Intra-operative Visualization of Deformation of the Infrapatellar Plica and Fat Pad -- The Link to Anterior Knee Pain

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OBJECTIVE

1. To provide historical, clinical, anatomic, histologic, biomechanical, and experimental data to support the following hypothesis:

The infrapatellar plica (IPP), attached to its bony central anchor, acts as a **non-isometric intra-articular ligament**, tethering the fat pad (FP) at its central body (CB). The effect of knee motion is to impart inexorable stretch and relaxation to the IPP, and CB, transmitting force to its attachments at the femur, and the FP. The FP is thus tethered and deforms as a result of the mechanical behavior of the IPP.

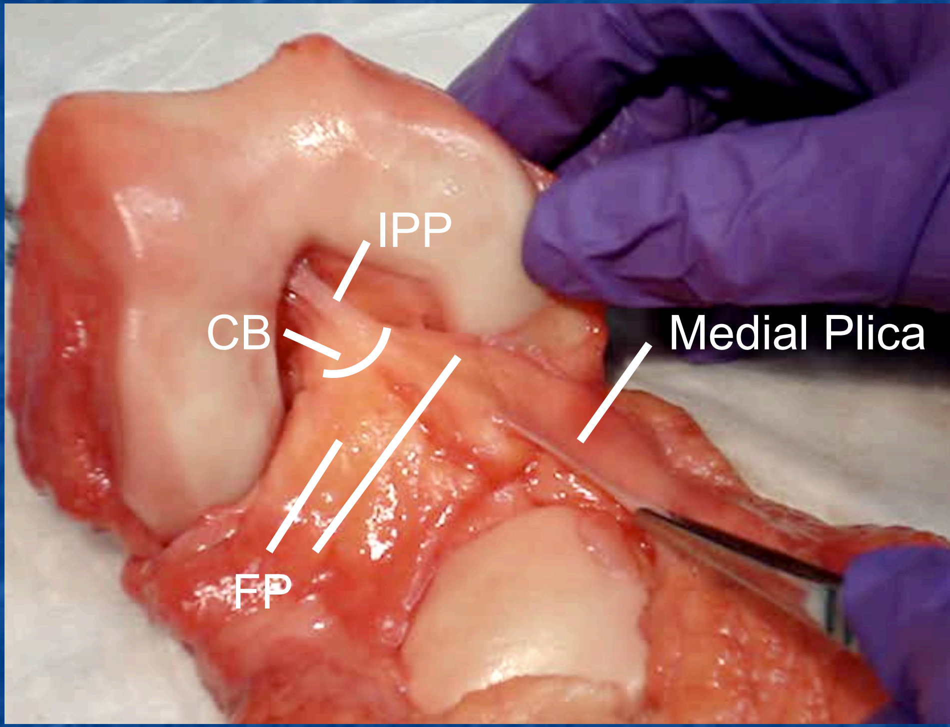


Figure 1. Synovial connective tissue continuum; flip of extensor apparatus 180^0

2 To suggest, given the above hypothesis, how releasing the IPP may eliminate or alter AKP.

BACKGROUND DATA -- HISTORICAL

CLINICAL IMPORTANCE OF THE IPP

In a German article in 1979 *Die Plica synovialis infrapatellaris beim Menschen*[1], Wachtler described the IPP. In the English abstract, he concluded: "…from a mechanical and teleological point of view, the IPP may have little relevance…"

The IPP has been described in the English literature as an embryonic remnant, a synovial fold of no clinical significance [2]:

"…most recent literature on the pathology of plica claims that the infrapatellar plica has little clinical relevance and does not cause symptoms…"[3]

*"…*It is generally agreed that the infrapatellar plica does not cause symptoms…**"** [4,5]

However, five clinical reports suggest that releasing the femoral insertion of the IPP improves idiopathic anterior knee pain (AKP) in most.[3,6,7,8,9]

