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Determinants of anterior knee pain following total knee replacement: a systematic review

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Abstract
Purpose Anterior knee pain (AKP) following total knee replacement (TKR) is both prevalent and clinically relevant. The purpose of this study was to systematically review the peer-reviewed literature, and to identify and assess the different modifiable and non-modifiable determinants that may be associated with the development of AKP in patients following primary TKR.
Methods A systematic computerized database search (Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, and Google Scholar) was performed in January 2012. The quality of the studies was assessed using the GRADE approach.
Results A total of 54 articles met the inclusion criteria. Variables that have been researched with regard to the prevalence of AKP include patient and knee-specific characteristics, prosthetic design, operative technique, treatment of the patella, and time of assessment. A weak correlation with AKP was found for specific retained presurgery gait patterns. A weak recommendation can be given for the use of femoral components with a posterior centre of rotation, resection of Hoffa's fat pad, patellar rim electrocautery, and preventing combined component internal rotation. The correlation between postsurgical AKP and the degree of patellar cartilage wear, tibial component bearing strategies, and patellar resurfacing is inconclusive. Due to substantial heterogeneity of the included studies, no meta-analysis was performed.
Conclusions No single variable is likely to explain the differences in the reported rates of AKP, although variables leading to abnormal patellofemoral joint loading appear to be of special significance.
Level of evidence III.

Keywords Knee · Total knee replacement · Anterior knee pain · Systematic review

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Introduction

The ultimate goal of total knee replacement (TKR) is to relieve pain and to improve the functional outcome. Patient expectations play an important role in achieving this goal [3]. Residual pain following TKR is an important reason for patients' dissatisfaction [9, 52]. Several factors that are associated with residual pain have been identified, both extra- and intra-articular, but often no cause can be found [53]. Moreover, female sex, young age at time of surgery, and a higher than normal depressive or anxiety state are associated with a more painful knee [9, 10].

Anterior knee pain (AKP) is reported to occur in up to one half of all patients following primary TKR. The presence of AKP after TKR is negatively correlated with patient satisfaction and quality of life [4, 11, 44]. With the increasing number of TKRs and the particular importance of patient expectations, addressing the problem of AKP after TKR is of special significance. Although several patient and technique related factors involved in AKP have been identified [5, 11, 16, 46, 54], no systematic evaluation and qualitative assessment of these data has been performed.

The purpose of this systematic review is therefore to identify and assess the different modifiable and non-modifiable determinants that may be associated with the development of AKP in patients following primary TKR.

Materials and methods

Identification of studies

An independent librarian performed the literature search using the following search terms with Boolean operators: anterior knee pain or patellofemoral pain or retropatellar pain and knee arthroplasty or knee arthroplasties or knee replacement or knee replacements or knee prosthesis or knee prostheses or TKA or TKR or TKP. Search queries were limited to title/abstract, and language was restricted to English, French, or German. The electronic search involved the Cochrane Database of Systematic Reviews, the Cochrane Central Register of Controlled Trials, MEDLINE, EMBASE, and Google Scholar, and included articles published until January 2012.

Assessment of study eligibility

Only published full-text peer-reviewed studies of AKP following primary TKR without regard for the underlying pathology were included if the prevalence of AKP was related to distinctive patient and technique related variables. Studies not reporting the prevalence of AKP were excluded, as were publications with incompletely described patient populations, less than 10 included patients, less than 6 months of follow-up, insufficient descriptions of treatment, and studies that failed to describe the method used to assess the prevalence of AKP. Two reviewers (HPWvJ and JMR) independently examined all titles and abstracts and selected the studies for full-text review. Where there were discrepancies in the studies included, the authors were able to reach a consensus. Additionally, the reference lists in the included studies were hand-searched for other relevant studies. The full texts were retrieved and further checked for inclusion and exclusion criteria. If articles described the same series of patients, both studies were included to evaluate for possible time-dependent differences in the prevalence of AKP.

Data abstraction

For all studies selected for full-text review, relevant data were abstracted from the text, figures, and tables using a structured data abstraction form. Data extraction was undertaken by one author (HPWvJ) and validated by a second (JMR). The elements abstracted included type of study, number of patients, details on intervention, outcome measures, follow-up, variables studied in relation to AKP, and the prevalence of AKP including the method used to assess the prevalence. When the reported data were incomplete, corresponding authors were contacted by email for additional data.

Assessment of methodological quality

Two authors (HPWvJ and JMR) assessed the quality of the included studies independently using the Grading of Recommendations Assessment, Development and Evaluation (GRADE) approach [21, 49]. A recommendation for or against the use of an intervention was given for the modifiable determinants. For the non-modifiable determinants, the strength of the correlation with AKP was graded as no correlation, inconclusive, weak, or a strong correlation.

Statistical analysis

Data from the included studies were tabulated to show the determinants investigated for their possible association with AKP and the reported prevalence of AKP. Data were analysed descriptively by using proportions and frequencies for categorical variables. A meta-analysis and statistical analysis were not feasible due to heterogeneity of the study designs and patient populations, surgical techniques, the type of knee prosthesis used, and the reported outcome measures.

Results

Search strategy and results are summarized in Fig. 1. Of 221 titles reviewed, 108 studies underwent a full review, of which 54 were included. The quality of the included studies according to GRADE is reported in Table 1.

Patient characteristics

Both age and gender were not found to be predictive of postsurgical AKP [11, 14, 16, 24, 54, 60, 61]. Also, a multitude of studies reported no association between postsurgical AKP and weight, height, or BMI [4, 6, 11, 14, 16, 24, 43, 48, 54, 55, 60]. A prospective cohort study found that the frequency and severity of AKP after TKR is related to retained presurgery gait patterns that had higher external flexion moments in the early mid-stance phase, which place higher forces on the patellofemoral joint [54]. A number of studies demonstrated that preoperative AKP was not predictive of postoperative AKP, whether the patella was resurfaced or not [2, 4, 6, 7, 11, 14, 15, 48, 54, 55, 61].

