Archives of Orthopaedic and Trauma Surgery (2024) 144:1703–1712
https://doi.org/10.1007/s00402-024-05234-4

KNEE REVISION SURGERY

Incidence of patella baja and pseudopatella baja in aseptic revision total knee arthroplasty

Dimitrios A. Flevas[1] · Marco Brenneis[1,2] · TKAF Consortium · Allina Nocon[1] · Ioannis Gkiatas[3] · Wali Pirzada[1] · Georgios Tsakotos[4] · Peter K. Sculco[1]

Received: 26 October 2023 / Accepted: 15 February 2024 / Published online: 15 March 2024

Abstract

Introduction There are two variants regarding the low location of the patella in relation to the tibio-femoral joint line: patella baja (PB) and pseudo-patella baja (PPB). The purpose of this study is to investigate the incidence of PB and PPB in a cohort of patients that underwent revision total knee arthroplasty (rTKA) for aseptic reasons and describe any differences in each group's ROM.

Methods This retrospective study included 114 patients that underwent aseptic revision TKA surgery between 2017 and 2022. Patients were revised either for stiffness (Group 1) or aseptic loosening/instability (Group 2). The Insall-Salvati ratio (ISR) and Blackburne-Peel ratio (BPR) were used to evaluate the patellar position. ISR < 0.8 defined PB, while cases with ISR ≥ 0.8 and BPI < 0.54 were defined as PPB. ROM was measured and a subanalysis was conducted to investigate the progression of the values of ISR and BPR.

Results 55 patients comprised Group 1, and 59 patients comprised Group 2. Overall, 13 cases (11.4%) had PB before rTKA and 24 (21%) had PB after rTKA. Cases with PPB were 13 (11.4%) before and 34 (29.9%) after rTKA. Group 1 patients presented with more PB before and after rTKA (12.8% vs 10.2% and 27.3% vs 15.2% respectively). However, after rTKA Group 1 patients presented with less PPB (20%) compared to Group 2 (39%) (p = 0.02). In Group 1, patients with PPB after rTKA had less ROM compared to those without PPB [83.2 (± 21.9) vs 102.1 (± 19.9) (p = 0.025)]. The subanalysis (69 patients) showed a statistically significant decrease in ISR before and after rTKA (p = 0.041), and from the native knee to post-rTKA (p = 0.001). There was a statistically significant decrease in BPR before and after rTKA (p = 0.001) and from the native knee to both pre- and post-rTKA (p < 001).

Conclusion After undergoing rTKA, the incidences of both patella baja (PB) and pseudo-patella baja (PPB) increased. Stiffness in the knee was associated with a higher incidence of PB, while non-stiffness cases showed a significantly higher incidence of PPB. Patients with stiff knees and PPB after rTKA experienced a significant reduction in range of motion (ROM). Additionally, the study revealed a noteworthy decrease in ISR and BPR with each subsequent surgery. This information is crucial for healthcare providers, as it sheds light on potential risks and outcomes of rTKA, allowing for improved patient management and surgical decision-making.

Level of evidence III.

Keywords Patella Baja · Pseudopatella Baja · Aseptic Revision Total Knee Arthroplasty · Complications · Patellar tendon

Introduction

The number of revision total knee arthroplasties (rTKA) continues to increase and one of the most frequent complications involves the patello-femoral (PF) articulation [1–3]. A number of complications are associated with PF dysfunction including stiffness, instability, patellar fracture, rupture of the patellar or the quadriceps tendon,

The members of the TKAF Consortium are mentioned in Acknowledgements section.

Extended author information available on the last page of the article

fat pad fibrosis, patellar tendon shortening, crepitus, and patellar clunk syndrome [4].

