PFJ: the last frontier

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Patellofemoral Joint: outline

- A Short History of the Human Knee
- The impact of alignment choices on PF/ Trochlear alignment
- Design Considerations in TKA
- Introducing the Trochlear Offset
- Clinical impact of Trochlear mismatch
- What are people doing out there?

The PF joint evolved separately from the Knee Joint.

- 300M years ago (Paleozoic)
  - Tetrapods: medial condyle articulated with the femur and the *lateral condyle articulated with the Fibula*
- 215M to 70m years ago (Mesozoic)
  - Fibula of protomammals shortened considerably and *both condyles began to articulate with the Tibia*.

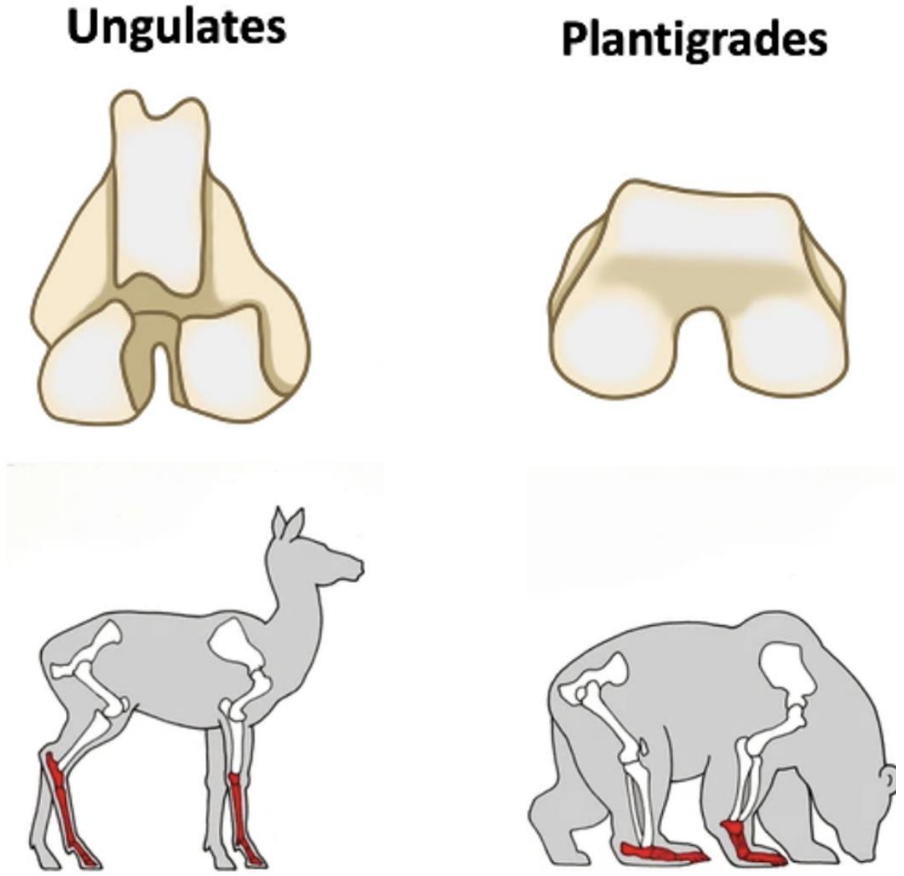
Seymouria

Megaconus

Michel Bonnin et al, *Knee Surgery, Sports Truamatology, Arthroscopy* 2024

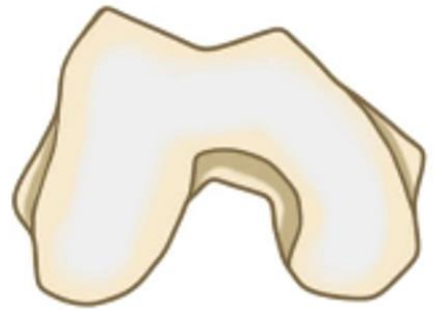
The PF joint has a unique evolution

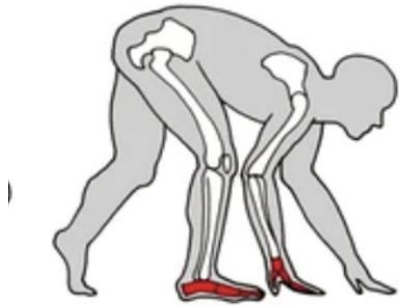
- 70M years ago, the first patellae appeared in mammals.
  - **Ungulates** (deer, walk on toes), the knee never extends, the PF joint (trochlea and condyles) remained distinct
  - **Plantigrades** (bear, knee extends), the trochlea became contiguous with the condyles and flat.



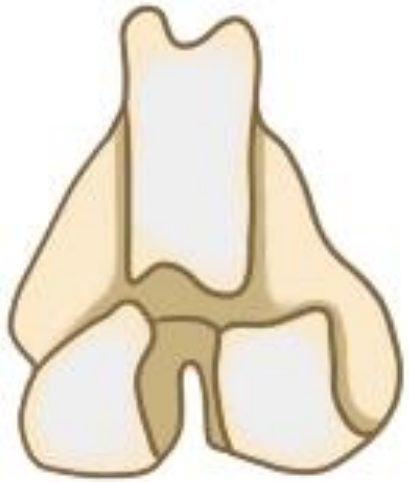
The PF joint has a unique evolution

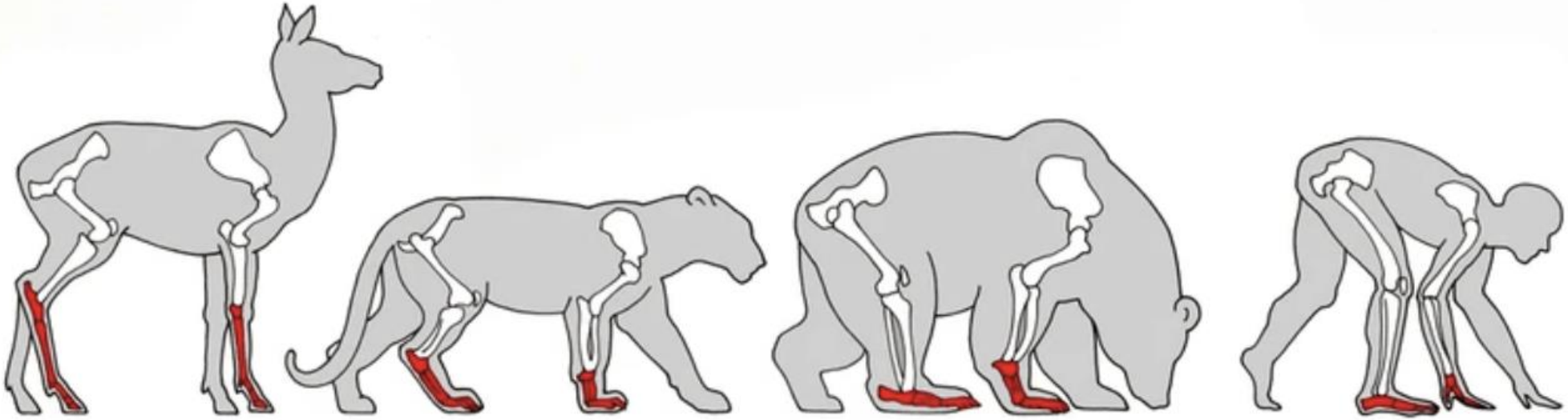
- 4M Years ago
  - **Hominids**: bipedal gait and full knee extension of the knee become common along with
    - 1) valgus orientation of the femur
    - 2) joint line Obliquity
    - 3) extension and anteriorization of the lateral femoral facet
    - 4) lateralization and flattening of the trochlea.
  - Evolutionarily, the joints are separate and distinct and this is why they **behave independently**