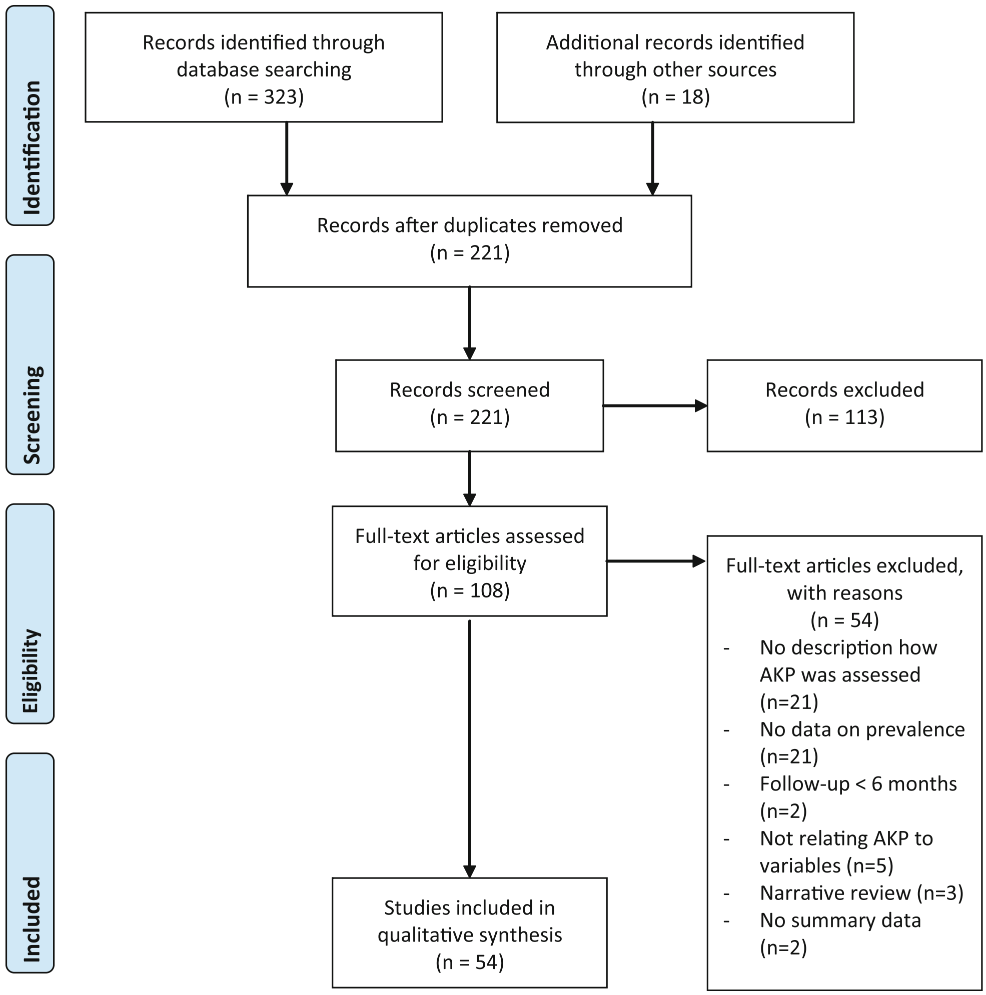

Fig. 1 PRISMA flow diagram of included studies

Knee-specific characteristics

Diagnosis (osteoarthritis vs. other) and preoperative radiographic stage are not predictive of postsurgical AKP [16, 43]. The relation between the degree of intra-operatively assessed patellar cartilage involvement and postsurgical AKP is inconclusive, with some studies reporting an association [50, 51], while others did not [4, 6, 7, 14, 15, 40, 43, 61]. Preoperative range of motion and preoperative Knee Society knee scores were not found to be predictive of AKP [61], and no correlation was found between a preoperative deformity and AKP [16].

Prosthetic design

Several studies evaluated the results of improving the 'patella-friendliness' of femoral component designs, and found no effect on AKP rates [16, 35, 41, 57]. In a recent meta-analysis on patellar resurfacing, the impact of prosthetic design was evaluated by classifying the TKRs in the included RCTs as patella-friendly or non-patella-friendly according to the conformity of the patella against the femoral component [46]. No differences in the incidence of AKP between groups were found. The use of prostheses with a more posterior centre of rotation may result in lower AKP rates [32]. No differences in the prevalence of AKP were seen between PCL-retaining- and PCL-substituting TKR [16, 57, 60]. With regard to the tibial component, no differences were found in the prevalence of AKP between a posterior-stabilized tibial component and a conforming deep-dish congruent component [28], or between a conventional posterior-stabilized and a high-flex posterior-stabilized polyethylene tibial insert [34]. Although one study reported lower AKP rates with mobile-bearing as compared to fixed-bearing tibial components [11], other studies found comparable proportions of AKP [1, 8, 26]. One study found similar AKP rates for one-peg patellar component fixation compared to three-peg fixation [27].

Table 1 GRADE evidence profile: non-modifiable and modifiable determinants of anterior knee pain following primary total knee replacement

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Patient characteristics—age and gender											
7	Retrospective case series [24]						32k (29p)		AKP 6/32 = 19 %; mean age 85y, no AKP 26/32 = 81 %; mean age 72y, $p = 0.16$	Low	No correlation
									AKP 6/32 = 19 %; F:M ratio 1:5, no AKP 26/32 = 81 %; F:M ratio 9:17, $p = 0.33$		
	RCT [61]				−1 (no statistics)		218k		AKP 54/218 = 24.8 %; age and gender: no difference	Moderate	No correlation
	RCT [60]						474k		AKP 71/474 = 15.0 %; age 68.7y ± 10.40, no AKP 403/474 = 85.0 %; age 69.0y ± 8.94, $p = 0.7619$	High	No correlation
									AKP 71/474 = 15.0 %; F:M ratio 41:30, no AKP 403/474 = 85.0 %; F:M ratio 248:155, $p = 0.6369$		
	RCT [14]						39k (36p)		AKP 12/39 = 31 %; age and gender ($p > 0.05$)	High	No correlation
	Prospective cohort [54]						41k (34p)		AKP 17/41 = 41 %; females more likely to develop AKP ($p = 0.051$)	Low	No correlation
	RCT [11]				−1 (no statistics)		100p		AKP 12/100 = 12 %; gender: no difference	Moderate	No correlation
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; age and gender: no difference	Very low	No correlation

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Patient characteristics—weight, height, and body mass index (BMI)											
13	Retrospective case series [50]						100k (84p)		OA: AKP 20/84 = 24 %; average height 170.4 cm, no AKP 64/84 = 76 %; average height 156 cm, $p < 0.01$ OA: AKP 20/84 = 24 %; average weight 85 kg, no AKP 64/84 = 76 %; average weight 60 kg, $p < 0.01$	Low	Weak correlation
	RCT [43]				−1 (no statistics)		95k (91p)		AKP 12/95 = 13 %; weight, height or BMI in patients with OA: no correlation	Moderate	No correlation
	RCT [6]			−1 (mean excess weight)			118k (86p)		AKP 12/118 = 10.2 %; mean percentage of excess weight ($p = 0.45$)	Moderate	No correlation
	Retrospective case series [24]						32k (29p)		AKP 6/32 = 19 %; mean weight 188 lb, no AKP 26/32 = 81 %; mean weight 176 lb, $p = 0.16$	Low	No correlation
	RCT [4]				−1 (no statistics)		93k (67p)		AKP 17/93 = 18 %; obesity: not predictive of postoperative AKP	Moderate	No correlation
	RCT [61]				−1 (confounder)		218k		AKP 54/218 = 24.8 %; weight significant predictor of AKP in group without patellar resurfacing (HR = 1.03, CI 1.003 to 1.05, $p = 0.027$), but not in group with patellar resurfacing ($p = 0.684$). After adjustment for age and sex, the influence of weight was no longer significant ($p = 0.070$)	Moderate	No correlation
	Prospective cohort [48]						70k (35p)		AKP 14/70 = 20 %; mean weight 69 kg, no AKP 56/70 = 80 %; mean weight 64 kg, $p = 0.513$	Low	No correlation