While not an absolute PF complication, patella baja is frequently observed after primary and rTKA. There are two variants regarding the low position of the patella in relation to the tibio-femoral joint line: patella baja (PB) and pseudo-patella baja (PPB) [1]. These conditions affect patello-femoral kinematics, leading to anterior knee pain, reduced range of motion, and increased risk of requiring further rTKA [1, 5–8]. PB occurs when the patellar tendon is shortened and located too distally compared to the femur, while PPB results from elevated knee joint lines due to surgical actions [4, 6, 9]. The causes of PB and PPB are multifactorial, involving factors like trauma to the patellar tendon, joint line elevation, and excessive fat pad resection [4, 6, 9–13]. Acquired true PB has an incidence of about 35%, while PPB occurs in approximately 34–65% of cases following total knee arthroplasty (TKA) [4, 14]. The clinical relevance of PPB is not extensively studied, particularly after rTKA. However there are a few studies investigating its clinical relevance and consequences [1, 3–5, 12, 14–21]. Also, when it comes to the investigation of the PB and PPB after rTKA, the literature is rather scarce with just a few reports, especially for septic revision [18, 22, 23], with no input regarding the prospective natural change of the patella position after consecutive surgeries.

This study aims to determine the incidence of PB and PPB in patients who underwent rTKA for aseptic reasons. Secondly, we will explore the impact of PB or PPB on range of motion. Lastly, we will describe the progression of patellar position ratios after subsequent surgical intervention [6, 13, 24–26].

Materials and methods

Patient cohort

Patients that underwent aseptic revision TKA surgery between January 2017 and March 2022 were included in this study. Exclusion criteria were revision TKAs for fracture or dislocation, history of infection or active use of suppressive antibiotics on the affected knees, inflammatory arthritis, patients with contraindications to MRI or CT, implants with age > 10 years and conversion TKAs.

Patients were divided into two groups. Group 1: patients that were revised for a diagnosis of stiffness. Group 2: patients that were revised for either aseptic loosening or instability. Stiff patients (Group 1) were defined by preoperative flexion less than 100° or greater than 10° flexion contracture. Patients that underwent rTKA for aseptic loosening or instability comprised Group 2.

Radiographic assessment

Conventional lateral X-rays of the knee at 30 degrees of flexion were used for radiographic assessment. Each case had one X-ray of the native knee before TKA, one before rTKA, and one after rTKA. All X-rays were performed following a standardized radiological protocol. To ensure consistency, two orthopedic surgeons, not involved in the patients' treatment and blinded to the patients' outcomes, independently measured the radiographs. The mean values of their measurements were used for analysis [15, 18]. The inter-observer reliability for both the ISR and BPR was excellent, with an average intraclass correlation coefficient (ICC) of 0.952 (95% CI [0.940–0.962]) and 0.970 (95% CI [0.963–0.976]), respectively.

The patellar position and the presence of patella baja and pseudo-patella baja were assessed using the Insall-Salvati ratio (ISR) and the Blackburne-Peel ratio (BPR) (Fig. 1). The ISR, which is the ratio between the length of the patellar tendon and the longitudinal diameter of the patella, was used to identify patellar tendon shortening, with normal ranges between 0.8 and 1.2 [27]. The BPR was calculated as the orthogonal distance from the joint line divided by the patellofemoral joint surface. The joint line was defined as a line parallel to the tibial plateau and tangent to the femoral component [3, 9, 15]. A patellar height was considered normal if the ratio was between 0.54 and 1.06 [9]. Cases with ISR < 0.8 were classified as patella baja (Fig. 2), while cases with ISR ≥ 0.8 and BPI < 0.54 were classified as pseudo-patella baja [9, 27, 28](Fig. 3).