THIS IS A PARADOX

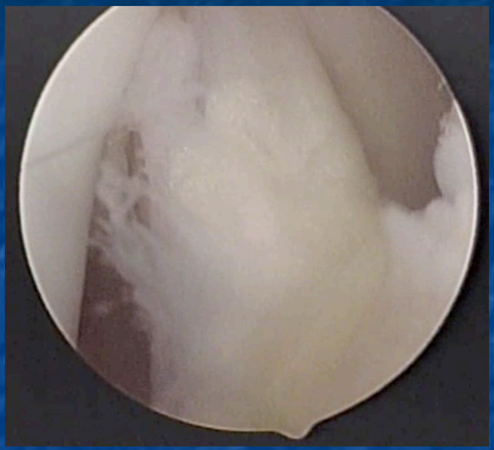
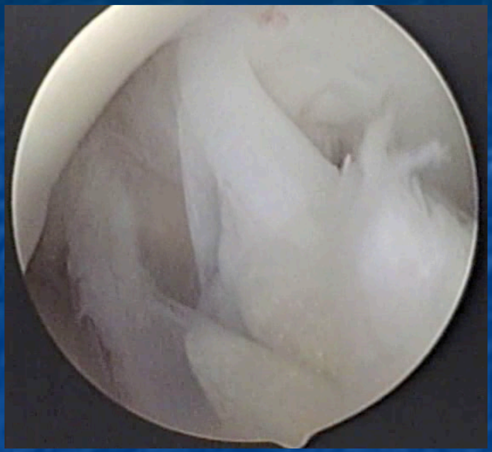
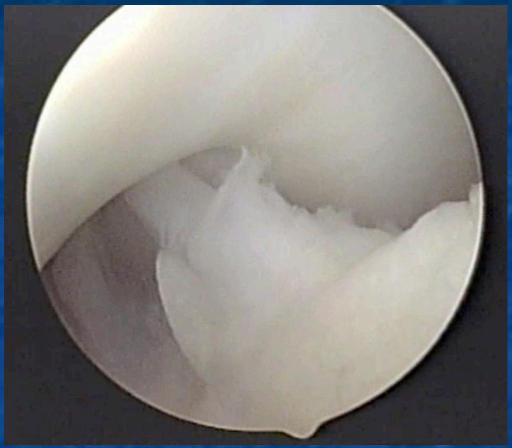
On one hand: Releasing the IPP helps AKP.

On the other: IPP is an embryonic remnant, a synovial fold of no clinical significance.

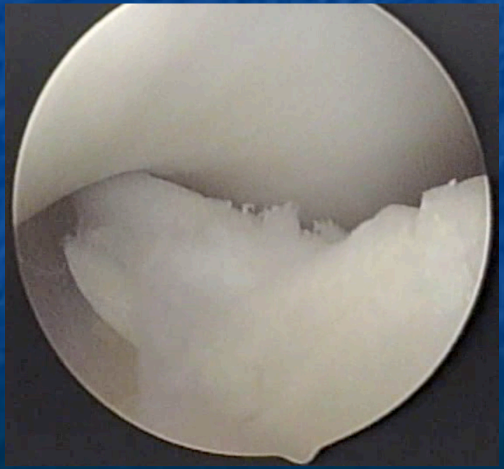
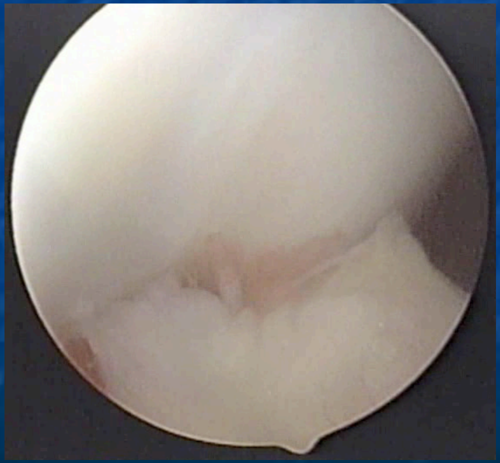
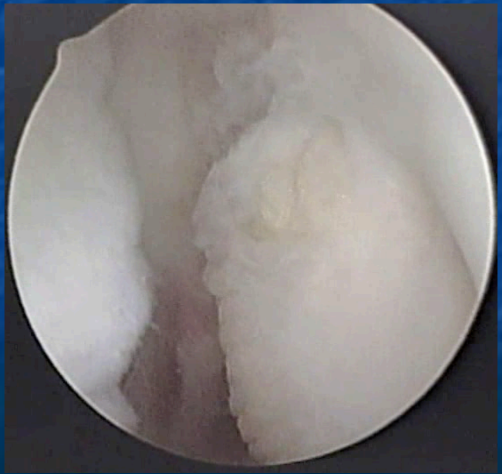
BACKGROUND DATA – CLINICAL

Sentinel Patient: ***the idea of linking AKP to the IPP*** originated with a fit soldier with this problem, whose knee at arthroscopy was pristine. Erythema at the IPP origin focused attention on apparent mechanical behavior as shown. With no other abnormalities, the IPP was released and the pain abolished.