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	RCT [60]						474k		AKP 71/474 = 15.0 %; weight 79.3 kg ± 14.69, no AKP 403/474 = 85.0 %; weight 77.2 kg ± 16.16, $p = 0.3088$	High	No correlation
	RCT [14]						39k (36p)		AKP 12/39 = 31 %; weight, height or BMI ($p > 0.05$)	High	No correlation
	Prospective cohort [54]						41k (34p)		AKP 17/41 = 41 %; weight ($p = 0.792$), BMI ($p = 0.595$)	Low	No correlation
	RCT [11]				−1 (no statistics)		100p		AKP 12/100 = 12 %; obesity: no difference	Moderate	No correlation
	RCT [55]				−1 (no statistics)		159k (142p)		AKP 40/159 = 25.1 %; weight, height or BMI: not predictive	Moderate	No correlation
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; weight, height or BMI: no difference	Very low	No correlation
Patient characteristics—gait pattern											
1	Prospective cohort [54]						41k (34p)	20k (20p)	AKP 17/41 = 41 %; knee joint loading in early mid-stance phase of walking prior to surgery significant predictor of the presence (exp(B) = 2.9, CI: 1.2–6.8, $p = 0.017$) and severity of postsurgery AKP ($R^2 = 0.314$, $p = 0.019$).	Low	Weak correlation
Patient characteristics—preoperative AKP											
12	Retrospective case series [50]				−1 (no statistics)		100k (84p)		AKP 29/100 = 29 %; 25/27 patients with preoperative AKP had postoperative AKP	Very low	Weak correlation
	RCT [6]						118k (86p)		AKP 12/118 = 10.2 %; 4/49 knees with preoperative AKP had postoperative AKP ($p = 0.24$)	High	No correlation
	RCT [4]				−1 (no statistics)		93k (67p)		AKP 17/93 = 18 %; 6/39 knees with preoperative AKP had postoperative AKP	Moderate	No correlation
	RCT [61]				−1 (no statistics)		218k		AKP 54/218 = 24.8 %; preoperative AKP: no significant predictor	Moderate	No correlation
	Prospective cohort [48]				−1 (no statistics)		70k (35p)		AKP 14/70 = 20 %; 9/14 new onset AKP	Very low	No correlation

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	Prospective cohort [2]				−1 (no statistics)		638k (536p)		AKP 78/638 = 12.2 %; 46/378 knees with preoperative AKP had postoperative AKP	Very low	No correlation
	RCT [14]						39k (36p)		AKP 12/39 = 31 %; 5/14 knees with preoperative AKP had postoperative AKP with non-resurfacing ($p = 0.003$), 7/17 knees with preoperative AKP had postoperative AKP with resurfacing ($p = 0.002$)	High	No correlation
	Prospective cohort [54]						41k (34p)		AKP 17/41 = 41 %; presurgery AKP not predictive ($p = 0.090$), presence of other lower limb/lower back symptoms ($p = 0.033$)	Low	No correlation
	Prospective cohort [7]				−1 (no statistics)		139k (80p)		AKP 12/139 = 8.6 %; presence of preoperative AKP not predictive of postoperative AKP	Very low	No correlation
	RCT [15]				−1 (no statistics)		58k (58p)		AKP 26/58 = 45 %; the presence of preoperative AKP: no relation	Moderate	No correlation
	RCT [11]				−1 (no statistics)		100p		AKP 12/100 = 12 %; AKP at baseline: no difference	Moderate	No correlation
	RCT [55]				−1 (no statistics)		159k (142p)		AKP 40/159 = 25.1 %; the presence of preoperative AKP: not predictive	Moderate	No correlation
Knee-specific characteristics—diagnosis (osteoarthritis vs. other)											
2	RCT [43]				−1 (no statistics)		95k (91p)		No resurfacing: AKP in OA 5/35 = 14 %, AKP in RA 4/13 = 31 %	Moderate	No correlation
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; preoperative diagnosis (OA or other): no difference	Very low	No correlation

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Knee-specific characteristics—radiographic grade of osteoarthritis											
2	RCT [43]				−1 (no statistics)		95k (91p)		AKP 12/95 = 13 %; preoperative radiographic stage in non-resurfacing: no correlation	Moderate	No correlation
	Retrospective case series [24]						32k (29p)		AKP 6/32 = 19 %; 4/6 postoperative lateral patellofemoral joint space narrowing (67 %), no AKP 26/32 = 81 %; 9/22 postoperative lateral patellofemoral joint space narrowing (41 %), $p = 0.26$ AKP 6/32 = 19 %; 3/6 postoperative isolated lateral facet sclerosis (50 %), no AKP 26/32 = 81 %; 7/22 postoperative isolated lateral facet sclerosis (31.8 %), $p = 0.63$	Low	No correlation
Knee-specific characteristics—intra-operative degree of patellar cartilage wear											
10	Retrospective case series [50]				−1 (no statistics)		100k (84p)		AKP 29/100 = 29 %; Grade III: AKP 7/29 = 24 %, Grade IV: AKP 22/29 = 76 %	Very low	Weak correlation
	RCT [43]				−1 (no statistics)		95k (91p)		AKP 12/95 = 13 %; patellar cartilage stage: no correlation	Moderate	No correlation
	RCT [6]						118k (86p)		AKP 12/118 = 10.2 %; grade of chondromalacia ($p = 0.35$)	High	No correlation
	RCT [4]				−1 (no statistics)		93k (67p)		AKP 17/93 = 18 %; degree of patellar chondromalacia: not predictive of postoperative AKP	Moderate	No correlation
	RCT [61]				−1 (no statistics)		218k		AKP 54/218 = 24.8 %; grade of patellar articular cartilage and degree of osteophytes: no significant predictor	Moderate	No correlation
	RCT [14]				−1 (no statistics)		39k (36p)		AKP 12/39 = 31 %; remaining articular cartilage: no association with AKP	Moderate	No correlation
	Prospective cohort [7]				−1 (no statistics)		139k (80p)		AKP 12/139 = 8.6 %; state of patellar articular cartilage not predictive of AKP	Very low	No correlation
	RCT [15]				−1 (no statistics)		58k (58p)		AKP 26/58 = 45 %; grade of chondromalacia: no relation	Moderate	No correlation

