MAX FLEXION -- slight stretch of the IPP/CB complex**
- **MID ARC – Complex is relaxed, leading edge curved, little tension**
- **TERMINAL EXTENSION – IPP and CB show remarkable distortion and stretch.**

•BOTTOM FRAMES: After release of femoral attachment –
- **the IPP/CB complex floats freely with little distortion.**

The behavior of the IPP and CB is consistent with the hypothesis.

IRB Subject Case # 1: Radiographic Contrast Fills IPP, CB, and FP



Top row: Broad base of IPP fills, IPP seen, CB not seen, FP overlap obscures some detail. Boltom row post release of IPP, FP floats free.

Results (continued)

IRB Case # 1 ***THESE ARE THE KEY OBSERVATIONS:*** Top row pre-IPP release
- The **broad origin of the IPP fills and changes shape** with knee motion.
- Max flexion -- **IPP detail is obscured**;
- Mid arc -- the **IPP is relaxed, CB not seen**;
- Full extension – **IPP and CB are stretched and distorted maximally;**
- Throughout the arc of motion -- **IPP captures the CB/FP**, preventing their natural conformation; **FP is distorted by this capture-effect,** and prevented from conforming with the distal femur.

IRB Case # 1 OBSERVATIONS: Bottom row post-IPP release
- **IFP changes shape with knee motion with no distortion**, leading edge simply conforming with the condyles and the patellar surface of the notch.

This behavior of the IPP,CB, FP is consistent with the hypothesis.

Discussion

We have shown evidence of a **previously unknown phenomenon** in the human knee. Previously considered a vestigial remnant, the IPP shows **unexpected mechanical behavior** arising from the fact that it is non-isometric. Our linked poster # 545.3 outlines evidence that **the IPP is structurally an intra-articular ligament**. Mechanically, its task is to tether the fat pad at the central body. *Functionally, it is the key link in an* ***"enthesis organ"***, *an exquisitely structured mix of connective tissue, fat, vessels and nerves, organized to handle the task of force attenuation.* We have shown in this report the **kinematics of this unit** in vitro and in vivo. Remarkable videos confirm that, because these structures are not isometric, as they rotate around the FA of the IPP, from a zone of relaxation of the tissues in mid arc, the **IPP increasingly stretches, and both the CB and FP stretch and deform.** When the IPP is released, the FP shows no distortion, simply occupying the anterior compartment as the knee moves. The biomechanical forces involved are conjectural at this time and will need to be studied.

CLINICAL RELEVANCE

Clinical reports suggest that **release of the IPP at its femoral attachment** improves anterior knee pain (AKP) in most patients.[3,4,6,7,11]There is thus an anatomic link between AKP and the *IPP enthesis organ,* also worthy of further clinical and experimental study.

References

Will provide an on line reference for this