These screen shots from similar case.

	90°	Mid Flexion ~ 50°	~ 25°
Knee Flexion:	90 ^{0}	Mid Flexion ~ 50^{0}	~ 25 ^{0}
IPP:	taut, straight lead edge (LE)	lax, gentle arc LE	LE straight, no notch contact

Knee Flexion: ~ 20 ^{0} Full extension, IPP not Post release of IPP at femur

IPP: LE contacts notch seen;CB/FP contacts notch FP now free, sits apart

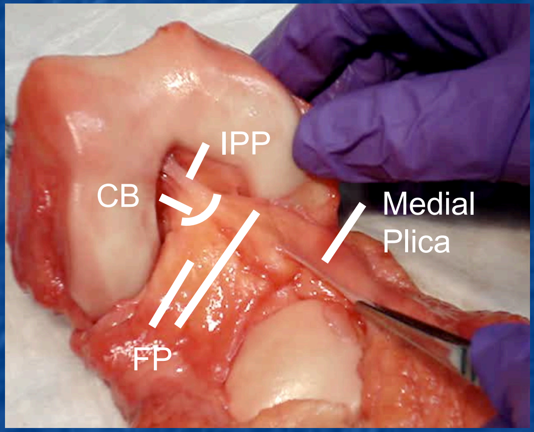
BACKGROUND DATA – ANATOMICAL, HISTOLOGICAL, BIOMECHANICAL

I. ANATOMICAL: IPP, CB and FP are part of the synovial layer which is a structural continuum.

Fundamental Concept: Connective tissue (CT) elements of the synovial layer are linked[10].

- For the IPP, attached to bone in the notch, and to the FP via the CB, the surrounding CT links include: NB…*EXTENSOR APPARATUS HAS BEEN FLIPPED 180 DEG TO SHOW RELATIONSHIPS*
  - From above -- medial and lateral alar folds, and centrally links below the patella
  - To structures below – menisci, inter-meniscal ligament, and tibia

Viewed from the femoral attachment of the IPP, knee motion involves rotation of the this linked CT array; the IPP is the link and the fat pad, in highly innervated lobules, is along for the ride.



II. HISTOLOGICAL: The IPP is an intra-articular ligament.

The microscopic structure of the IPP:[11]

- Femoral attachment -- Fibro-cartilagenous transition CT to bone
- Rope-like central portion -- dense CT
- FP attachment at the CB -- CT bands from the IPP merge like fingers with the septa of the CB; neurovascular bundles lodged in fat between septa, are tortuous, adapted to stretch