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	Prospective cohort [40]						65k	57k	Mild/moderate patellar cartilage wear: AKP 6/65 = 9 %, severe patellar cartilage wear: AKP 7/57 = 12 %, $p = 0.952$	Low	No correlation
	RCT [51]			−1 (AKP with need for resurfacing)			500k		No resurfacing. Outerbridge I, II, III: AKP 1/164 = 0.6 %, Outerbridge IV: AKP 10/86 = 12 %, $p = 0.001$, OR 21.5	Moderate	Strong correlation
Knee-specific characteristics—preoperative knee scores, preoperative range of motion											
2	RCT [61]				−1 (no statistics)		218k		AKP 54/218 = 24.8 %; preoperative Knee Society knee score and preoperative range of motion: no significant predictor	Moderate	No correlation
	RCT [55]				−1 (no statistics)		159k (142p)		AKP 40/159 = 25.1 %; with resurfacing: flexion contracture, $p = 0.006$ (OR 9.73, 95 % CI 1.93–48.99)	Moderate	Weak correlation
Knee-specific characteristics—preoperative deformity											
1	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; preoperative deformity (varus or valgus): no difference	Very low	No correlation
Prosthetic design—design geometry femoral component											
6	Matched case series [57]	−1 (confounder)					74k	74k	PCL sacrificing Total Condylar Prosthesis: AKP 9/74 = 12 %, PCL substituting Press Fit Condylar: AKP 3/74 = 4 %, $p = 0.07$	Very low	Weak against
	Prospective cohort [32]						83k (74p)	101k (76p)	Multiradius Series 7000 PPSK: AKP 18/83 = 22 %, Single-radius Scorpio: AKP 1/101 = 1 %, $p = 0.001$	Low	Weak for
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; type of prosthesis (Genesis I or II): no difference	Very low	Weak against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	RCT [35]						36k (27p)	44k (32p)	Insall-Burstein II: AKP 8/36 = 22 %, Press Fit Condylar: AKP 8/44 = 18 %, $p = 0.86$	High	Strong against
	RCT [41]						45k (42p)	46k (42p)	Insall-Burstein PS II: AKP 4/45 = 9 %, NexGen Legacy PS: AKP 5/46 = 11 %, $p = 0.49$	High	Strong against
	Meta-analysis [46]						6925k		No meta-analysis due to heterogeneity. Summary data: patella-friendly or non-patella-friendly: no differences	High	Strong against*
Prosthetic design—PCL retaining versus PCL substituting											
3	Matched case series [57]	−1 (confounder)					74k	74k	PCL sacrificing Total Condylar Prosthesis: AKP 9/74 = 12 %, PCL substituting Press Fit Condylar: AKP 3/74 = 4.1 %, $p = 0.07$	Very low	Weak against
	RCT [60]						169k	305k	PCL retaining: AKP 27/169 = 16.0 %, PCL substituting 44/305 = 14.4 %, $p = 0.118$	High	Strong against
	Retrospective case series [16]				−1 (no statistics)		242k (204p)	66k	AKP 19/242 = 7.9 %; PCL retention or not: no difference	Very low	Weak against
Prosthetic design—design geometry tibial insert											
2	Prospective cohort [28]	−1 (no follow-up stated)					62k	48k, 66k	Posterior-stabilized tibial component, femoral component with recess and cam: AKP 4/62 = 6 %, Deep-dish tibial component, femoral component with recess and cam: AKP 5/66 = 8 %, Deep-dish tibial component, femoral component without recess or cam: AKP 5 %, $p > 0.05$	Very low	Weak against
	RCT [34]				−1 (no statistics)		50k	50k	High-Flex PS tibial insert: AKP 2/50 = 4 %, Standard PS tibial insert: AKP 2/50 = 4 %	Moderate	Weak against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Prosthetic design—mobile-bearing versus fixed-bearing											
4	RCT [1]				−1 (no statistics)		107k	103k	Legacy Posterior-Stabilized (fixed): AKP 10/107 = 9.3 %, Meniscal-Bearing Knee (mobile): AKP 9/103 = 8.7 %	Moderate	Weak against
	Prospective cohort [8]	−1 (confounder: weight, kss)					101k	105k	Fixed-bearing HLS: AKP 5/101 = 5 %, Mobile-bearing HLS: AKP 0/105 = 0 %, $p = 0.06$	Very low	Weak against
	RCT [11]						53p	47p	Fixed-bearing NexGen PS: AKP 10/53 = 19 %, Mobile-bearing NexGen PSM: AKP 2/47 = 4 %, $p = 0.03$	High	Strong for
	RCT [26]						50k	50k	Fixed-bearing PFC: AKP 11/50 = 22 %, Mobile-bearing PFC: AKP 7/50 = 14 %, $p = 0.43$	High	Strong against
Prosthetic design—patellar component fixation											
1	Prospective cohort [27]						84k	144k	One-peg fixation: AKP 6/84 = 7 %, three-peg fixation: AKP 13/144 = 9.0 %, $p = 0.80$	Low	Weak against
Operative technique—surgical approach											
1	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; approach (lateral or medial): no difference	Very low	Weak against
Operative technique—use of navigation											
2	Prospective cohort [33]				−1 (no statistics)		22k	22k	CT-based navigation: AKP 1/22 = 5 %, Imageless navigation: AKP 1/22 = 5 %	Very low	Weak against
	RCT [56]						32k	30k	Computer-navigated: AKP 14/32 = 44 %, Conventional technique: AKP 14/30 = 47 %, $p = 0.818$	High	Strong against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Operative technique—component alignment											
9	Prospective cohort [18]				−1 (no statistics)		116k (101p)		Neutral range (anterior–posterior tibial position ≥0, change in joint line ≤8 mm, patellar height between 10 and 30 mm): AKP 0/41 = 0 % Outside of neutral range: AKP 23/75 = 31 %	Very low	Weak for
	Prospective cohort [17]						119k		AKP 29/119 = 24.4 %; mean patellar height 12.4 mm (95 % CI 10.55 to 14.27), no AKP 90/119 = 75.6 %; mean patellar height 18.1 mm (95 % CI 17.03 to 19.18), $p < 0.0001$	Low	Weak for
	Retrospective case series [37]						31k		AKP 25/31 = 81 %; patella height 27.4 mm ± 8.2, no AKP 6/31 = 19 %; patella height 19.5 mm ± 5.4, $p < 0.05$ AKP 25/31 = 81 %; lateralisation of patella 0.66 mm ± 0.12, no AKP 6/31 = 19 %; lateralisation of patella 0.56 mm ± 0.05, $p < 0.05$ AKP 25/31 = 81 %; tibiaventralisation 0.37 ± 0.06, no AKP 6/31 = 19 %; tibiaventralisation 0.35 ± 0.07, $p > 0.05$	Low	Weak for
	Retrospective case series [24]				−1 (no statistics)		32k (29p)		AKP 6/28 = 21 %; Insall-Salvati ratio 1.1, no AKP 22/28 = 79 %; Insall-Salvati ratio 1.1	Very low	Weak against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	Matched case series [5]				+1 (strong evidence relation)		14k (11p)	14k (11p)	Average femoral component external rotation; with AKP: 1.5°, without AKP: 2.2°, $p > 0.4$; Average tibial component internal rotation; with AKP: 6.2°, without AKP: 0.4°, $p = 0.012$ Combined component rotation; with AKP: 4.7° internal rotation, without AKP: 2.6° external rotation, $p = 0.0035$ Tibiofemoral angle ($p > 0.05$), femoral component valgus ($p > 0.05$), tibial component varus ($p > 0.05$). No correlation between amount of patellar tilt or subluxation and AKP	Moderate	Weak for
	Retrospective case series [47]						44p		AKP 17/44 = 39 %; lateral femorotibial angle ($F = 0.2273$), average patella height ($F = 0.4521$), Merchant's congruence angle ($F = 0.923$), average patella shift ($F = 0.8352$), mean patella tilt ($F = 0.4063$), patella type (Wiberg) ($p > 0.05$)	Low	Weak against
	RCT [61]						218k		AKP 54/218 = 24.8 %; patellar tilt ($p = 0.294$), anatomical alignment ($p = 0.335$), distal femoral resection ($p = 0.493$), proximal tibial resection ($p = 0.672$), Insall-Salvati ratio ($p = 0.202$)	High	Strong against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	RCT [12]				−1 (no statistics)		40k (20p)		AKP = 16.5–17.3 %; radiographic changes in joint line, anterior or posterior offset of tibial component relative to centre of tibia, distance between inferior pole of patella and tibial prosthesis, centralization of tibial component on cut surface of tibia: no differences detected	Moderate	Weak against
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; Insall-Salvati, Blackburne-Peel ratio, percentage cover of patella implant on lateral radiograph, tilt of patella component: no difference	Very low	Weak against
Operative technique—lateral release											
5	RCT [61]				−1 (no statistics)		218k		AKP 54/218 = 24.8 %; lateral release: no difference	Moderate	Weak against
	RCT [60]						474k		AKP 71/474 = 15.0 %; 22.5 % lateral release, no AKP 403/474 = 85.0 %; 22.8 % lateral release, $p = 0.9211$	High	Strong against
	RCT [14]						39k (36p)		AKP 12/39 = 31 %; retinacular release ($p > 0.05$)	High	Strong against
	RCT [55]				−1 (no statistics)		159k (142p)		AKP 40/159 = 25.1 %; lateral patellar release: not predictive	Moderate	Weak against
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; use of lateral release: no difference	Very low	Weak against
Operative technique—resection Hoffa's fat pad											
1	RCT [31]				−1 (study quality)		34k	34k	Resection Hoffa: AKP 8/34 = 24 %, no resection Hoffa: AKP 18/34 = 53 %, $p < 0.05$	Moderate	Weak for

