Evaluation of the Natural Patella in a Modern Posterior Stabilized Total Knee Arthroplasty Design Under Physiologic Loading

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Introduction: The Insall-Burstein Posterior Stabilized knee was designed to be implanted with a dome shaped all-polyethylene patellar button.[1] Excellent clinical results have been reported using this construct.[2] The latest versions of the HSS posterior stabilized knee incorporates several design changes making the patellar sulcus more anatomic. In view of these changes, the authors wished to study the kinematics of the natural patella in the latest version of the PS total knee, the forces experienced by the natural patella, and what anatomic, implant design, and implant positioning factors might affect the natural patella when using this implant. The purpose of this study was to compare patella kinematics before and after implantation and to measure contact areas, patellofemoral and tendo-femoral contact pressures and forces under physiologic loads. This was done in preparation for a finite element model that can provide patient specific predictions of best candidates for a retained natural patella.

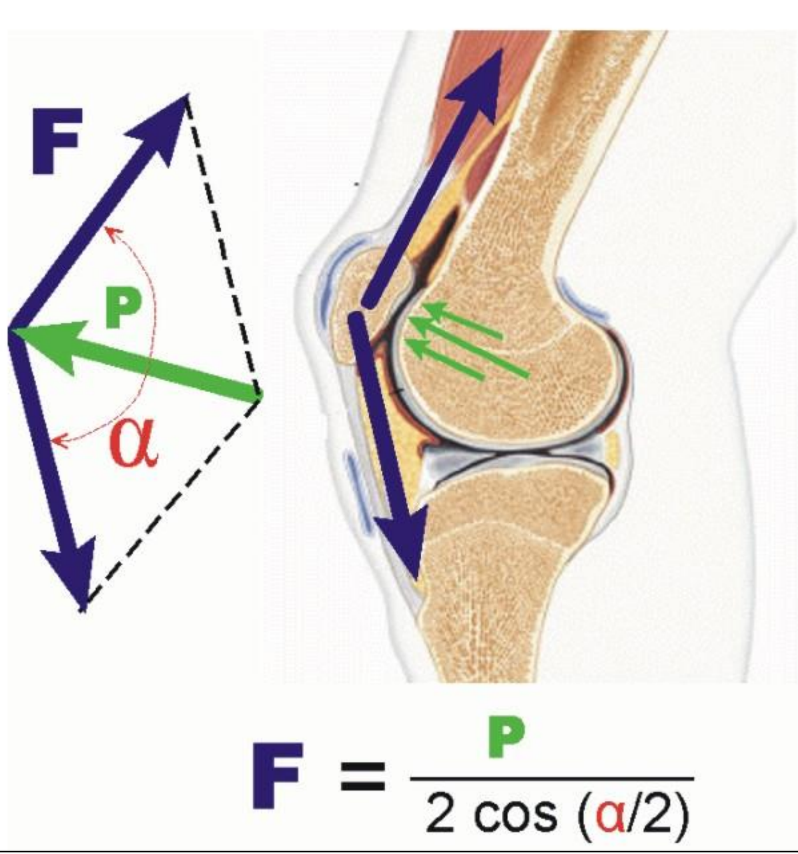

Fig. 1- Free body diagram of joint reactive forces acting on patella

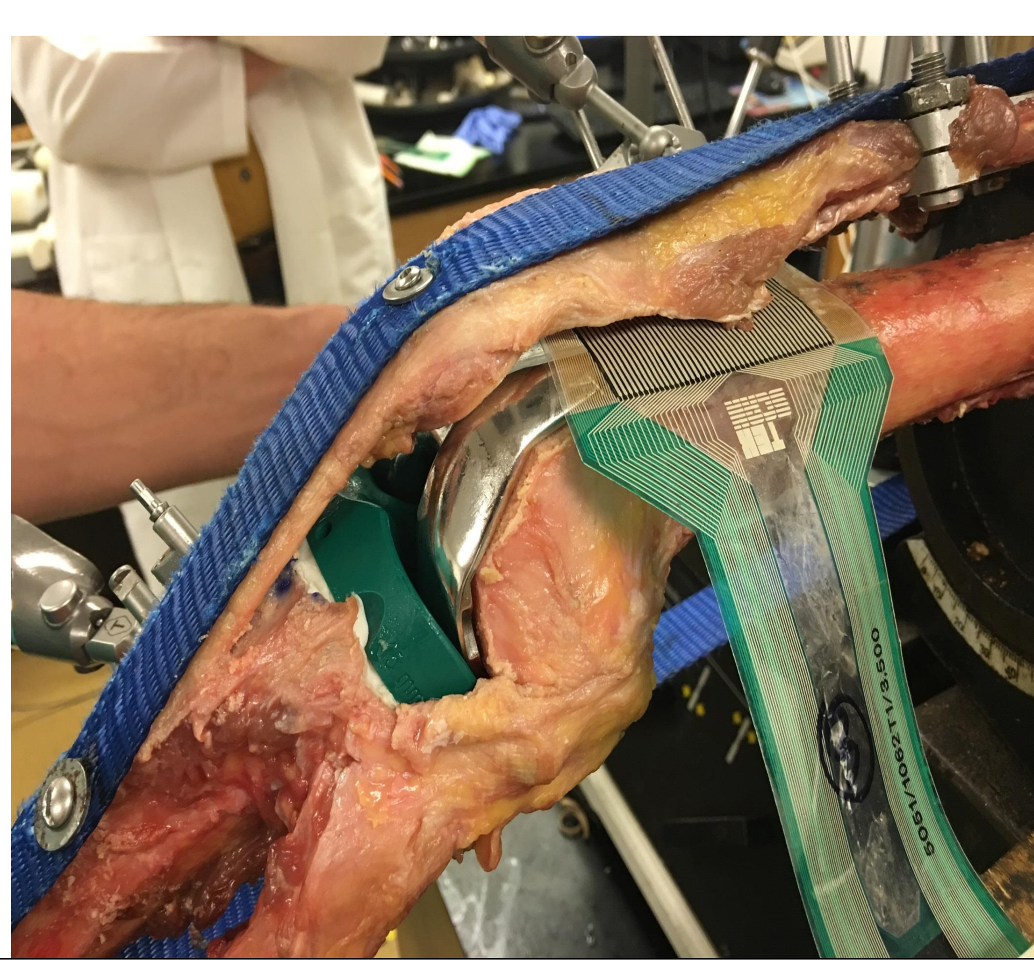

Fig. 2- Depicts the implanted cadaveric knee, experimental apparatus and transducer used to measure contact areas, pressure, and force

Fig. 3 - Peak pressures occurred at 50° of flexion consistent with the point that the patella articulated with the edges of a recess just proximal to the prosthetic box designed to reduce soft tissue entrapment (arrow)