III. BIOMECHANICAL: Center of rotation for the FP is the femoral attachment of the IPP.

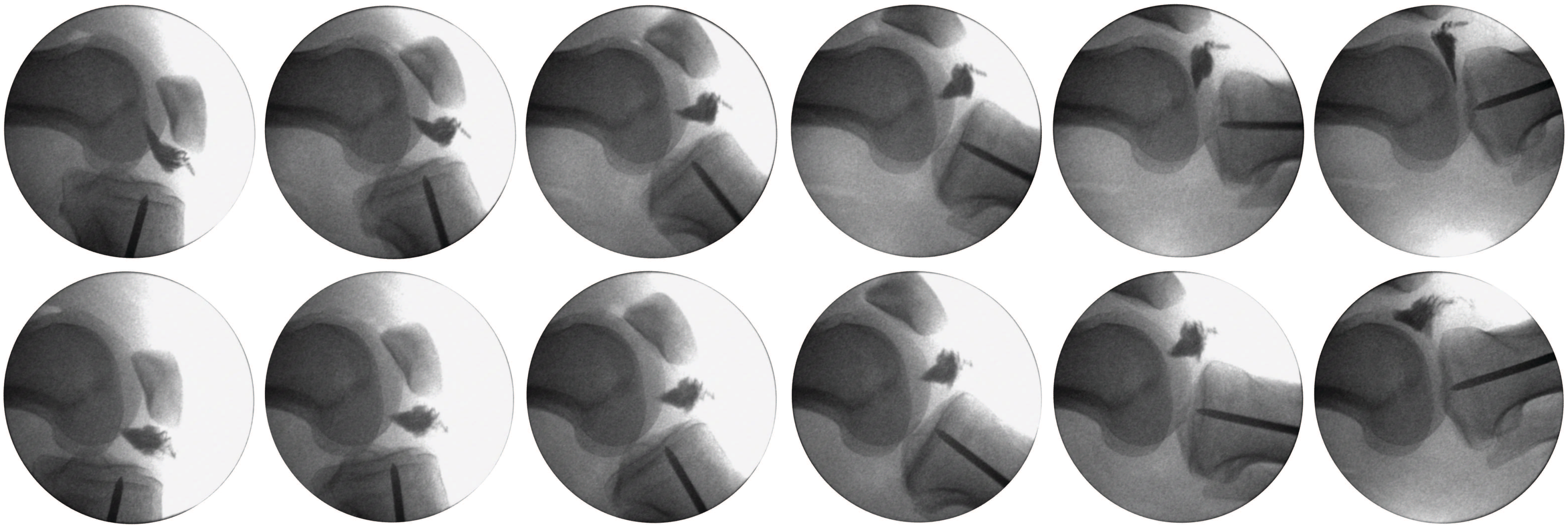
This is not the center of rotation of the knee. The IPP, CB, and FP are thus non-isometric structures which must deform as the knee moves.

- This is the key concept linking AKP to the IPP/FP complex; the CB and FP are highly innervated structures undergoing deformation. [11]

MATERIALS AND METHODS – EXPERIMENTAL IN-VITRO

Radiographic contrast was implanted in IPP, CB, and central FP in an intact cadaver knee. Lateral fluoroscopy allowed the dynamics of these structures to be visualized pre and post resection of femoral attachment of IPP. Below are selected screen shots from the videos.

Pre-resection of IPP



Post-resection of IPP

The IPP, CB, and central FP only have filled; accordingly their behavior is seen in isolation from the rest of the FP, which has not filled with contrast.

TOP ROW: Sequence from flexion to extension shows –

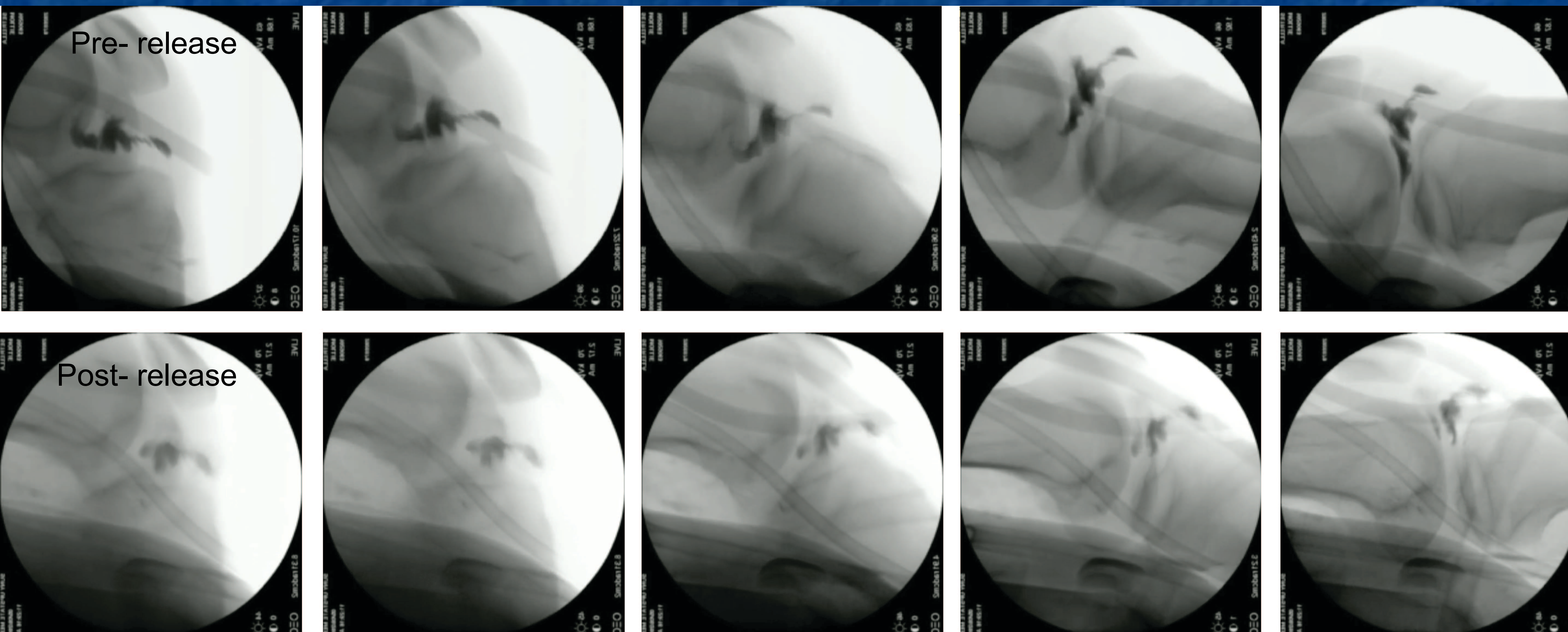
- slight stretch of the IPP/CB complex in maximal flexion; then a mid-flexion zone where there is little change other than in direction, then remarkable distortion and stretch in terminal extension (5^0 flexion to 5^0 hyperextension).