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
Operative technique—residual patellar thickness											
2	Retrospective case series [25]				−1 (confounder)		42k	53k	Residual patellar thickness ≤12 mm: AKP 19/42 = 45 %, residual patellar thickness >12 mm: AKP 31/53 = 58 %, $p = 0.625$	Very low	Weak against
	Retrospective case series [16]				−1 (no statistics)		242k (204p)		AKP 19/242 = 7.9 %; thickness of residual patella bone: no difference	Very low	Weak against
Treatment of the patella—patellar resurfacing											
24	Prospective cohort [23]				−1 (confounder)		52k (bilateral)	52k (bilateral)	Patellar resurfacing: AKP 3/52 = 6 %, no resurfacing: AKP 3/52 = 6 %	Very low	Weak against
	RCT [43]				−1 (confounder)		47k	48k	Patellar resurfacing: AKP 1/47 = 2 %, no resurfacing: AKP 11/48 = 23 %, $p < 0.001$	Moderate	Weak for
	RCT [6]						58k	60k	Patellar resurfacing: AKP 4/58 = 7 %, no resurfacing: AKP 8/60 = 13 %, $p = 0.38$	High	Strong against
	RCT [59]				−1 (no statistics)		21p	26p	Patellar resurfacing: AKP 1/21 = 5 %, no resurfacing: AKP 3/21 = 14 %	Moderate	Weak for
	RCT [38]				−1 (no statistics)		42k	42k	Patellar resurfacing: AKP 0/42 = 0 %, no resurfacing: AKP 10/42 = 24 %	Moderate	Weak for
	RCT [4]						47k	46k	Patellar resurfacing: AKP 9/47 = 19 %, no resurfacing: AKP 8/46 = 17 %, $p = 0.79$	High	Strong against

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	RCT [61]						91k	127k	Patellar resurfacing: AKP 15/91 = 16 % (95 % CI 9 % to 24 %), no resurfacing: AKP 39/127 = 30.7 % (95 % CI 23–39 %), $p = 0.016$	High	Strong for
	Prospective cohort [36]				−1 (no statistics)		48k	57k	Patellar resurfacing: AKP 2/48 = 4 %, no resurfacing: AKP 2/57 = 4 %	Very low	Weak against
	Prospective cohort [48]						35k(bilateral)	35k (bilateral)	Patellar resurfacing: AKP 7/35 = 20 %, no resurfacing: AKP 7/35 = 20 %, $p = 1.00$	Low	Weak against
	RCT [60]						243k	231k	Patellar resurfacing: AKP 13/243 = 5.3 %, no resurfacing: AKP 58/231 = 25.1 %, $p < 0.0001$	High	Strong for
	RCT [14]						19k (18p)	20k (18p)	Patellar resurfacing: AKP 7/19 = 37 %, no resurfacing: AKP 5/20 = 25 %, $p = 0.501$	High	Strong against
	RCT [20]				−1 (no statistics)		28k	28k	Patellar resurfacing: AKP 0/28 = 0 %, no resurfacing: AKP 6/28 = 21 %	Moderate	Weak for
	Meta-analysis [39]						568k	587k	Patellar resurfacing: AKP 43/568 = 7.6 %, no resurfacing: AKP 131/587 = 22.3 %, RR for significant AKP 0.39 (95 % CI 0.20 to 0.75) in favour of resurfacing, $p = 0.005$	High	Strong for*

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	Meta-analysis [42]						447k	477k	Patellar resurfacing reduced the absolute risk of AKP by 13.8 % (95 % CI 6.4–21.2 %)	High	Strong for*
	Meta-analysis [44]						744k	775k	Patellar resurfacing: AKP 89/744 = 12.0 %, no resurfacing: AKP 185/775 = 23.9 %, $p = 0.00001$	High	Strong for*
	RCT [15]						30k	28k	Patellar resurfacing: AKP 14/30 = 47 %, no resurfacing: AKP 12/28 = 43 %, p = ns	High	Strong against
	RCT [12]				−1 (no statistics)		20k (bilateral)	20k (bilateral)	Patellar resurfacing: AKP = 16.5 %, no resurfacing: AKP = 17.3 %, $p = 0.90$	Moderate	Weak against
	RCT [55]						73k	86k	Patellar resurfacing: AKP 22/73 = 30 % (95 % CI 20–41 %), no resurfacing: AKP 18/86 = 21 % (95 % CI 12–30 %), $p = 0.182$	High	Strong against
	RCT [13]						38k	40k	Patellar resurfacing: AKP 8/38 = 21 %, no resurfacing: AKP = 16 %, $p = 0.35$	High	Strong against
	Meta-analysis [19]						346k	403k	Patellar resurfacing: AKP 80/346 = 23.1 %, no resurfacing: AKP 108/403 = 26.8 %, RR for AKP 0.97 (95 % CI 0.64–1.46), $p = 0.88$	High	Strong against*
	Meta-analysis [22]						580k	634k	Patellar resurfacing: AKP 94/580 = 16.2 %, no resurfacing: AKP 166/634 = 26.2 %, RR for AKP 0.71 (95 % CI 0.38–1.36), $p = 0.31$	High	Strong against*
	Systematic review [29]						1421k		Patellar resurfacing: AKP 12.9 %, no resurfacing: AKP 24.1 %, RR for AKP 0.60 (95 % CI 0.32–1.11), $p = 0.10$	High	Strong against*

Table 1 continued

Quality assessment							Summary of findings				Correlation or recommendation
							No of patients		Effect	Quality	
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	Prospective cohort [45]				−1 (no statistics)		60k (bilateral)	60k (bilateral)	Patellar resurfacing: AKP 2/60 = 3 %, no resurfacing: AKP 6/60 = 10 %	Very low	Weak for
	Meta-analysis [46]						3388k	3537k	No meta-analysis due to heterogeneity. Summary data: resurfacing or non-resurfacing: no differences	High	Strong against*
Treatment of the patella—patellar reshaping											
1	RCT [30]			−1 (no control)			64k	68k	Reshaping: AKP 8/64 = 13 %, resurfacing: AKP 10/68 = 15 %, $p = 0.712$	Moderate	Weak against
Treatment of the patella—patellar rim electrocautery											
1	RCT [58]						131k	131k	Electrocautery: AKP 25/131 = 19.1 % (95 % CI 12–26 %), no electrocautery: AKP 42/131 = 32.1 % (95 % CI 24–40 %), $p = 0.02$	High	Strong for
Time of assessment											
6	RCT [4]				−1 (no statistics)		93k (67p)		AKP at 2–4y FU: 12/118 = 10 %, AKP at 5–7y FU: 17/93 = 18 %	Moderate	Increase over time
	Prospective cohort [32]				−1 (no statistics)		184k		AKP at 1y FU: 29/184 = 15.7 %, AKP at 2y FU: 19/184 = 10.3 %	Very low	Decrease over time
	Prospective cohort [2]				−1 (no statistics)		638k (536p)		With no preoperative AKP: AKP at 3 m FU: 32/260 = 12.3 %, AKP at 1y FU: 20/260 = 7.7 %	Very low	Decrease over time
	RCT [15]				−1 (no statistics)		100k (100p)		AKP at 4y FU: 26/83 = 31 %, AKP at 10y FU: 26/58 = 45 %	Moderate	Increase over time