Ungulates Digitigrades Plantigrades Homo Sapiens



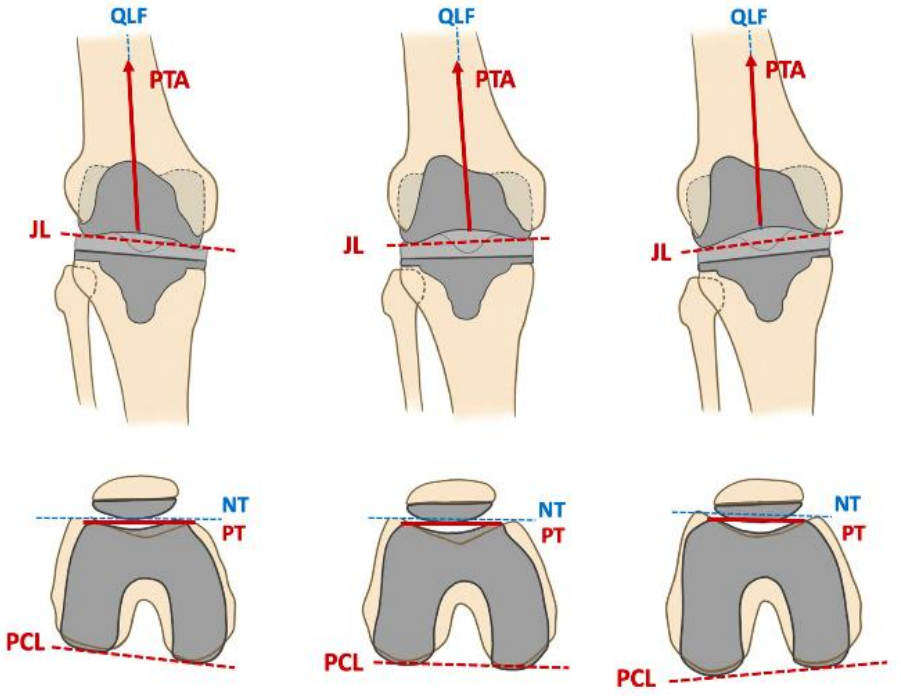


Houston, do we have a problem?

- All off the shelf implants link the Tibio-Femoral Joint with the P/F joint
- The Trochlea and Patella have Variable geometries
  - Tilt
  - Angles
  - Depth
- The Patella has a Different Axis of Rotation from TF axis
  - You can argue it doesn't have a true "axis"

Variation in relationship btw PFJ and TFJ

- Extensive variation in
  - Trochlear Tilt
  - Trochlear Angle
  - Depth of Sulcus
  - Shape and size of Patella
  - Presence of osteophytes
  - Patellar tendon

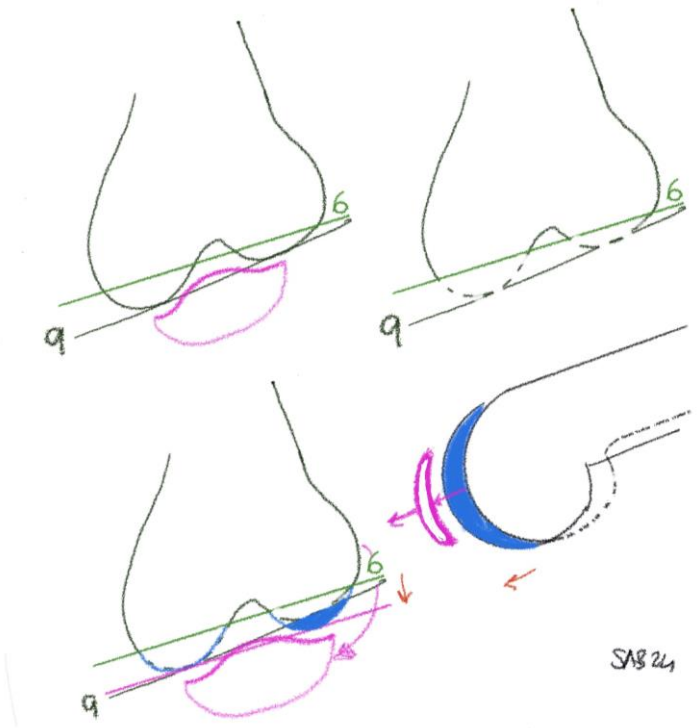


Michel Bonnin et al, *Knee Surgery, Sports Traumatology, Arthroscopy* 2024

Impact of Alignment Strategies on PFJ using conventional implants

Mechanical Alignment

- Measured Resection off MFC
- Fixed 6 of valgus
- Generally under resects the LFC[1,2]
  - <u>"lengthens the lateral column"</u> Tightens the Lateral Retinaculum
  - Distal Prosthetic Overstuffing
- Decreased Flexion
- Patellar wear



1.Current Concepts in Alignment in Total Knee Arthroplasty. Karasavvidis, Theofilos et al. The Journal of Arthroplasty, Volume 38, Issue 7, S29 - S37 July 2023

2.Riviere C, Iranpour F, Auvinet E, Aframian A, Asare K, Harris S, et al. Mechanical alignment technique for TKA: are there intrinsic technical limita- tions? Orthop Traumatol Surg Res 2017;103:1057e67

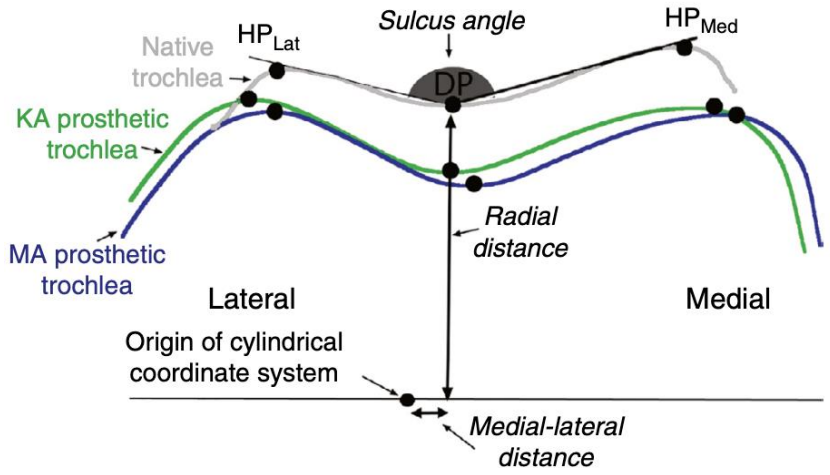
Impact of Alignment Strategies on PFJ using conventional implants

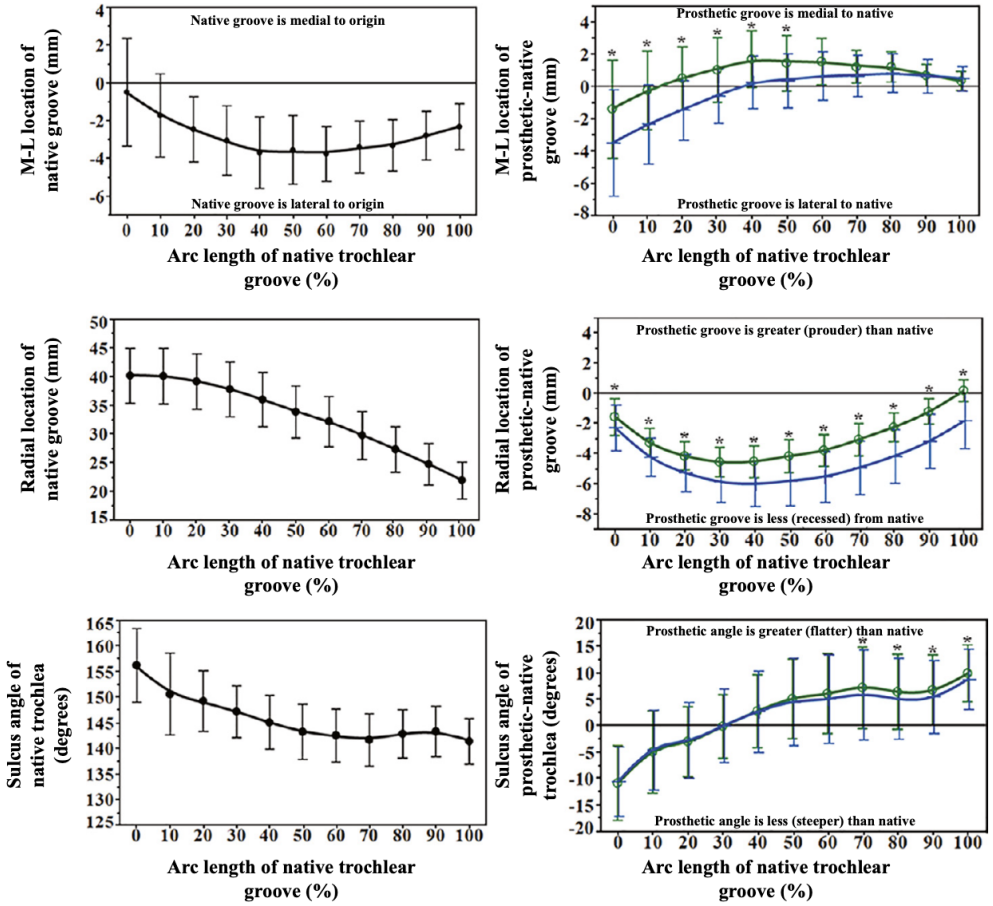
Kinematic Alignment

- Equal resection bilaterally, 8-9 valgus of the joint line.
- Generally more flexed in the sagittal plane than in MA
  - The patella button may not capture late in the trochlea
  - Trochlear angle 6 degrees may lead to patellar instability in valgus knees

Implant Design Considerations: Trochlea

- Depth and Geometry of Implant Trochlea does not match anatomy
  - PF “over” and “under” stuffing





Maurey Hull, Ch 10. Howell, S. M., Bini, S. A., & Steele, G. D. (Eds.). (2021). *Calipered kinematically aligned total knee arthroplasty: Theory, surgical techniques and perspectives* (1st ed.). Elsevier.