BOTTOM FRAMES: After release of femoral attachment –

- the IPP/CB complex floats freely with little distortion other than in terminal extension.

MATERIALS AND METHODS – IN VIVO

An IRB approved study of patients undergoing arthroscopy, the cadaver experiment was reproduced. If an IPP was present, contrast was placed in the FP, CB, and IPP, motion observed and recorded using fluoroscopy. The IPP was released and observations recorded. This was the first patent, 18 Y/O MS, who suffered from anterior knee pain. The observations mimic those of the cadaver knee.



OBSERVATIONS: Top row pre-IPP release

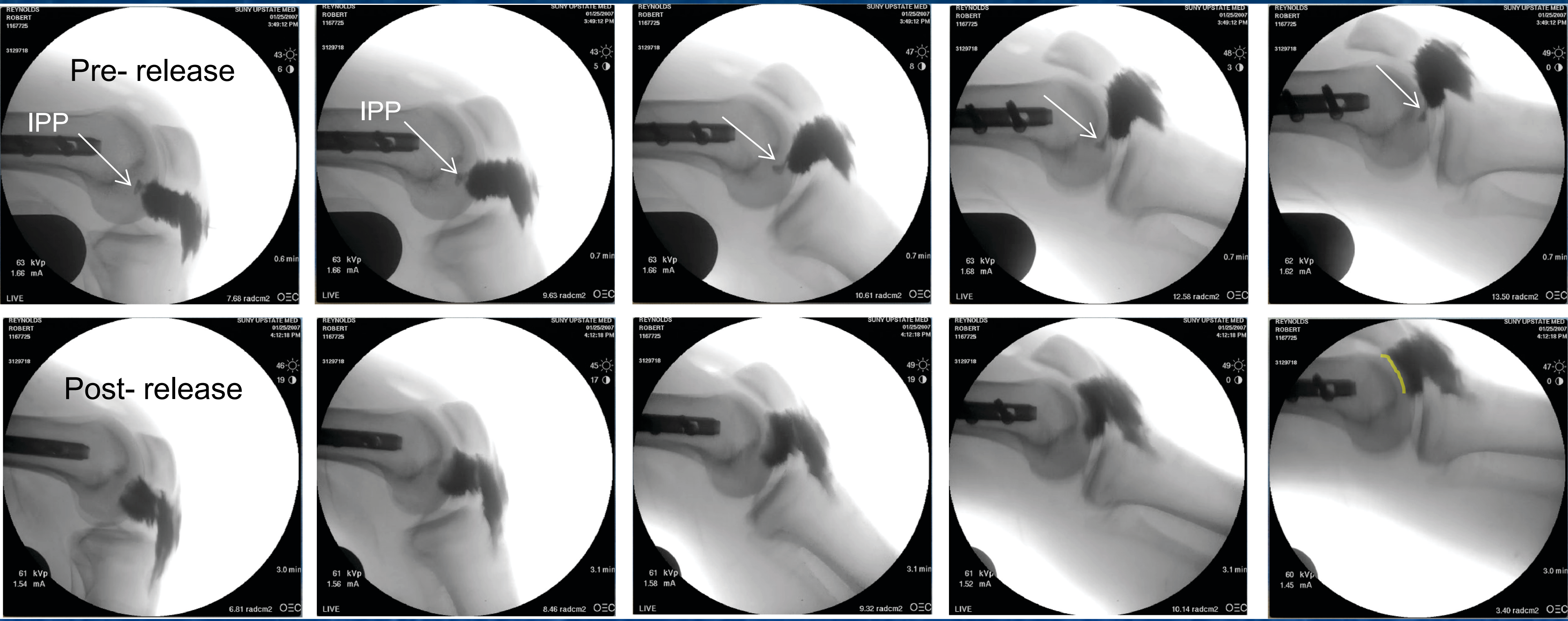
- The contrast filled the worm-like IPP/CB complex, and a small central region of the FP; this mimics the cadaver experiment; one can see behavior of worm-like IPP/CB complex without FP overlap.
- In flexion IPP is vertical; mid flexion zone shows curved leading edge suggesting little tension; stretch and distortion begins at about 5^0 and continues to max at terminal extension.