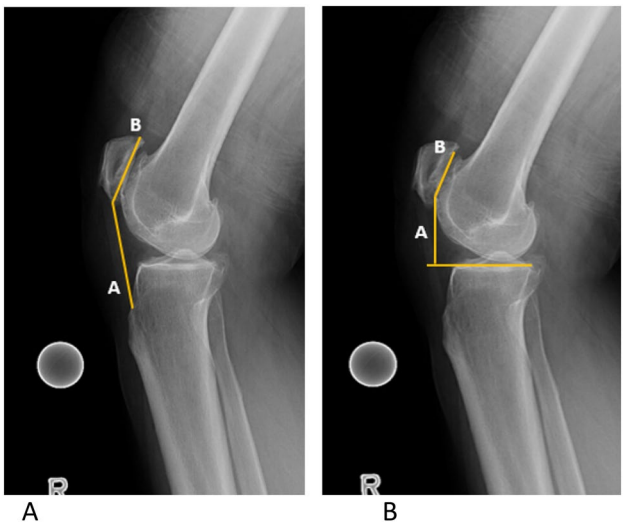

Fig. 1 **A** The Insall-Salvati ratio A/B and **B** The Blacburne-Peel ratio A/B

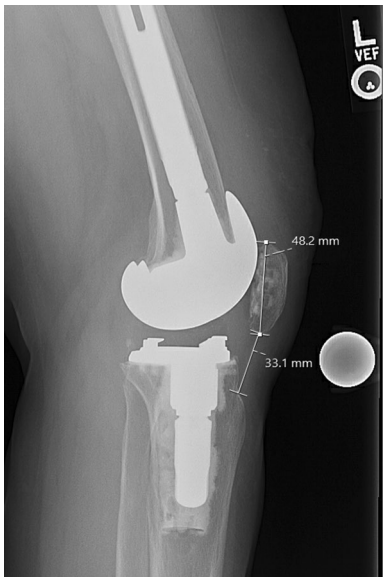

Fig. 2 ISR < 0.8. Patella Baja

ROM

ROM was measured using a standardized protocol. Extension and flexion were measured using a goniometer at all visits and ROM was calculated. In all patients, clinical photographs of the joint were taken with goniometer placement for verification, and additional measurements were performed by a fellowship-trained orthopedic surgeon for inter-observer consistency. ROM was captured preoperatively, at 6 weeks, at 6 months, and at 1 year postoperatively. The mean ROM between both readers was used for the final analysis.

Statistical analysis

Inter-rater reliability between reviewers for radiographic assessment of presence or absence of PB/PPB was evaluated using Cohen's kappa. Categorical outcomes were evaluated using the Fisher's exact test and continuous variables were assessed using the Mann–Whitney U-test to determine baseline differences between groups. A subanalysis was done to explore the changes in ISR and BPR values after consecutive surgical procedures (i.e., after primary TKA and rTKA) This subanalysis included patients from the total cohort who had a set of three X-rays, including one of their native knee before primary TKA, one after primary TKA and before rTKA, and one after rTKA. The Fisher's exact test was used to determine if there was an association between the preoperative and postoperative presence of PB or PPB and final ROM at 1 year.

All statistical analyses were performed using SAS Software version 9.3 (SAS Institute, Cary, NC); statistical significance was defined as $p < 0.05$.

Results

In this study, 114 patients were included, consisting of 80 females (70%) and 34 males (30%), with a mean age of 67.2 years (range 36.5–89.9 years) and mean body mass index of 30.7 kg/m2 (range 18.2–51.7). Among them, 55 patients were revised for knee stiffness, and 59 patients were revised for either aseptic loosening (25 patients) or instability (34 patients). Patients were homogenous at baseline with the exception of time to revision and the length of revision surgery (Table 1). In all cases, a medial parapatellar approach