Optimal Design features for a KA friendly knee

- +/- 3mm is the Std Dev Medial Lateral Location of Native Groove/Sulcus
  - +/- 6mm width to include 95% of the population
- Orientation of Q angle (ref: Rectus Femoris) Mean = 6.5 degrees, Std. Deviation +/- 6.5 Degrees
  - Range -6.5 deg – 19.5 deg to include 95% of the population
  - Two designs
- Flange widened laterally
- Trochlea depth lessened
- Sulcus angle steepened in flexion

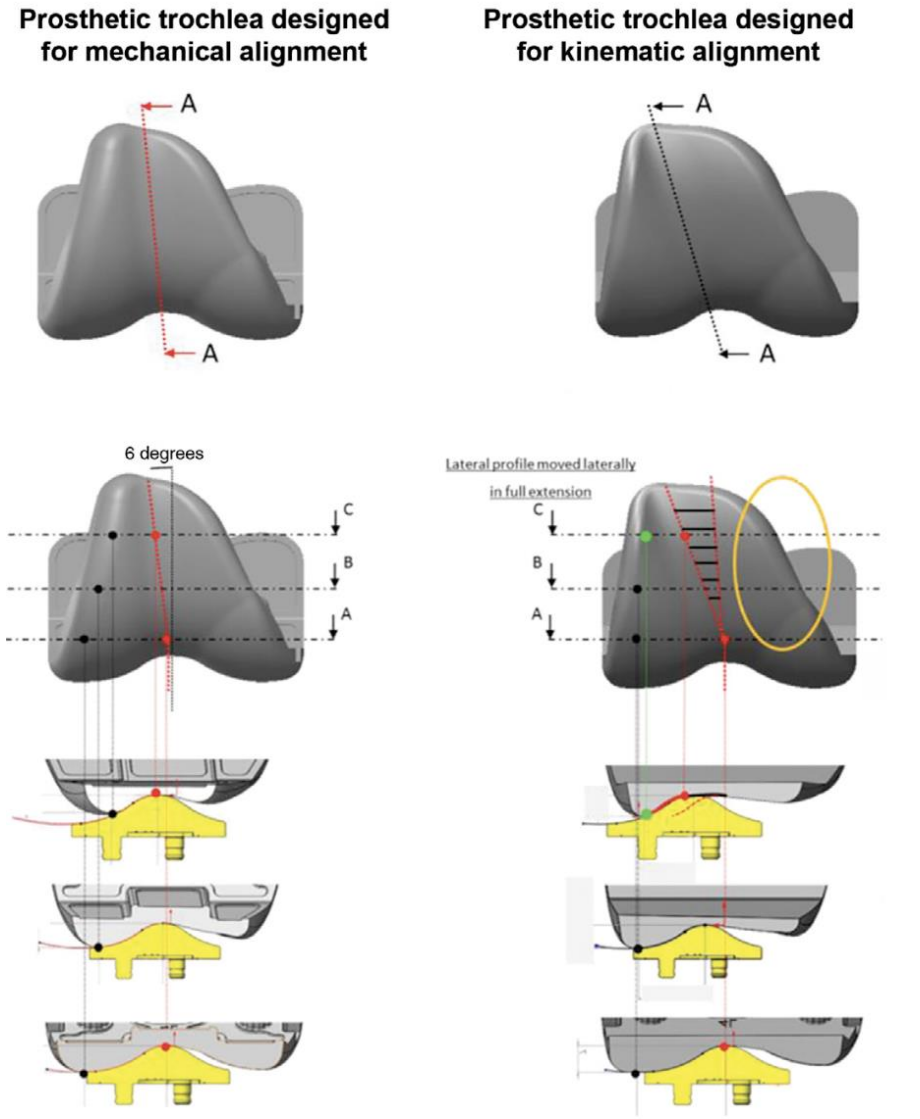


Figure 10.6 Schematic shows the prosthetic trochlea designed for mechanical alignment *(left)* modified into one for kinematic alignment *(right)* by lateralizing the proximal trochlea, widening the proximal trochlea, lateralizing the groove, and widening the groove to accommodate for kinematically aligned positioning of the femoral component in the valgus knee and the wide variability in the medial-lateral location of the groove and Q-angle.

Imageless robots: anatomic congruence

- Kreutzer et all KSSTA March 2024
- 61 imageless robotic TKAs
- Native Trochlea Digitized
- FA, MA, KA, GB, rKA, riKA were simulated
- Trochlear Angle, Over Stuffing, and Sulcus Offset calculated
- *All increased the Trochlear Angle Valgus*
- *All shifted Sulcus laterally*
- *All understuffed the Trochlear Groove (KA and rKA the least)*
- *Translated sulcus laterally in Extension and medially in Flexion (MA and GB more so)*

KSSTA Knee Surgery Sports Traumatology Arthroscopy
THE OFFICIAL CLINICAL JOURNAL OF ESSKA

KNEE ARTHROPLASTY

Personalized alignment techniques better restore the native trochlear groove compared to systematic alignment techniques in total knee arthroplasty

Alexander D. Orsi, Jobe Shatrov, Christopher Plaskos, Stefan Kreuzer

First published: 01 March 2024 | https://doi.org/10.1002/ksa.12104 | Citations: 3

The Trochlea in the Robotic Age: 200 TKAs

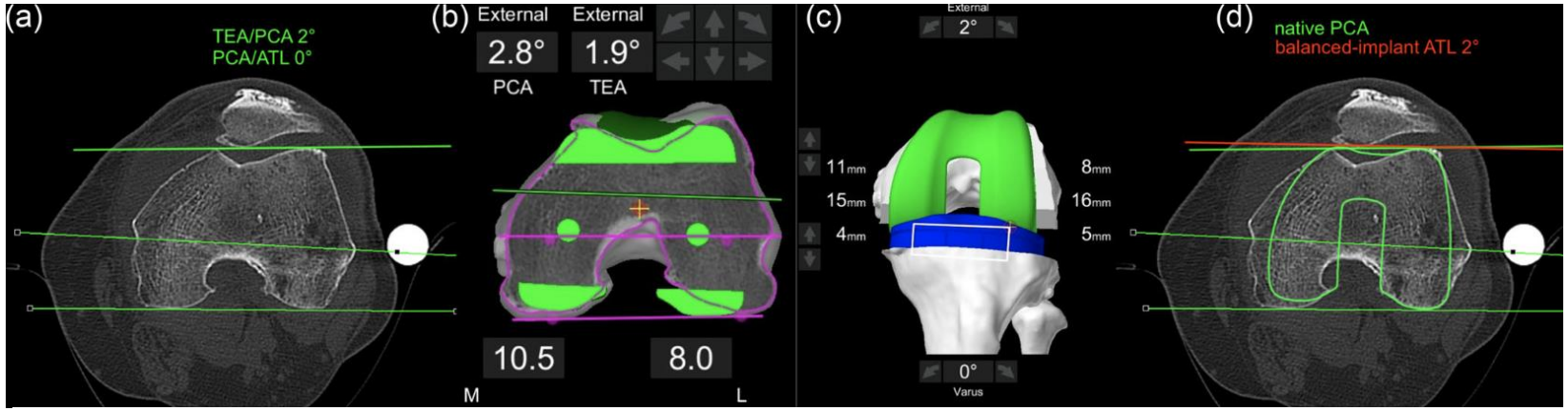


TABLE 4 Lateral trochlear inclination angle values and outliers.