OBSERVATIONS: Bottom row post-IPP release

- Little distortion of visualized FP elements until terminal extension.

MATERIALS AND METHODS – IN VIVO

Case 2, 18 Y/O RR, complaining of anterior knee pain post MVA and IM rodding of femur. Release of the IPP markedly improved AKP in this knee, and in both knees in Case 1.



OBSERVATIONS: Top row pre-IPP release

- Some of the detail of IPP/CB behavior is obscured by overlying FP; however, the origin of the IPP fills and changes shape with knee motion.
- IPP detail is obscured in max flexion; in mid flexion the IPP changes little; at 15^0 stretch and distortion of the IPP/CB complex begins, and is maximal at terminal extension of -5^0;
- the IPP prevents natural translation of the FP; FP is distorted, and prevented from conforming with the distal femur.

OBSERVATIONS: Bottom row post-IPP release

- IPP/CB complex no longer seen; FP changes shape, leading edge conforming with the condyles.

RESULTS

Cadaver studies: IPP/CB demonstrates non-isometric mechanical behavior.

- Experiment 1(radiographic contrast, example screen shots shown): The IPP/CB complex fills
  - IPP, CB, and a portion of the FP fill; bulk of FP (lateral extensions not seen)
  - From flexion to extension there is initial stretch, then a zone of minimal tension, then with terminal extension, increasing stretch and distortion.
  - Release of the femoral attachment of the IPP virtually eliminates stretch and distortion.

In-Vivo Volunteer Study: Technically difficult, successful intra-operative visualization of deformation of the IPP, and FP was achieved in 3/9 cases of which 2 are shown.

- Case 1, MS, example screen shots shown, mimics the cadaver experiment perfectly:
  - Visualization poor in max flexion; leading edge is an arc in mid-flexion, suggesting little tension; IPP elongated with CB and FP distortion as the knee approaches full extension.
  - Release of the IPP at the femur eliminated almost all of the distortion through the full arc of motion.
- Case 2, RR, screen shots show filling of IPP and the bulk of the FP, gives key info on FP changes:
  - FP and IPP fill; the normal broad femoral attachment of IPP is very well seen; some overlap of FP obscures detail in IPP/CB complex.
  - Distortion of IPP origin is seen in full flexion; mid-flexion, IPP shows little change; at 15^0 stretch and distortion of IPP/CB begins and is maximal at terminal extension.
  - Release of the IPP obscures the IPP/CB from view
  - Pre release, FP distorts because of IPP tether; post release, leading edge matches condyles and there is little distortion.

CONCLUSIONS

- Preliminary data suggests that the IPP is a non-isometric, intra-articular ligament whose effect is to capture the fat pad. The fat pad, and its central body are highly innervated, pain sensitive structures.[2]

- Experimental evidence in vitro (1 cadaver knees) and in vivo (2 examples shown in volunteer patients), using lateral fluoroscopy demonstrates that the fat pad rotates about the femoral attachment of the IPP. Because this axis of rotation is not that of the knee, motion imparts inexorable stretch and relaxation to the IPP, and central body, transmitting force to its attachments at the femur, and the fat pad.