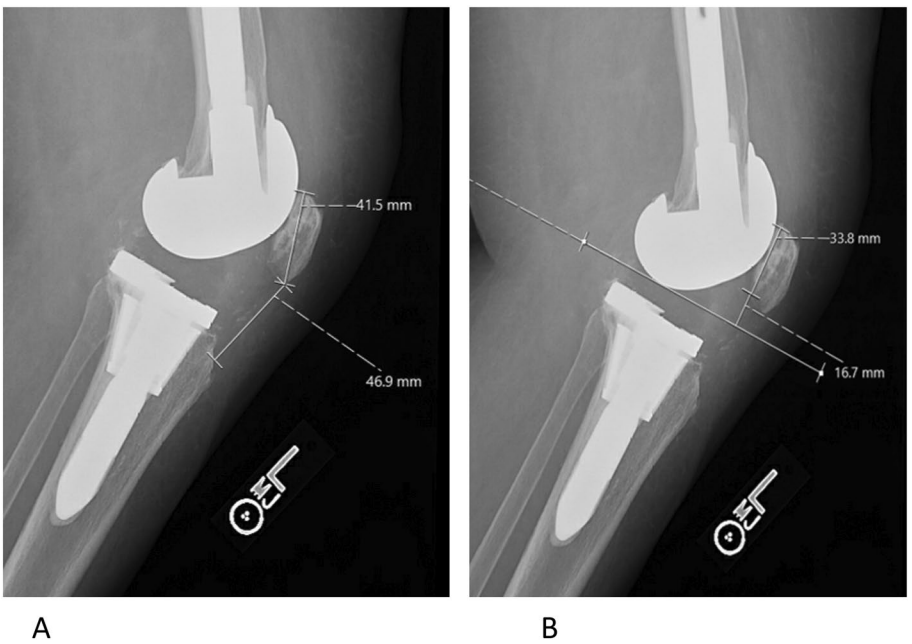

Fig. 3 **A** ISR > 0.8 **B** BPR < 0.54. Pseudopatella Baja

Table 1 Patients' demographics and surgery information

	Group 1	Group 2	*P*-value
Age (y)	63.1 (SD: 7.2)	66.2 (SD: 9.3)	0.053
BMI	31.3 (SD: 5.6)	30.2 (SD: 6.3)	0.236
Time to revision (d)	821.4 (SD: 676.2)	1502.4 (SD: 1499.3)	**0.001**
Gender (male)	15 (27.2%)	19 (32.2%)	0.565
Tourniquet time (primary)	58.7 (SD: 23.8)	54.5 (SD: 26.9)	0.4866
Length of surgery (primary)	47.6 (SD:61.2)	66.5 (SD: 54.8)	0.1765
Tourniquet time (revision)	76.2 (SD: 43.3)	69.7 (SD: 39.8)	0.3886
Length of surgery (revisions)	149.7 (SD:54.6)	110.2 (SD: 51.2)	**< 0.001**

Bold indicates statistically significant values

Table 2 Information about the surgical procedure in primary TKA

	Group 1 ($N=55$)	Group 2 ($N=59$)
Medial parapatellar approach	55/55	59/59
Mechanical alignment	55/55	59/59
Patellar Fixation in primary TKA		
Cemented	39/55	44/59
Cementless	1/55	3/59

was employed for the primary TKA. The mechanical alignment technique was utilized, and the patella was resurfaced in 40 cases in Group 1 and 47 cases in Group 2 (Table 2).

Before rTKA, 13 cases (11.4%) showed PB, and this increased to 24 cases (21%) after rTKA. Additionally, we identified 13 cases (11.4%) of PPB before rTKA, which increased to 34 cases (29.8%) after rTKA. In the stiff knee group, 7 cases (12.8%) had PB before rTKA, while 15 cases (27.3%) had PB after rTKA. For PPB, 7 cases (12.8%) were observed before rTKA, and 11 cases (20%) were seen after rTKA. In the group revised for aseptic loosening or instability, 6 cases (10.2%) had PB before rTKA, and 9 cases (15.2%) had PB after rTKA. For PPB, 6 cases (10.2%) were found before rTKA, and 23 cases (39%) were observed after rTKA. There was a significant difference in the incidence rate of PPB between the two groups after rTKA ($p=0.02$), while no differences was found for the incidence of PB (Table 3).

Furthermore, both groups showed an increase in PB and PPB cases after rTKA. In Group 1, PB cases increased by 8 (14.5%), and in Group 2, they increased by 3 (5%), both of which were statistically significant ($p=0.005$ and $p<0.001$, respectively). For PPB, Group 1 had an increase of 4 cases (7.2%), and Group 2 had an increase of 17 cases (28.8%), with the latter being statistically significant ($p=0.02$) (Table 4).

