Bone & Joint Research

Supplementary Material

10.1302/2046-3758.118.BJR-2021-0533.R1

1. Tables of results

Table i. Risk of fracture for isolated medial unicondylar knee arthroplasty (UKA-M) in the medial region of interest for the baseline load case, using different percentiles of maximum principal elastic strain in the risk of fracture formula.

Model	Medial implant position	Risk of fracture			
		95th	99th	99.9th	100th
Male	As planned	0.036	0.057	0.107	0.309
	Laterally translated	0.057	0.093	0.171	2.526
	Distally translated	0.041	0.067	0.127	0.344
	Extended	0.038	0.060	0.107	0.293
	Varus rotated	0.035	0.057	0.107	0.326
	Externally rotated	0.047	0.079	0.142	0.514
Female	As planned	0.052	0.073	0.123	0.371

Table ii. Risk of fracture for bi-unicondylar knee arthroplasty in the medial region of interest for the baseline load case, using different percentiles of maximum principal elastic strain in the risk of fracture formula.

Model	Medial implant position	Risk of fracture			
		95th	99th	99.9th	100th
Male	As planned	0.040	0.065	0.127	0.422
	Laterally translated	0.064	0.107	0.205	2.947
	Distally translated	0.045	0.072	0.136	0.363
	Extended	0.043	0.069	0.123	0.307
	Varus rotated	0.039	0.065	0.123	0.371
	Externally rotated	0.052	0.089	0.172	0.729
Female	As planned	0.057	0.081	0.135	0.394

Table iii. Risk of fracture with additional anterior bone removal, similar to that required for bicruciate-retaining total knee arthroplasty, in the medial region of interest for the baseline load case, using different percentiles of maximum principal elastic strain in the risk of fracture formula.

Model	Anterior bone removed	Risk of fracture			
		95th	**99th**	**99.9th**	**100th**
Male	5 mm	0.061	0.120	0.242	1.208
	10 mm	0.081	0.142	0.251	0.850

Table iv. Risk of fracture for bi-unicondylar knee arthroplasty in the whole spine region of interest for the baseline loadcase, using different percentiles of maximum principal elastic strain in the risk of fracture formula.

Model	Implant position		ROF for baseline load case				ROF for overstuffed load case			
			95th	**99th**	**99.9th**	**100th**	**95th**	**99th**	**99.9th**	**100th**
Male	As planned		0.034	0.054	0.107	0.422	0.187	0.300	0.585	2.363
	UKA-M laterally translated UKA-L medially translated	UKA-M + 2 SD	0.048	0.088	0.169	2.947	0.261	0.473	0.898	14.545
		UKA-L + 2 SD	0.041	0.065	0.116	0.382	0.234	0.371	0.651	2.115
		Both + 1 SD	0.048	0.078	0.138	0.411	0.260	0.414	0.704	1.926
	Distally translated	UKA-M + 2 SD	0.037	0.061	0.113	0.363	0.205	0.331	0.601	1.991
		UKA-L + 2 SD	0.034	0.056	0.107	0.439	0.191	0.304	0.579	2.384
		Both + 1 SD	0.034	0.057	0.074	0.352	0.154	0.241	0.430	3.211
	Extended	UKA-M + 2 SD	0.036	0.058	0.107	0.307	0.204	0.319	0.589	1.730
		UKA-L + 2 SD	0.034	0.055	0.106	0.325	0.189	0.302	0.580	1.902
		Both + 1 SD	0.036	0.058	0.110	0.372	0.200	0.317	0.603	2.016
	Varus rotated	UKA-M + 2 SD	0.033	0.054	0.104	0.371	0.186	0.296	0.568	2.046
		UKA-L + 2 SD	0.034	0.055	0.107	0.399	0.188	0.304	0.584	2.222
		Both + 1 SD	0.033	0.053	0.102	4.408	0.186	0.292	0.560	25.480
	UKA-M externally rotated UKA-L internally rotated	UKA-M + 2 SD	0.041	0.073	0.142	0.729	0.223	0.390	0.745	3.438
		UKA-L + 2 SD	0.035	0.055	0.106	0.412	0.196	0.303	0.581	2.355
		Both + 1 SD	0.035	0.057	0.111	0.289	0.194	0.316	0.606	1.553

ROF, risk of fracture; SD, standard deviation; UKA-M, medial unicondylar knee arthroplasty; UKA-L, lateral unicondylar knee arthroplasty.

2. Sensitivity studies

2.1 Load distribution within the ACL

The load imparted to the tibia from the anterior cruciate ligament (ACL) is not uniform, and varies as successive fibres are recruited. Hence, a sensitivity study investigated whether the load distribution within the ACL attachment influenced the results.