Methods: A 66 year old male left cadaveric lower extremity had all soft tissues removed except for the collateral and cruciate ligaments, the quadriceps and hamstrings. Exactech GPS trackers were mounted on the tibia and femur to actively determine knee flexion angles. Based on the measurements of patello-femoral forces reported by Bondi,[3] and a free-body diagram of the patellofemoral joint showing the "parallelogram of forces" [F= p / 2 cos(α/2)] we calculated the quadriceps forces at 30°, 50°, 70°, 90°, 100°, 110°, 120° knee flexion. (Figure 1) A passive load of 200 N was placed on the quadriceps tendon while the an MTS machine was used to apply additional force of 377, 830, 1388, 1822, 1822 & 1812, 1700 N to a strap anterior to the extensor mechanism. (Figure 2) This was done at each of the 7 flexion angles. Still lateral fluoroscopic images were recorded at each flexion angle as well as lateral motion video and flouroscopic images. (Figure 3) A PS total knee prosthesis (size 4 femoral and tibial components, 13 mm tibial insert) was implanted using traditional extramedullary tibial and intramedullary femoral jigs (6 degree femoral valgus, 3 degrees femoral external rotation referencing the posterior femoral condyles) and the lateral still and motion images repeated. (Figure 2) A Tekscan 5150 transducer was positioned in the patellofemoral articulation and under the quadriceps tendon, allowing measurements of pressure, force, and contact areas under physiologic loads at each flexion angle. (Figure 2)