	MA	KA	aMA	FA
Outliers (%)	120/200 (60%)	94/200 (47%)	93/157 (59.2%)	21/43 (48.8%)
Value in ° [IQR]	15 [0]	18 [0]	15 [2]	15 [4]

Abbreviations: aMA, adjusted mechanical alignment; FA, functional alignment; IQR, interquartile range; KA, kinematic alignment; MA, mechanical alignment.

TABLE 5 Anterior trochlear line angle values and outliers.

	MA	KA	aMA	FA
Outliers (%)	170/200 (85%)	81/200 (40.5%)	130/157 (82.8%)	31/43 (72.1%)
Value in ° [IQR]	−1 [0]	2 [0]	−1 [2]	−1 [4.5]

Abbreviations: aMA, adjusted mechanical alignment; FA, functional alignment; IQR, interquartile range; KA, kinematic alignment; MA, mechanical alignment.

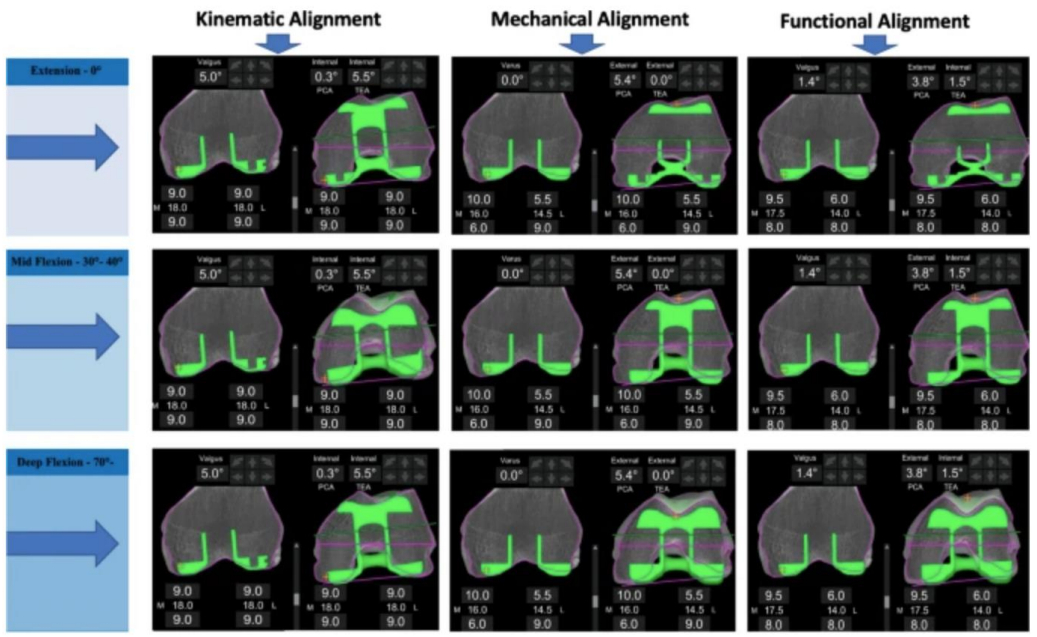
- Klasan A, Anelli-Monti V, Putnis SE, Neri T, Kammerlander C. The effect of different alignment strategies on trochlear orientation after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc*. 2024; 32: 1734–1742. https://doi.org/10.1002/ksa.12178

The Trochlea in the Robotic Age: Clinical

120 consecutive TKAs

- KA better than MA at restoring Trochlea
- Trochlear Depth Restoration poor and under-appreciated
- Under-stuffing did not impact PROMS
- Over-stuffing negatively impacted PROMs

Fig. 3



Shatrov, J., Coulin, B., Batailler, C. *et al.* Alignment philosophy influences trochlea recreation in total knee arthroplasty: a comparative study using image-based robotic technology. *International Orthopaedics (SICOT)* **47**, 329–341 (2023).

Overstuffing in mid flexion decreases KSS scores

- 96 Primary TKAs
- FA
- KSS and FJS at one year
- Under-stuffed 0,30, 70 Flexion
- Overstuffed at 90 Flexion (2-3mm)
- <KSS p=0.009 and Flexion (p=0.04)

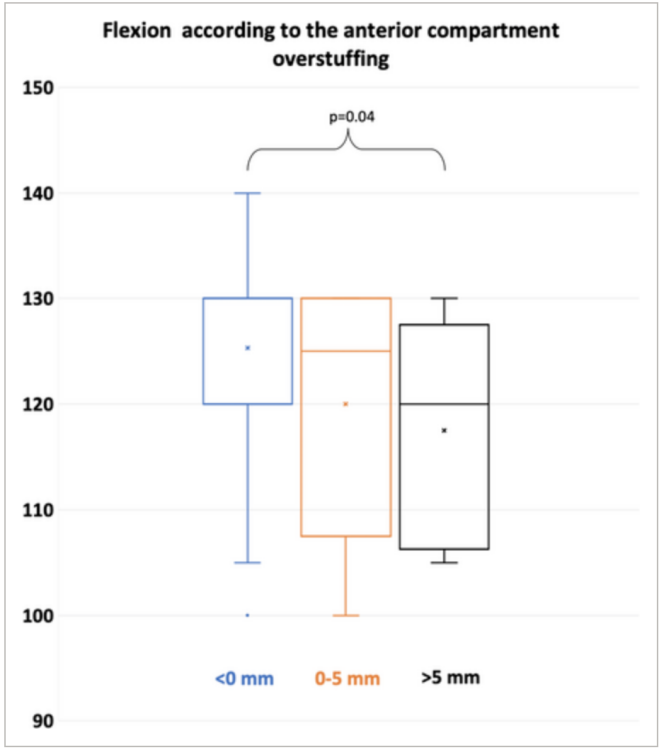


Figure 5 Open in figure viewer | PowerPoint

Boxplot reporting the flexion at the last follow-up according to the anterior compartment restoration at 90° (<0, 0–5 or >5 mm).

Kafelov, M., Batailler, C., Servien, E. & Lustig, S. (2024) Restoration of the anterior compartment after robotic total knee arthroplasty significantly improves functional outcome and range of motion at 1 year. Knee Surgery, Sports Traumatology, Arthroscopy, 1–10. https://doi.org/10.1002/ksa.12337

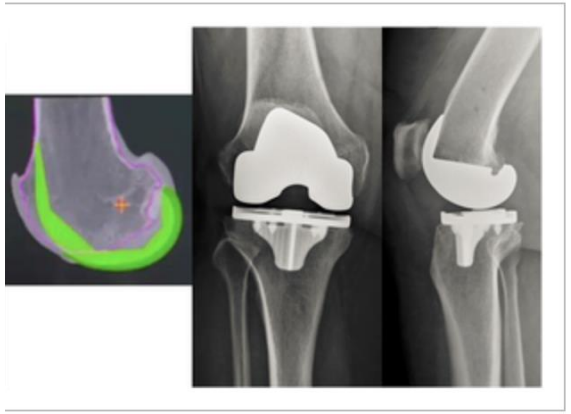
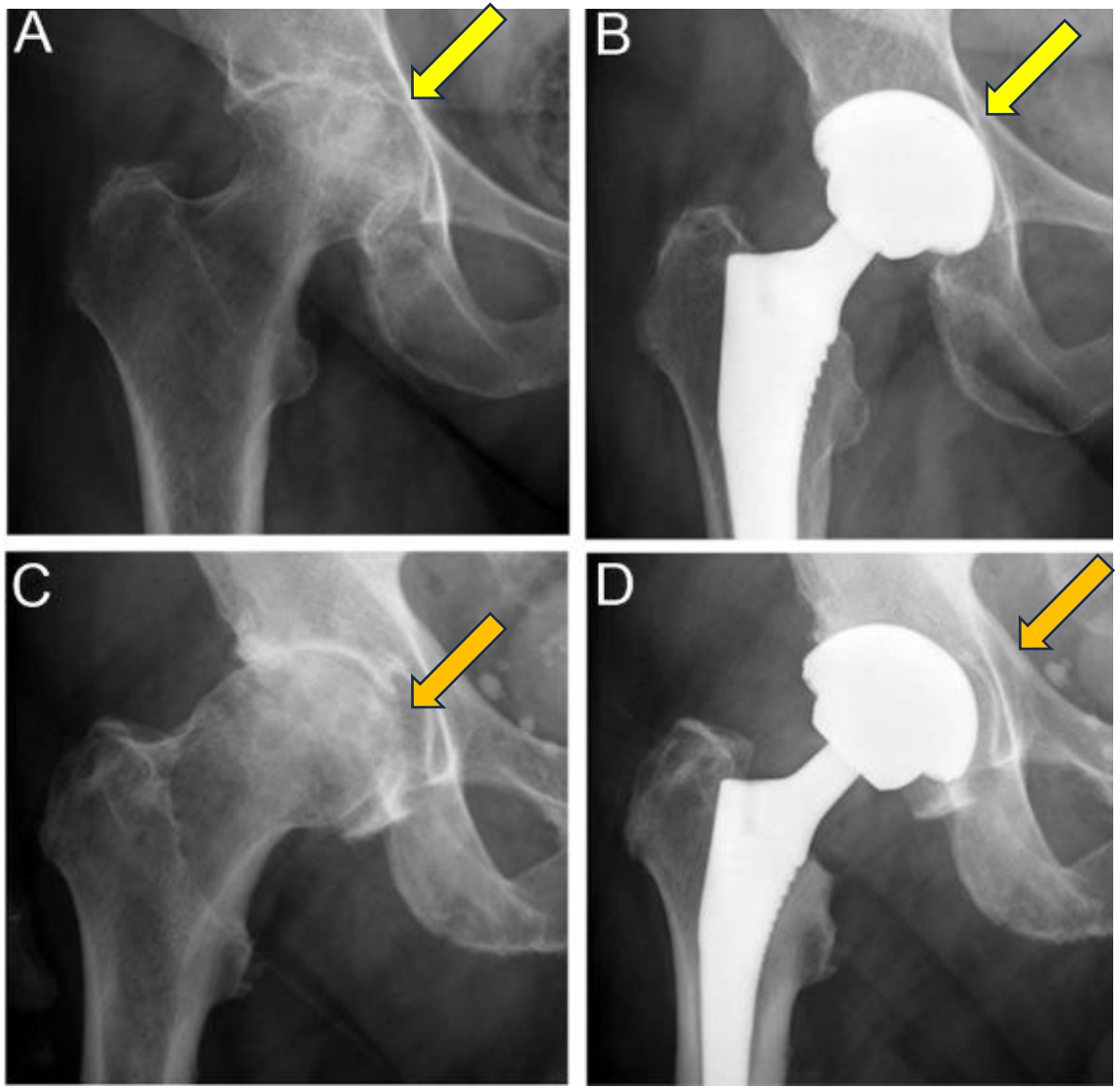