According to the distributions measured by Lord et al,[1] the anteromedial (AM) bundle was divided into two sections: a medial segment running anteroposteriorly; and an anterior segment running mediolaterally (Supplementary Figure a). The posterolateral (PL) bundle was split in half into anterior and posterior sections. In the AM bundle, the original load[2] was split so that three times more load went through the medial section than the anterior section. In the PL bundle, the load split was biased towards the posterior portion of the attachment, which was loaded with 55% of the original PL load.[1]

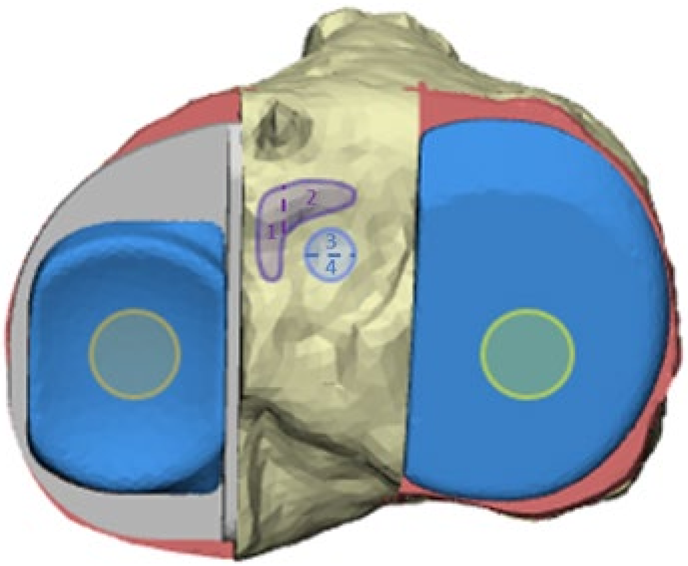

Fig. a. Schematic showing the geometry of the refined anterior cruciate ligament load split; the anteromedial bundle (purple) is split into medial (1) and anterior (2) portions, and the posterolateral bundle is split into anterior (3) and posterior (4) portions.

The location of the highest strains was insensitive to the ACL load distribution, still occurring anteriorly on the medial sagittal cut surface. The conclusion that ACL avulsion risk for bi-unicondylar knee arthroplasty (Bi-UKA) is similar to unicondylar arthroplasty (UKA) was upheld; refinement of the ACL loading reduced risk of fracture (ROF) by 12% for Bi-UKA, and increased ROF by 9% for isolated medial unicondylar knee arthroplasty (UKA-M). As such, the conclusion of this study was deemed to be insensitive to the choice of ACL load distribution.

2.2 Assessing the influence of partial volume effects on material property assignment and study outcomes

The sensitivity of the model to errors in material assignment was investigated for the UKA-M and Bi-UKA models by applying homogeneous cancellous bone material properties (400 MPa elastic modulus) rather than CT-derived properties. The intraoperative load case for a well-sized bearing was applied.

Use of homogeneous cancellous bone material properties affected results, but not the conclusions that have been drawn from them. With homogeneous material properties applied, strain concentrations were still observed in the same locations predicted with the heterogeneous models. The conclusion that ACL avulsion risk for Bi-UKA is similar to UKA-M was again upheld; the ACL avulsion risk was only 3% higher in Bi-UKA than in UKA-M with homogeneous properties. As such, the conclusions of this study were deemed to be insensitive to errors in material property assignment.

3. Qualitative comparison of internal tibial stresses

Recent experimental work[3] enabled comparison of the internal stresses predicted at a transverse cross-section of the proximal tibial models, to pressures measured in vitro. Only a qualitative comparison is possible, given that the specimens used experimentally are not the same as those used computationally. Maintaining the geometries and materials of the models used in this study, simulations were run using the boundary conditions of the experiment and found comparable spatial distribution of contact pressures (Supplementary Figure b).

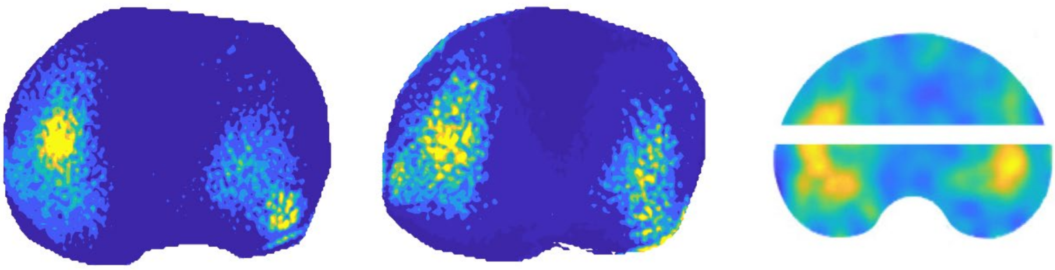

Fig. b. Qualitative comparison of spatial distribution of contact pressures predicted in the male (left) and female (centre) finite element models, and those measured experimentally (right).[3] Note that colour scales are not comparable here.

References

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2. **Markolf KL, Park S, Jackson SR, McAllister DR.** Contributions of the posterolateral bundle of the anterior cruciate ligament to anterior-posterior knee laxity and ligament forces. *Arthroscopy*. 2008;24(7):805-809.

3. **Munford MJ, Stoddart JC, Liddle AD, Cobb JP, Jeffers JRT.** Total and partial knee arthroplasty implants that maintain native load transfer in the tibia. *Bone Joint Res*. 2022;11(2):91-101.