Results: Lateral still and motion fluoroscopic images revealed very similar patellar positions in the natural and prosthetic knee in the various flexion angles. (Figure 4**)** The patellofemoral-contact area at both 30° and 50° of flexion were bipartite but close together. At 100° medial and lateral contact areas broadened. (Figure 5) The quadriceps tendon did not contact the prosthetic sulcus until 70 ° of flexion. Its footprint then progressively increased as flexion increased. Maximum contact pressures in the patellofemoral joint as recorded in (Table 1) never exceeded 6.0 MPa. The quadriceps tendon took on increasing loads with increasing flexion.

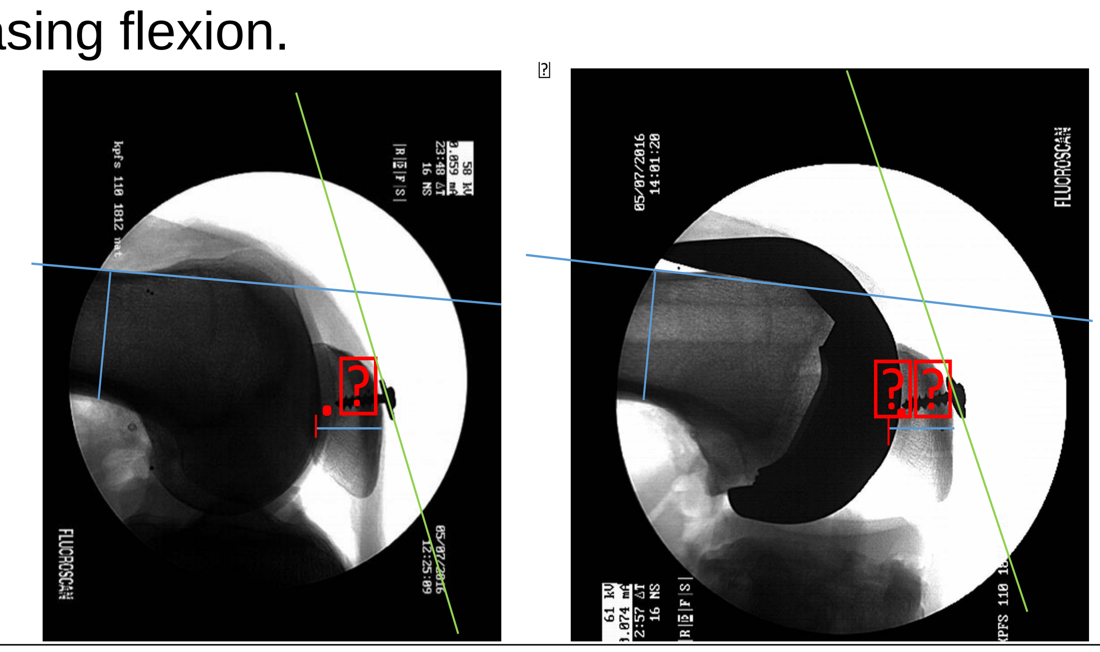

Fig. 4 – The kinematics of the quad tendon and patella were similar in both the implanted and unimplanted knee throughout the arc of motion