Figure 4 Open in figure viewer | PowerPoint

A 70-year-old woman with anterior compartment understuffing by trochlear understuffing at 30° and 70° of flexion. Preoperative and postoperative radiographs (AP and lateral views) and robotic planning in the sagittal plane.

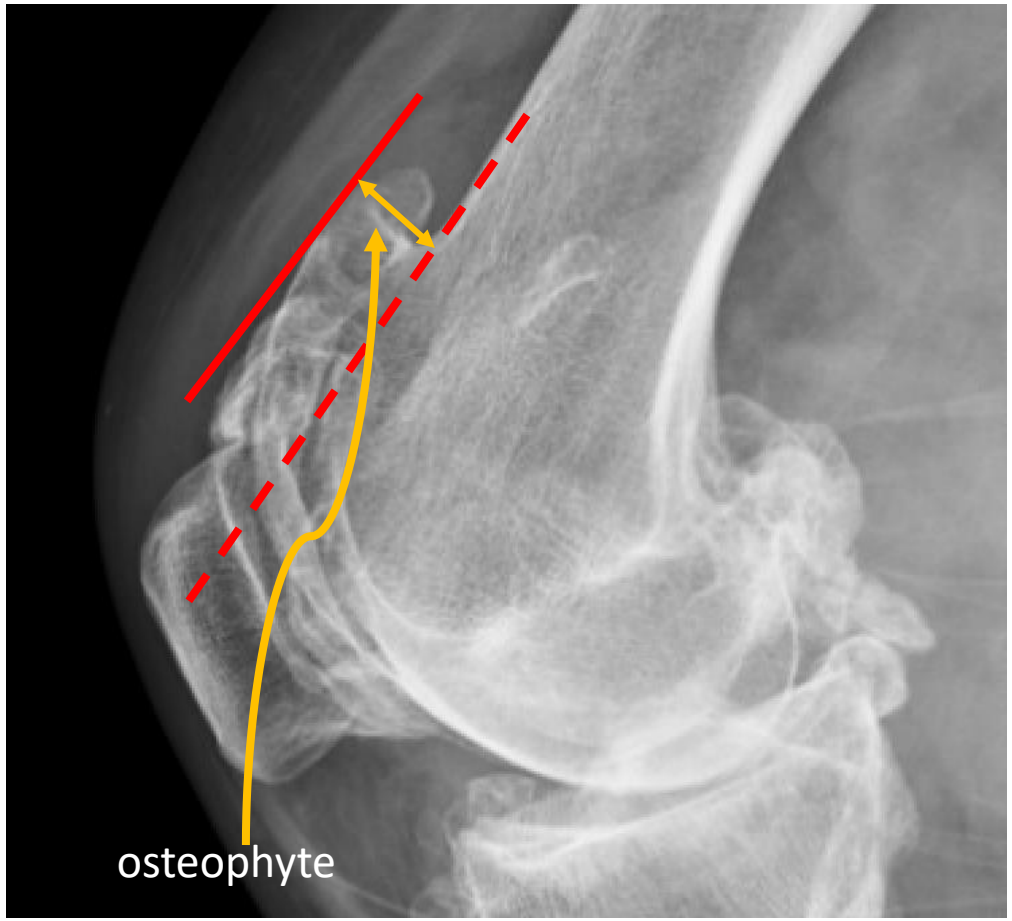
Medial Acetabular Osteophyte

- **Medial Osteophyte**
- Acquired (arthritis)
- If resected leads to decreased offset from pre-op
  - Instability
  - Abductor Weakness

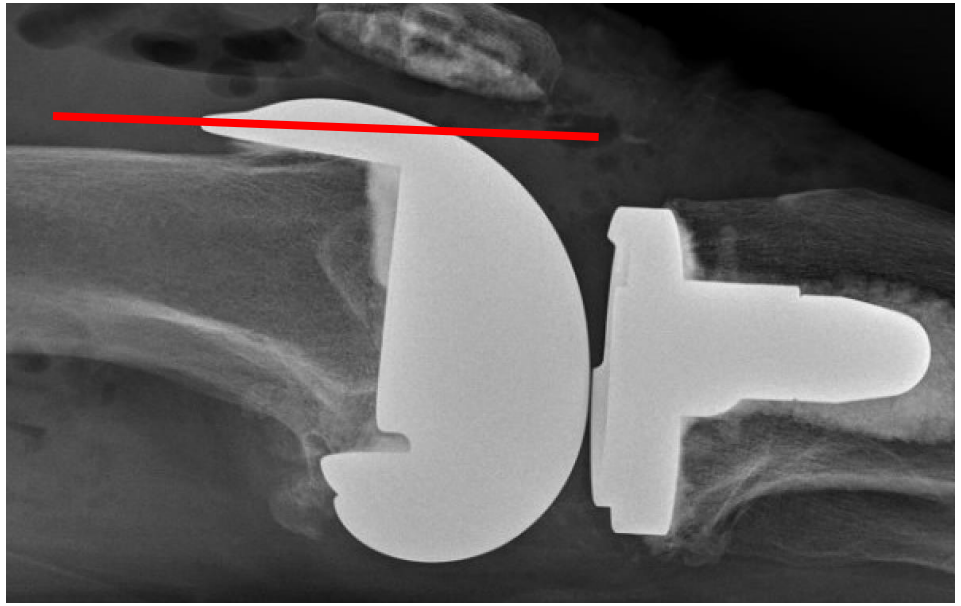


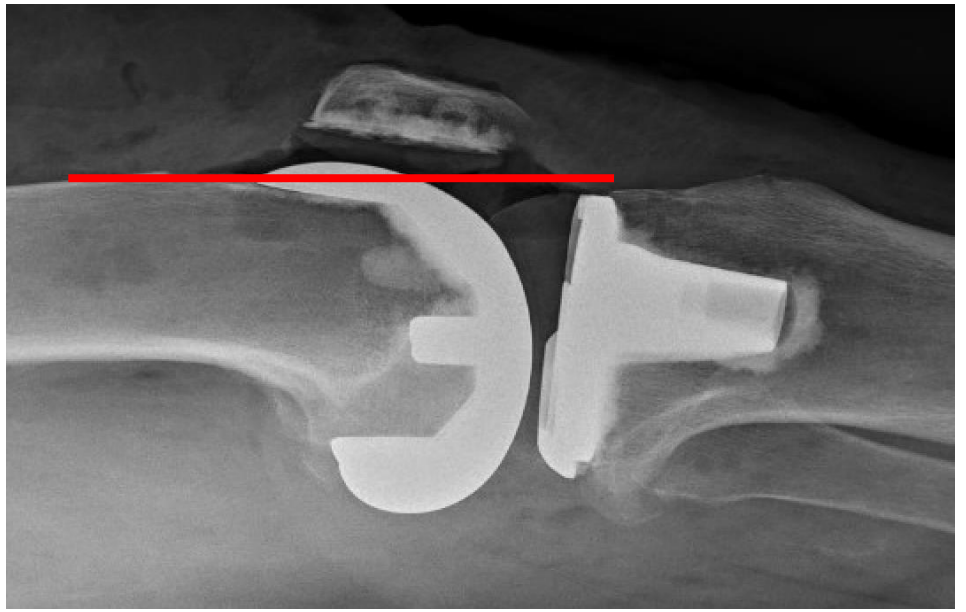
Geert Meermans et al, EFFORT Open Reviews 2022