- The fat pad, thus tethered to the IPP through its central body, must deform as a result of this non-isometric mechanical behavior of the IPP.

- In vivo experiments involving volunteers provided intra-operative replication of the observations in cadavers, and added data on deformation of the fat pad. When tethered by the IPP, the fat pad deforms in response to its link to the notch.

- Release of the IPP at the femoral attachment virtually eliminates the perturbations arising from fat pad capture of the IPP/CB, and fat pad. After release, the fat pad conforms to the contours of the femoral condyles.

SIGNIFICANCE OF THE FINDINGS

- This report outlines a previously unknown phenomenon in the human knee. Previously considered not relevant, clinically or mechanically, the infrapatellar plica shows unexpected mechanical behaviour in that it is:
  - Non-isometric, and
  - It tethers the fat pad at its femoral attachment.

- With respect to idiopathic anterior knee pain, while the mechanism initiating the pain is not known, the clinical observation is that chronic pain of this nature, not responsive to conservative management is relieved in 80 to 90% of knees by release of the femoral attachment of the IPP. [5,8,9,10,14]

- There is thus an anatomic link between the fat pad/IPP complex and anterior knee pain. These unexpected mechanical effects may warrant reconsideration of the source of pain in other knee disorders.

- Pain relief may be a result of the demonstrated elimination of the observed mechanical perturbations, or of interruption of neurogenic pathways (denervation).

- Linking AKP to the IPP and fat pad, which are centrally located and innervated soft tissue structures, bypasses considerations related to malalignment, tilt, and articular surface damage in considering unilateral pain when both knees have such findings.

- Idiopathic anterior knee pain could be termed the fat pad capture syndrome, reflecting this described link.

References

1. **Wachtler, F. Die Plica Synovialis infrapatellaris beim Menschen,** ***Acta Anat (Basel),*** 1979;104:451-459.
2. **Schindler, OS.** Synovial plicae of the knee, ***Current Orthopaedics***, 2004, 18, 3, 210-219, Elsevier
3. Boyd CR, Eakin C, Matheson GO. Infrapatellar plica as a cause of anterior knee pain. *Clinical Journal of Sport Medicine*. 2005;15:98-103.
4. **Hardaker W, et al. Diagnosis and treatment of the plica syndrome of the knee.** ***J Bone Joint Surg Am*** **1980**
5. **O'Dwyer KJ, Peace PK. The Plica Syndrome** ***Injury*** **1988, 19, Issue 5: 350-352**
6. Demirag, B; Ozturk, C; Karakayali K. Symptomatic infrapatellar plica. Knee Surg Sports Traumatol Arthrosc 2006,14: 156–160
7. **Kim, SJ, Chloe.** Pathological Infrapatellar Plica: A Report of Two Cases and Literature Review. *Arthroscopy: The Journal of Arthroscopic and Related Surgery*, 1996, Vol 12, No 2: 236-239
8. Kim SJ, Kim JY, Lee JW. Pathologic Infrapatellar Plica. *Arthroscopy: The Journal of Arthroscopic and Related Surgery,* 2002, Vol 18, No 5: pp E25
9. Smallman, T, Race, A, Shekitka, K. Resection of the Infrapatellar Plica for Adolescent Anterior Knee Pain – Successful Treatment with Long-Term Follow-Up, *EFORT 13 Proceedings,* 2013
10. Gray H. *Gray's Anatomy.* xx ed. Edinburgh ; New York: Elsevier Churchill Livingstone; 2005.
11. Smallman, T.; Race, A.; Shekitka, K. The Infrapatellar Plica and Fat Pad: Gross Anatomy and Histology Suggests that the Infrapatellar Plica Functions as an Intra-articular Ligament – a Preliminary Report; *EFORT Transactions*, 2012, 12-5213
12. Kim SJ, Choe WS. Arthroscopic Findings of the Synovial Plicae of the Knee. *Arthroscopy: The Journal of Arthroscopic and Related Surgery,* Vol 13, No 1 (February), 1997: pp 33-41
13. Dye, S, Vaupel, GL, Dye, CC. *Fconscious Neurosensory Mapping of the Internal Structures of the Human Knee Without Intraarticular Anesthesia*, Am J Sports Med, 1998 26: 773