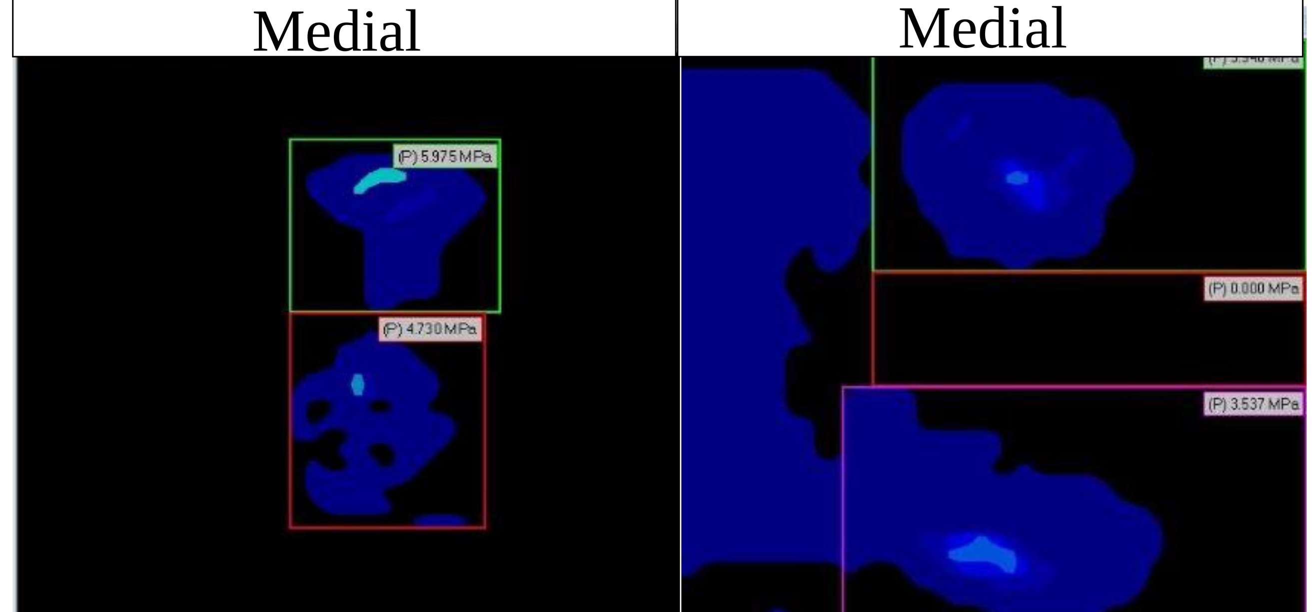

Fig. 5 – Pressure maps at 50° & 100° flexion show the quad tendon comes in contact with the implant at 70° and wider P-F contact points with increased flexion

Flexion	Pressure (MPa)		Force (N)		Contact Area (mm²)	
	Lateral	Medial	Lateral	Medial	Lateral	Medial
30°	0.6	3.0	111	247	184	82
50°	4.7	6.0	633	752	134	126
70°	0.37	2.3	106	544	287	234
90°	5.2	2.5	1437	648	274	260
100°	3.5	4.0	1289	1032	365	261
110°	4.7	3.5	1325	967	284	277
120°	3.9	4.2	971	1065	252	255

Table 1 – Patellofemoral contact measurements on the prosthetic sulcus.

Discussion:

- The kinematics of the natural patella in this prosthetic knee were similar to those in the natural knee.
- Patellar contact areas were central but clearly bipartite at 30° and 50° flexion and then widened as the patella reached the chamfered surfaces at the beginning of the femoral box. This was consistent with the geometry of the prosthetic sulcus. (Figure 3)
- The maximum contact pressure measured was 6.0 MPa at 50° flexion consistent with the point that the patella articulated with the edges of a recess just proximal to the prosthetic box that was designed to reduce soft tissue entrapment. (figure 3) Prior studies have suggested that human cartilage can safely tolerate pressures of <7 MPa long term.[4,5]
- The quadriceps tendon came in contact with the prosthetic sulcus at 70° flexion and then increased as flexion progressed. This "turn around" phenomenon coined by Frick in 1911 in the natural knee was the same in this prosthetic knee and functioned to share contact pressures between the patella and the quad tendon thus reducing pressure on the patella at higher flexion angles.[6]

Conclusion: The contact pressures experienced by the natural patella in our cadaver model did not exceed those expected to be tolerated long term.

References:

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