The Normal Knee:
Sulcus is flush with the anterior femoral cortex



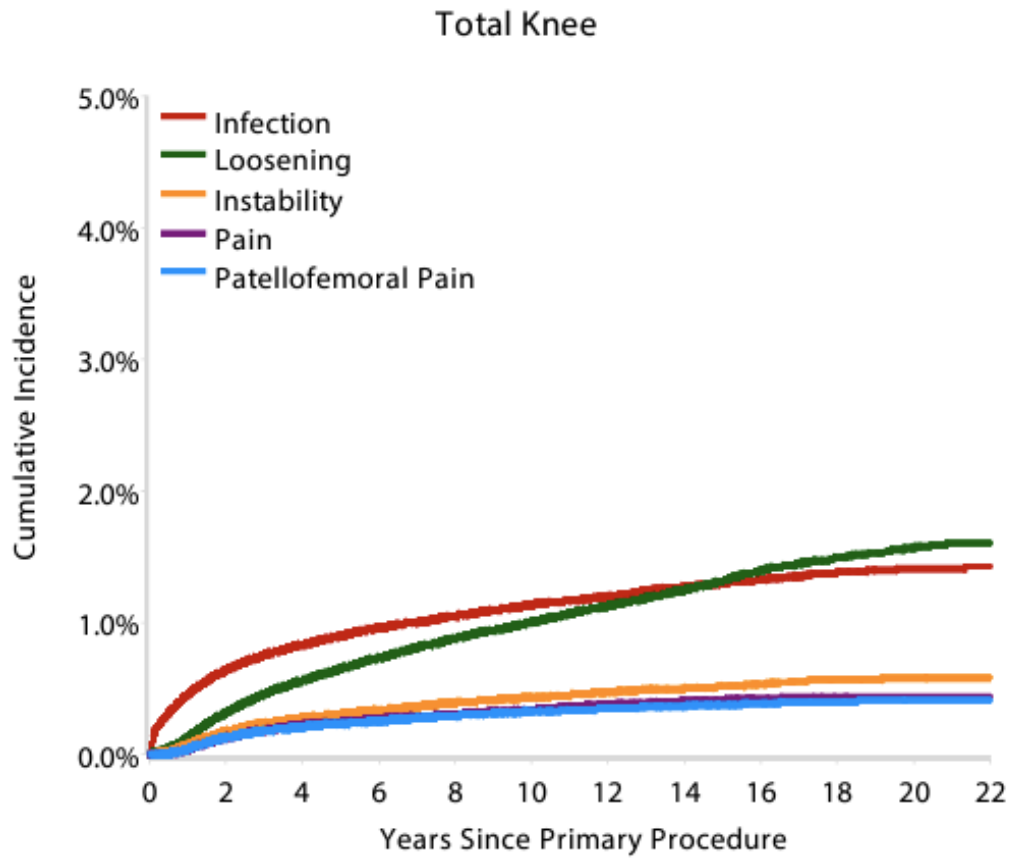
The Trochlear osteophyte: Under Stuffing or Overstuffing





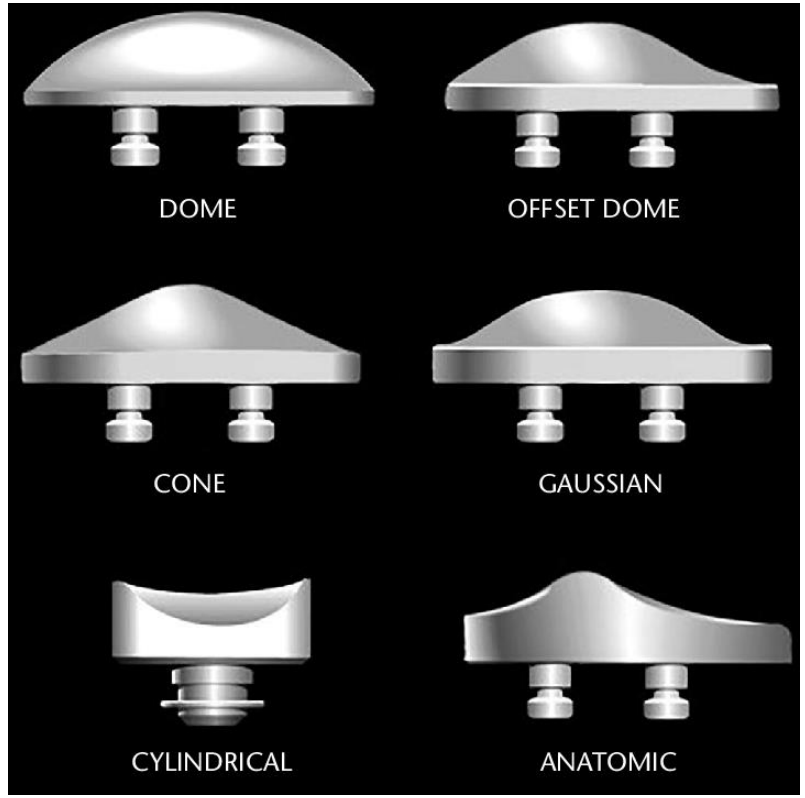
Revision Due to PF Pain (AJRR 2023)

Figure KT8 Cumulative Incidence Revision Diagnosis of Primary Total Knee Replacement (Primary Diagnosis OA)



The Patella and Patellar Prosthesis

- Modified Dome
  - More adaptable
  - Higher contact stresses
    - Less conforming
- Anatomic Implants
  - Lower contact stresses
    - More conforming
  - Very sensitive to
    - Mal-positioning
    - variations in Q angle



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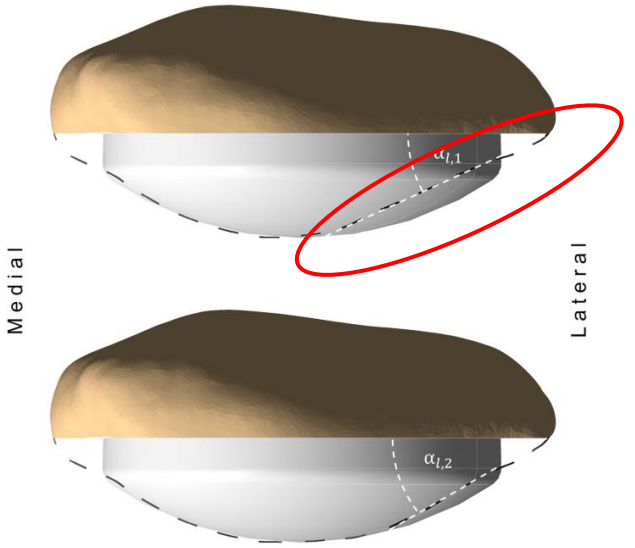
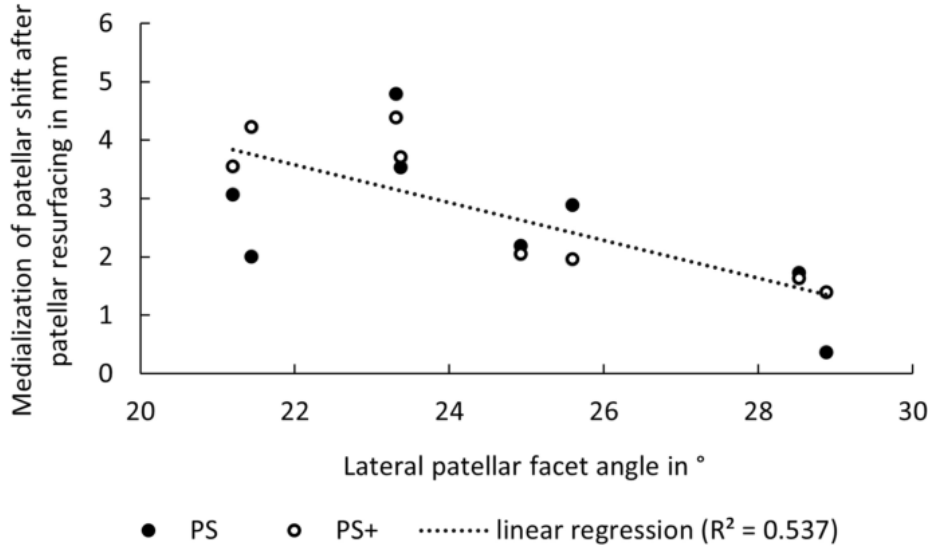
Roussot, Mark Anthony, and Fares Sami Haddad. "The evolution of patellofemoral prosthetic design in total knee arthroplasty: how far have we come?." *EFORT open reviews* 4.8 (2019): 503-512.