Table 1 continued

Quality assessment							Summary of findings				
							No of patients		Effect	Quality	Correlation or recommendation
No. of studies	Design	Limitations	Inconsistency	Indirectness	Imprecision	Publication bias	Treatment	Control	Absolute (95 % CI)		
	RCT [12]				−1 (no statistics)		40k (20p)		Patellar resurfacing: AKP at 10y FU = 17 %, no resurfacing: AKP at 10y FU = 17 % Patellar resurfacing: AKP at 5y FU 9/47 = 19 %, no resurfacing: AKP at 5y FU 8/46 = 17 % [4]	Moderate	No change over time
	RCT [35]				−1 (no statistics)		80k (59p)		AKP at 1y FU: 29/80 = 36 %, AKP at 10y FU: 16/80 = 20 %	Moderate	Decrease over time

AKP Anterior knee pain, *BMI* body mass index, *CI* confidence interval, *FU* follow-up, *HLS* Hopital Lyon Sud, *HR* hazard ratio, *k* knees, *OA* osteoarthritis, *OR* odds ratio, *p* patients, *PCL* posterior cruciate ligament, *PS* posterior stabilized, *RA* rheumatoid arthritis, *RCT* randomized controlled trial, *RR* relative risk

Asterisk denotes results from systematic review or meta-analysis

Operative technique

A retrospective case series demonstrated no differences in AKP rate between the lateral and medial approach [16]. Imageless navigation and computed tomography (CT)-based navigation resulted in an equal occurrence of AKP [33]. Others also found no differences in the AKP rate between computer-navigated and conventional jig-based TKR [56]. An inconclusive relation was found between postsurgical AKP and radiographic measurements of changes in the joint line, the anterior or posterior offset of the tibial component relative to the centre of the tibia (the distance from the neutral axis), the distance between the inferior pole of the patella and the tibial prosthesis, or centralization of the tibial component on the cut surface of the tibia [12, 18]. Barrack et al. [5] used computed tomography to evaluate the relationship between AKP and component rotation after TKR. Patients with combined component internal rotation were more than 5 times as likely to experience AKP compared with those with combined component external rotation [5]. A number of studies found no correlation between the amount of patellar tilt or subluxation and the presence of AKP [5, 16, 24, 47, 61]. Similarly, several studies did not find an association between the development of AKP and patella height [12, 16, 24, 47, 61], or between lateral tibiofemoral angle and AKP [5, 47, 61]. However, one study noted more AKP with greater patella height [37], while another study noted the opposite [17]. No association was found between the prevalence of AKP and whether an uncovered lateral patellar facet was articulating with the femoral component, the percentage cover of the implant of the patella on a lateral radiograph, or tilt of the patellar component [16]. Also, a number of studies demonstrated no relation between lateral release performed for patellar tracking and the occurrence of AKP [14, 16, 55, 60, 61]. Resection of Hoffa's fat pad may result in a lower prevalence of post-surgical AKP [31]. In case of patellar resurfacing, residual patellar thickness was not found to be predictive of AKP [16, 25].

Treatment of the patella

Several RCTs and observational studies reported on resurfacing versus non-resurfacing of the patella with regard to the prevalence of AKP, with some studies finding no differences [4, 6, 12–15, 23, 48, 55], whereas others have shown a lower prevalence of AKP following patellar resurfacing [20, 38, 43, 45, 59–61]. Some of these studies have given conflicting results even when the same implant has been used [4, 61]. A number of meta-analyses have demonstrated a quantitative estimate of overall effect of patellar resurfacing through sample pooling of different

RCTs. The rate of AKP favoured patellar resurfacing in 3 meta-analyses [39, 42, 44], yet between-study heterogeneity existed in all of these three meta-analyses. More recent meta-analyses demonstrated no differences between resurfacing and not resurfacing in terms of AKP [19, 22, 29]. Of note, these recent meta-analysis studies included more recent RCTs that showed no advantage of resurfacing in TKR [13, 55]. In a study evaluating the results of selective patellar resurfacing, no difference in AKP rate was observed between resurfacing and retaining [36]. Resurfacing was performed when patients had preoperative patellofemoral symptoms, patellar instability/malalignment, and Grade III/IV articular cartilage changes with a patellar thickness >15 mm, and the decision not to resurface was made if Grade 0/I/II changes, or a patella thickness of less than 15 mm were observed. Patellar resurfacing and patellar reshaping with partial resection of lateral facet and osteophytes resulted in comparable rates of postsurgical AKP [30]. Electrocautery of the patellar rim in TKR without patellar resurfacing may result in a lower incidence of AKP as compared to TKR without patellar rim electrocautery [58].

Time of assessment

Some studies describe a gradual reduction in the incidence of patellar pain over time [2, 32, 35], others found no change in the incidence between 5 and 10 years postoperatively [12], and two studies noted an increase in the overall prevalence of AKP over time [4, 15].

Discussion

The most important finding of the present study was that a multitude of variables have been researched with regard to the prevalence of AKP, with some clearly demonstrating a correlation with AKP, while others have shown no correlation. Patient characteristics including age, gender, weight, height, BMI, and the presence of preoperative AKP were not found to be predictive of AKP. Knee-specific characteristics including diagnosis, radiographic grade of osteoarthritis, knee scores, range of motion, and deformity were not related to the occurrence of postsurgical AKP. An inconclusive relation was found for the intra-operative degree of patellar cartilage wear. With regard to prosthetic design, no recommendation can be given for the use of 'patella-friendly' trochlear designs, specific PCL management strategies, tibial component bearing strategies, design geometry of the tibial insert, and patellar component fixation. In contrast, a weak recommendation can be given for prostheses with a posterior centre of rotation. With regard to operative technique, no recommendation can be given for the use of a specific surgical approach, navigation, lateral release, or residual patellar thickness. However, a weak recommendation can be given for preventing combined component internal rotation and for resecting Hoffa's fat pad. No recommendation can be given for patellar resurfacing, patellar reshaping is provided with a weak recommendation against, and the use of patellar rim electrocautery is recommended. The relation between AKP and time of assessment is inconclusive.

The main limitation of our study is that the retrieved studies have not been quantitatively assessed because we found important heterogeneity in both study design and outcome assessment. Most of the included studies evaluated one single factor with regard to the prevalence of AKP, although several RCTs presented data on multiple factors potentially influencing AKP [4, 6, 12, 14, 15, 43, 55, 60, 61]. The presence of confounding factors, whether clinical, technique, or prosthesis related, thus reduces the generalizability of the reported findings. Furthermore, the use of different scoring systems for AKP that consider both the presence and the severity of AKP has resulted in variations in the objective assessment of pain and contributes to the observed heterogeneity. Another limitation is that we included patellofemoral pain in our search strategy while AKP may not be necessarily synonymous with patellofemoral pain.

Some investigators found that the occurrence of postoperative AKP is negatively correlated with patient satisfaction [4, 44]. Also, patients with AKP reported lower levels of quality of life than patients without AKP [11]. Considering the implications of AKP following TKR on reoperation rate, patient satisfaction, and quality of life, further study into the causative mechanisms of AKP is needed.