Patellar Overstuffing

- Patellas with low native lateral facet angles may be overstuffed when replaced by a patellar button centered over the patella.
- Overstuffs laterally
- Causes medialization of the patella 2-3 mm

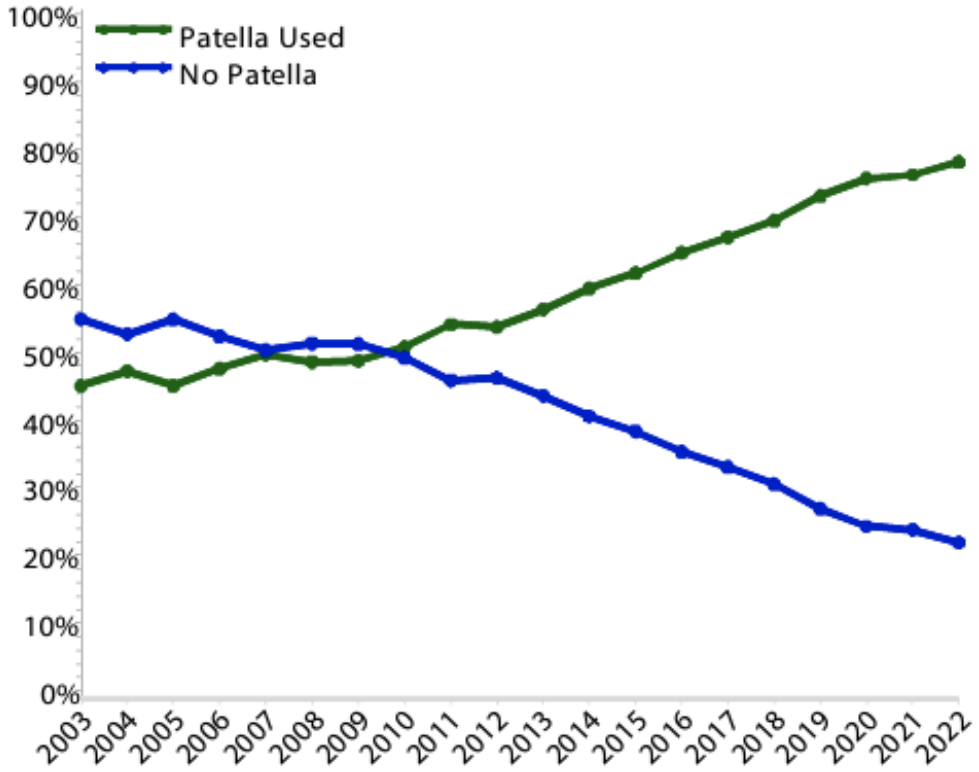
- *Sauer et al, Scientific Reports, 2022*





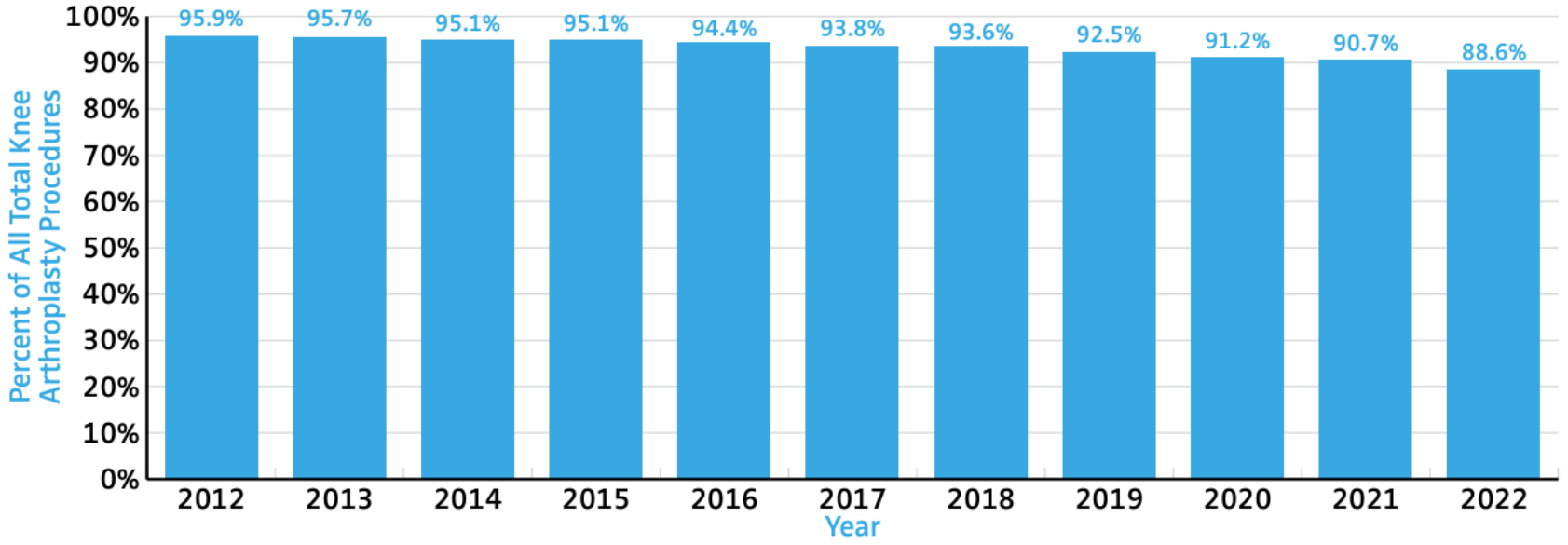
TKA by use of Patellar Component over time (Australian Registry 2023)

Figure KT3 Primary Total Knee Replacement by Patella Component Usage



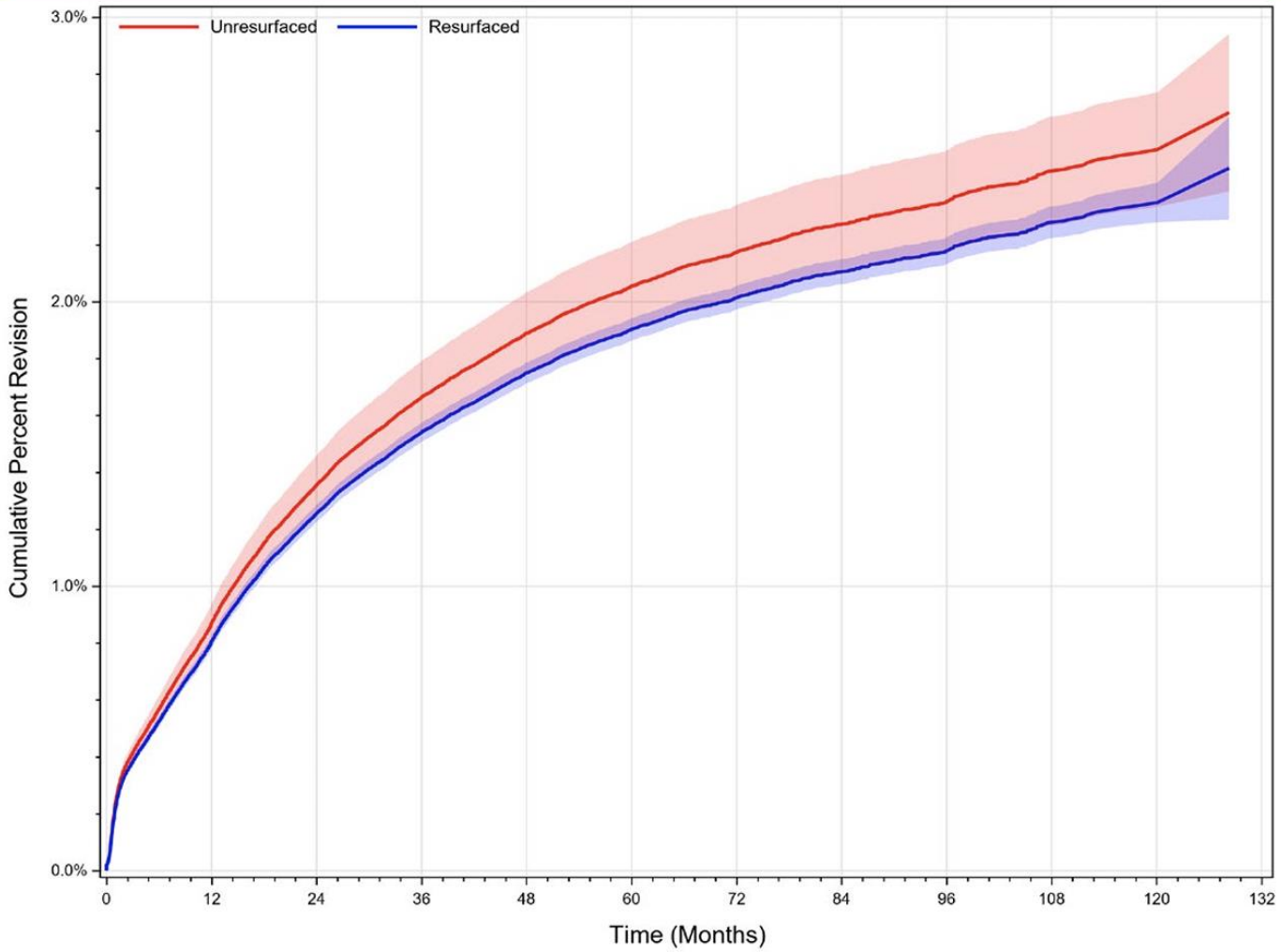
AJRR % TKA with Patellar Resurfacing

Figure 3.8 Percentage of Primary Total Knee Arthroplasty with Patellar Resurfacing, 2012-2022 (N=1,135,842)



No difference in revision rates +/- Resurfacing TKA >65 AJRR 2023

Figure 3.9 Cumulative Percent Revision for Total Knee Arthroplasty Patellar-Resurfacing in Medicare Patients 65 Years of Age and older with Primary Osteoarthritis, 2012-2022



Clinical Overview

- PFJ is distinct from TFJ
- PFJ Complications can be high
- PF issues Cause of Revision 7.7% In Australian Registry
- Un-resurfaced variably increased risk of revision
- Resurfaced Tracks better if patella is worn
- KA is more PF Friendly

1. Assiotis, A., To, K., Morgan-Jones, R., Pengas, I.P. & Khan, W. (2019) Patellar complications following total knee arthroplasty: a review of the current literature. European Journal of Orthopaedic Surgery & Traumatology, 29(8), 1605–1615. Available from: https://doi.org/10.1007/s00590-019-02499-z

Implant Advancements

- Custom implants (femoral) may be an answer and are increasingly cost neutral
- There may be sufficient overlap to justify just two versions of a femoral component (two different Trochlear Angles accepting 4-8 and 6-10) degrees of valgus to cover 95% of the population
  - Asian Knee?
- Better designs of the trochlea to better match native tracking (shallower, lateral and broader proximally, Deeper and steeper distally. lateral)
- Patellar design is relevant, sombrero more forgiving of malalignment between implant and native
- Patellar resurfacing may be indicated in situations with wear and increased q angles to help with tracking

The PF Story has just begun

- Do we overstuff the PF space when closing the medial retinaculum?
- What role does the fat pad have on PF kinematics?
- Do we change tibial rotation in certain PF phenotypes?
- At what point is a custom knee appropriate?
- What is the role of tri-compartmental UKA?
- Does removing the Trochlear Osteophyte decrease quad strength enough to be symptomatic?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PFA as % of all TKA. AJRR 2023

- 2012 4% of surgeons performing PFA
- 2022 1% of surgeons performing PFA

Figure 3.21 Patellofemoral Arthroplasty as a Percentage of All Primary Knee Arthroplasty, 2012-2022 (N=6,447)

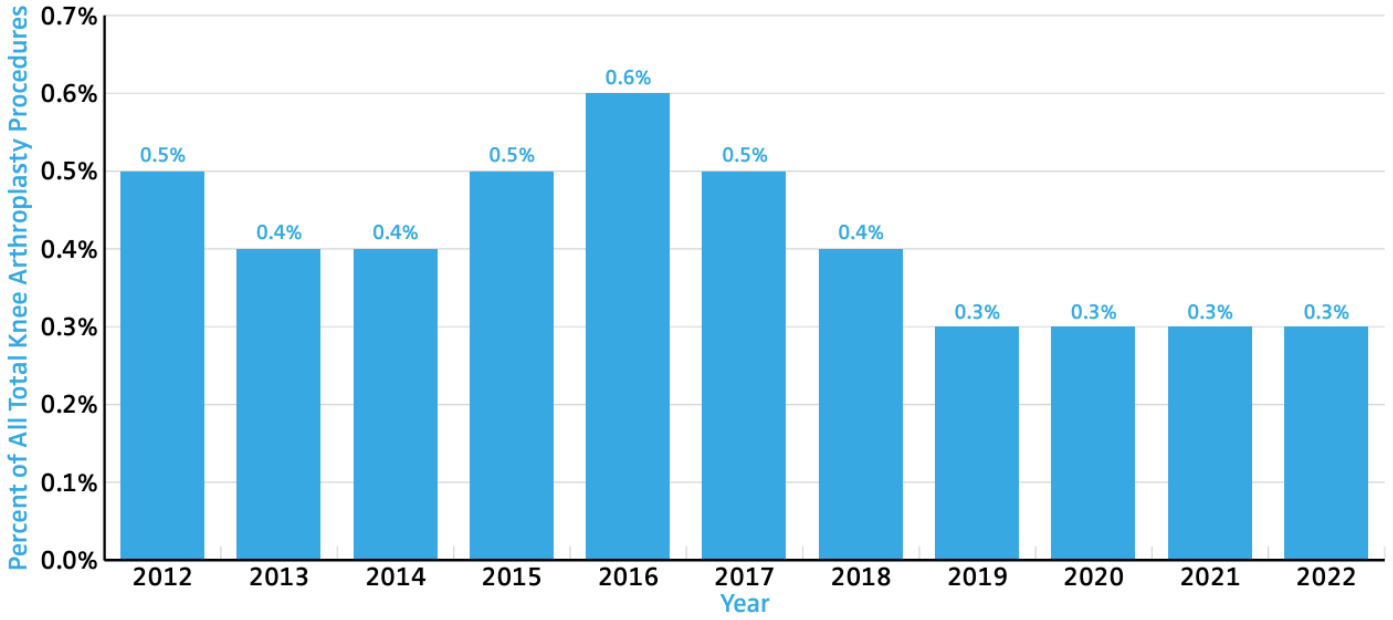

Table 3.6 Surgeons Performing Patellofemoral and Unicompartmental Knee Arthroplasty, 2012-2022

Surgeons Performing Type of Knee Arthroplasty	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Surgeons Performing Unicompartmental Knee Arthroplasty	200 (20.81%)	428 (21.59%)	704 (22.89%)	936 (22.99%)	1,056 (21.28%)	985 (19.79%)	1,151 (23.23%)	1,253 (23.77%)	1,230 (23.01%)	1,137 (22.90%)	1,100 (23.80%)
Suregeons Performing Patellofemoral Arthroplasty	40 (4.16%)	82 (4.14%)	134 (4.36%)	164 (4.03%)	105 (2.12%)	90 (1.81%)	90 (1.82%)	74 (1.40%)	69 (1.29%)	55 (1.11%)	42 (0.91%)
Total number of Surgeons submitting TKA	721 (75.03%)	1,472 (74.27%)	2,237 (72.75%)	2,971 (72.98%)	3,802 (76.61%)	3,902 (78.40%)	3,713 (74.95%)	3,945 (74.83%)	4,046 (75.70%)	3,772 (75.99%)	3,479 (75.29%)