So far, most studies evaluating AKP have focused on the patella as the pain generator. In the majority of the included studies, neither the grade of patellar cartilage damage (radiographically or intra-operatively assessed), nor the patella-friendliness of the femoral component exhibits a clear relation with the occurrence of AKP. In contrast, we found that patellofemoral joint loading is associated with the occurrence of AKP, and this may be an important hypothesis-generating observation. Several factors resulting in abnormal patellofemoral joint loading have been identified in our review, including gait pattern [54], an anterior position of the centre of rotation of the femoral component [32], suboptimal component alignment with changes in joint line height [17, 18, 37], and rotational errors [5]. The presence of these factors may explain the generally unsuccessful results of secondary resurfacing. However, other factors influencing patellofemoral load, including the anterior or posterior offset of the tibial component [12], patella height [12, 16, 24, 47, 61], and patellar thickness [16, 25] demonstrated no or an inconclusive correlation with AKP. Clearly, further study into the causative mechanisms of AKP after TKR is needed.

In order to reduce the prevalence of AKP following primary TKR, we recommend the use of femoral components with a posterior centre of rotation, resection of Hoffa's fat pad, patellar rim electrocautery, and preventing combined component internal rotation. No recommendation can be given for the use of specific prosthetic designs, PCL management strategies, tibial component bearing strategies, specific surgical techniques, or patellar resurfacing, since the available evidence did not show a correlation with these factors and the occurrence of postsurgical AKP.

Conclusion

AKP following primary TKR is both prevalent and clinically relevant. A multitude of patient and technique related factors have been researched with regard to the prevalence of AKP. No single variable is likely to explain the differences in the reported rates of AKP, although variables resulting in abnormal patellofemoral joint loading appear to be of special significance.

References

1. Aglietti P, Baldini A, Buzzi R, Lup D, De Luca L (2005) Comparison of mobile-bearing and fixed-bearing total knee arthroplasty: a prospective randomized study. J Arthroplasty 20:145–153
2. Arbuthnot JE, McNicholas MJ, McGurty DW, Rowley DI (2004) Total knee replacement and patellofemoral pain. Surgeon 2:230–233
3. Baker PN, van der Meulen JH, Lewsey J, Gregg PJ (2007) The role of pain and function in determining patient satisfaction after total knee replacement. Data from the National Joint Registry for England and Wales. J Bone Joint Surg (Br) 89:893–900
4. Barrack RL, Bertot AJ, Wolfe MW, Waldman DA, Milicic M, Myers L (2001) Patellar resurfacing in total knee arthroplasty. A prospective, randomized, double-blind study with five to seven years of follow-up. J Bone Joint Surg (Am) 83:1376–1381
5. Barrack RL, Schrader T, Bertot AJ, Wolfe MW, Myers L (2001) Component rotation and anterior knee pain after total knee arthroplasty. Clin Orthop Relat Res 392:46–55
6. Barrack RL, Wolfe MW, Waldman DA, Milicic M, Bertot AJ, Myers L (1997) Resurfacing of the patella in total knee arthroplasty. A prospective, randomized, double-blind study. J Bone Joint Surg (Am) 79:1121–1131
7. Bhan S, Malhotra R, Eachempati KK (2006) Total knee arthroplasty without patellar resurfacing in patients with rheumatoid arthritis. Clin Orthop Relat Res 450:157–163
8. Biau D, Mullins MM, Judet T, Piriou P (2006) Mobile versus fixed-bearing total knee arthroplasty: mid-term comparative clinical results of 216 prostheses. Knee Surg Sports Traumatol Arthrosc 14:927–933
9. Bonnin MP, Basiglini L, Archbold HA (2011) What are the factors of residual pain after uncomplicated TKA? Knee Surg Sports Traumatol Arthrosc 19:1411–1417
10. Brander VA, Stulberg SD, Adams AD, Harden RN, Bruehl S, Stanos SP, Houle T (2003) Predicting total knee replacement pain: a prospective, observational study. Clin Orthop Relat Res 416:27–36
11. Breugem SJ, Sierevelt IN, Schafroth MU, Blankevoort L, Schaap GR, van Dijk CN (2008) Less anterior knee pain with a mobile-bearing prosthesis compared with a fixed-bearing prosthesis. Clin Orthop Relat Res 466:1959–1965
12. Burnett RS, Boone JL, McCarthy KP, Rosenzweig S, Barrack RL (2007) A prospective randomized clinical trial of patellar resurfacing and nonresurfacing in bilateral TKA. Clin Orthop Relat Res 464:65–72
13. Burnett RS, Boone JL, Rosenzweig SD, Steger-May K, Barrack RL (2009) Patellar resurfacing compared with nonresurfacing in total knee arthroplasty. A concise follow-up of a randomized trial. J Bone Joint Surg (Am) 91:2562–2567
14. Burnett RS, Haydon CM, Rorabeck CH, Bourne RB (2004) Patella resurfacing versus nonresurfacing in total knee arthroplasty: results of a randomized controlled clinical trial at a minimum of 10 years' followup. Clin Orthop Relat Res 428:12–25
15. Campbell DG, Duncan WW, Ashworth M, Mintz A, Stirling J, Wakefield L, Stevenson TM (2006) Patellar resurfacing in total knee replacement: a ten-year randomised prospective trial. J Bone Joint Surg (Br) 88:734–739
16. Erak S, Rajgopal V, Macdonald SJ, McCalden RW, Bourne RB (2009) Ten-year results of an inset biconvex patella prosthesis in primary knee arthroplasty. Clin Orthop Relat Res 467:1781–1792
17. Fern ED, Winson IG, Getty CJ (1992) Anterior knee pain in rheumatoid patients after total knee replacement. Possible selection criteria for patellar resurfacing. J Bone Joint Surg (Br) 74:745–748
18. Figgie HE, Goldberg VM, Heiple KG, Moller HS III, Gordon NH (1986) The influence of tibial-patellofemoral location on function of the knee in patients with the posterior stabilized condylar knee prosthesis. J Bone Joint Surg (Am) 68:1035–1040
19. Fu Y, Wang G, Fu Q (2011) Patellar resurfacing in total knee arthroplasty for osteoarthritis: a meta-analysis. Knee Surg Sports Traumatol Arthrosc 19:1460–1466
20. Gildone A, Manfredini M, Biscione R, Faccini R (2005) Patella resurfacing in posterior stabilised total knee arthroplasty: a follow-up study in 56 patients. Acta Orthop Belg 71:445–451
21. Guyatt GH, Oxman AD, Kunz R, Falck-Ytter Y, Vist GE, Liberati A, Schunemann HJ (2008) Going from evidence to recommendations. BMJ 336:1049–1051
22. He JY, Jiang LS, Dai LY (2011) Is patellar resurfacing superior than nonresurfacing in total knee arthroplasty? A meta-analysis of randomized trials. Knee 18:137–144
23. Keblish PA, Varma AK, Greenwald AS (1994) Patellar resurfacing or retention in total knee arthroplasty. A prospective study of patients with bilateral replacements. J Bone Joint Surg (Br) 76:930–937
24. Kim BS, Reitman RD, Schai PA, Scott RD (1999) Selective patellar nonresurfacing in total knee arthroplasty. 10 year results. Clin Orthop Relat Res 367:81–88
25. Koh JS, Yeo SJ, Lee BP, Lo NN, Seow KH, Tan SK (2002) Influence of patellar thickness on results of total knee arthroplasty: does a residual bony patellar thickness of <12 mm lead to poorer clinical outcome and increased complication rates? J Arthroplasty 17:56–61
26. Lädermann A, Saudan M, Riand N, Fritschy D (2008) Prothèse totale du genou: étude prospective randomisée comparant les plateaux tibiaux fixes et mobiles. Rev Chir Orthop 94:247–251

27. Larson CM, McDowell CM, Lachiewicz PF (2001) One-peg versus three-peg patella component fixation in total knee arthroplasty. Clin Orthop Relat Res 392:94–100
28. Laskin RS, Maruyama Y, Villaneuva M, Bourne R (2000) Deep-dish congruent tibial component use in total knee arthroplasty: a randomized prospective study. Clin Orthop Relat Res 380:36–44
29. Li S, Chen Y, Su W, Zhao J, He S, Luo X (2011) Systematic review of patellar resurfacing in total knee arthroplasty. Int Orthop 35:305–316
30. Liu ZT, Fu PL, Wu HS, Zhu Y (2011) Patellar reshaping versus resurfacing in total knee arthroplasty—results of a randomized prospective trial at a minimum of 7 years' follow-up. Knee 19:198–202
31. Maculé F, Sastre S, Lasurt S, Sala P, Segur JM, Mallofre C (2005) Hoffa's fat pad resection in total knee arthroplasty. Acta Orthop Belg 71:714–717
32. Mahoney OM, McClung CD, dela Rosa MA, Schmalzried TP (2002) The effect of total knee arthroplasty design on extensor mechanism function. J Arthroplasty 17:416–421
33. Martin A, von Strempel A (2006) Two-year outcomes of computed tomography-based and computed tomography free navigation for total knee arthroplasties. Clin Orthop Relat Res 449:275–282
34. McCalden RW, MacDonald SJ, Bourne RB, Marr JT (2009) A randomized controlled trial comparing "high-flex" vs "standard" posterior cruciate substituting polyethylene tibial inserts in total knee arthroplasty. J Arthroplasty 24:33–38
35. Meftah M, Ranawat AS, Ranawat CS (2011) The natural history of anterior knee pain in 2 posterior-stabilized, modular total knee arthroplasty designs. J Arthroplasty 26:1145–1148
36. Misra AN, Smith RB, Fiddian NJ (2003) Five year results of selective patellar resurfacing in cruciate sparing total knee replacements. Knee 10:199–203
37. Nebelung W, Awiszus F, Mahlfeld K, Neumann HW (1995) Beeinflussen Patellahochstand, Patellaventralisation und Patellalateralisation das patellare Schmerzsyndrom nach Implantation von GSB-Totalendoprothesen? Z Orthop Ihre Grenzgeb 133:535–538
38. Newman JH, Ackroyd CE, Shah NA, Karachalios T (2000) Should the patella be resurfaced during total knee replacement? Knee 7:17–23
39. Nizard RS, Biau D, Porcher R, Ravaud P, Bizot P, Hannouche D, Sedel L (2005) A meta-analysis of patellar replacement in total knee arthroplasty. Clin Orthop Relat Res 432:196–203
40. Oh IS, Lee TJ, Lee WC, Lee SH (2010) Effect of degenerative changes of unresurfaced patella on pain and range of motion in total knee arthroplasty. Curr Orthop Practice 21:586–590
41. Oh KJ, Goodman SB, Yang JH (2011) Prospective, randomized study between Insall-Burstein II and NexGen Legacy with a minimum 9-year follow-up. J Arthroplasty 26:1232–1238
42. Pakos EE, Ntzani EE, Trikalinos TA (2005) Patellar resurfacing in total knee arthroplasty. A meta-analysis. J Bone Joint Surg (Am) 87:1438–1445
43. Partio E, Wirta J (1995) Comparison of patellar resurfacing and nonresurfacing in total knee arthroplasty: a prospective randomized study. J Orthop Rheumatology 8:69–74
44. Parvizi J, Rapuri VR, Saleh KJ, Kuskowski MA, Sharkey PF, Mont MA (2005) Failure to resurface the patella during total knee arthroplasty may result in more knee pain and secondary surgery. Clin Orthop Relat Res 438:191–196
45. Patel K, Raut V (2011) Patella in total knee arthroplasty: to resurface or not to. A cohort study of staged bilateral total knee arthroplasty. Int Orthop 35:349–353
46. Pavlou G, Meyer C, Leonidou A, As-Sultany M, West R, Tsiridis E (2011) Patellar resurfacing in total knee arthroplasty: does design matter? A meta-analysis of 7075 cases. J Bone Joint Surg (Am) 93:1301–1309
47. Pellengahr C, Maier M, Muller PE, Durr HR, Schulz CU, Zysk S, Trouillier H, Lindhorst E, Jansson V, Refior HJ (2002) Surgical and anatomic parameters influencing femoropatellar pain in total knee arthroplasty. Eur J Trauma 28:242–246
48. Peng CW, Tay BK, Lee BP (2003) Prospective trial of resurfaced patella versus non-resurfaced patella in simultaneous bilateral total knee replacement. Singapore Med J 44:347–351
49. Petrisor BA, Keating J, Schemitsch E (2006) Grading the evidence: levels of evidence and grades of recommendation. Injury 37:321–327
50. Picetti GD III, McGann WA, Welch RB (1990) The patellofemoral joint after total knee arthroplasty without patellar resurfacing. J Bone Joint Surg (Am) 72:1379–1382
51. Rodriguez-Merchan EC, Gomez-Cardero P (2010) The outerbridge classification predicts the need for patellar resurfacing in TKA. Clin Orthop Relat Res 468:1254–1257
52. Scott CE, Howie CR, MacDonald D, Biant LC (2010) Predicting dissatisfaction following total knee replacement: a prospective study of 1217 patients. J Bone Joint Surg (Br) 92:1253–1258
53. Seil R, Pape D (2011) Causes of failure and etiology of painful primary total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 19:1418–1432
54. Smith AJ, Lloyd DG, Wood DJ (2004) Pre-surgery knee joint loading patterns during walking predict the presence and severity of anterior knee pain after total knee arthroplasty. J Orthop Res 22:260–266
55. Smith AJ, Wood DJ, Li MG (2008) Total knee replacement with and without patellar resurfacing: a prospective, randomised trial using the profix total knee system. J Bone Joint Surg (Br) 90:43–49
56. Spencer JM, Chauhan SK, Sloan K, Taylor A, Beaver RJ (2007) Computer navigation versus conventional total knee replacement: no difference in functional results at two years. J Bone Joint Surg (Br) 89:477–480
57. Title CI, Rodriguez JA, Ranawat CS (2001) Posterior cruciate-sacrificing versus posterior cruciate-substituting total knee arthroplasty: a study of clinical and functional outcomes in matched patients. J Arthroplasty 16:409–414
58. van Jonbergen HP, Scholtes VA, van Kampen A, Poolman RW (2011) A randomised, controlled trial of circumpatellar electrocautery in total knee replacement without patellar resurfacing. J Bone Joint Surg (Br) 93:1054–1059
59. Waikakul S, Vanadurongwan V, Bintachitt P (2000) The effects of patellar resurfacing in total knee arthroplasty on position sense: a prospective randomized study. J Med Assoc Thai 83:975–982
60. Waters TS, Bentley G (2003) Patellar resurfacing in total knee arthroplasty. A prospective, randomized study. J Bone Joint Surg (Am) 85:212–217
61. Wood DJ, Smith AJ, Collopy D, White B, Brankov B, Bulsara MK (2002) Patellar resurfacing in total knee arthroplasty: a prospective, randomized trial. J Bone Joint Surg (Am) 84:187–193