No statistically significant association was found between ROM and the presence of PB or PPB before rTKA in both groups. When exploring the same association for stiff

Table 3 Incidence of PB and PPB in total and per Group before and after rTKA

	Total	Group 1	Group 2	*p* value
Patella Baja (PB) Pre rTKA	13 (11.4%)	7 (12.8%)	6 (10.2%)	0.68
Patella Baja (PB) Post rTKA	24 (21%)	15 (27.3%)	9 (15.2%)	0.82
Pseudopatella Baja (PPB) Pre rTKA	13 (11.4%)	7 (12.8%)	6 (10.2%)	0.82
Pseudopatella Baja (PPB) Post rTKA	34 (29.8%)	11 (20%)	23 (39%)	**0.02**

Bold indicates statistically significant values

Table 4 Increase in cases of PB and PPB per Group

	Patients (*n*)	PB pre rTKA	PB post rTKA	Difference	*p* value
Group 1	55	7 (12.8%)	15 (27.3%)	8 (14.5%)	**0.005**
Group 2	59	6 (10.2%)	9 (15.2%)	3 (5%)	**< 0.001**
	Patients (*n*)	PPB pre rTKA	PPB post rTKA	Difference	*p* value
Group 1	55	7 (12.8%)	11 (20%)	4 (7.2%)	0.6
Group 2	59	6 (10.2%)	23 (39%)	17 (28.8%)	**0.02**

Bold indicates statistically significant values

Table 5 Correlations of ROM in Group 1

Group 1						
	Pre-PB (Y)	Pre-PB (N)	*p* value	Post-PB (Y)	Post-PB (N)	*p* value
Range of motion	96.22 (±9.1)	91.3 (±26.1)	0.8559	86.8 (±31.9)	94.2 (±21.2)	0.4341
	Pre-PPB(Y)	Pre-PPB(N)	*p* value	Post-PPB (Y)	Post-PPB (N)	*p* value
Range of motion	94.5 (±31.5)	93.6 (±24.1)	0.3858	83.2 (±21.9)	102.1 (±19.9)	**0.025**

Bold indicates statistically significant values

Pre-PB (Y): Patients with Patella Baja before rTKA

Pre-PB (N): Patients without Patella Baja before rTKA

Post-PB (Y): Patients with Patella Baja after rTKA

Post-PB (N): Patients without Patella Baja after rTKA

Pre-PPB(Y): Patients with Pseudopatella Baja before rTKA

Pre-PPB(N): Patients without Pseudopatella Baja before rTKA

Post-PPB (Y): Patients with Pseudopatella Baja after rTKA

Post-PPB (N): Patients without Pseudopatella Baja after rTKA

Table 6 Correlations of ROM in Group 2

Group 2						
	Pre-PB (Y)	Pre-PB (N)	*P* value	Post-PB (Y)	Post-PB (N)	*P* value
Range of motion	106.3 (±10.0)	118 (±14,6)	0.1605	109.3 (±7.9)	118.5 (±15.1)	0.1316
	Pre-PPB(Y)	Pre-PPB(N)	*P* value	Post-PPB (Y)	Post-PPB (N)	*P* value
Range of motion	114.4 (±8.3)	115 (±18.5)	0.8541	116.2 (±11.7)	113.1 (±19.6)	0.6459

Pre-PB (Y): Patients with Patella Baja before rTKA

Pre-PB (N): Patients without Patella Baja before rTKA

Post-PB (Y): Patients with Patella Baja after rTKA

Post-PB (N): Patients without Patella Baja after rTKA

Pre-PPB(Y): Patients with Pseudopatella Baja before rTKA

Pre-PPB(N): Patients without Pseudopatella Baja before rTKA

Post-PPB (Y): Patients with Pseudopatella Baja after rTKA

Post-PPB (N): Patients without Pseudopatella Baja after rTKA

patients who presented with PPB after rTKA, we discovered a difference mean ROM at last follow-up (83.2 ± 21.9) when compared to rTKA without indication of PPB(102.1 ± 19.9) (p = 0.025) (Table 5, 6).

The subanalysis aimed to examine the trajectory of patella positioning after subsequent revisions consisted of 69 patients. We found that there was a decrease in the values of both the ISR and the BPR from each previous time point (Figs. 4, 5). The decrease in ISR values was statistically significant before and after revision (p = 0.041) and from the natural knee to post-revision knee (p = 0.001) (Table 7). Similarly, the decrease in BPR values was statistically significant before and after revision (p = 0.001) and from the natural knee to both pre- and post-revision knees (p < 0.001) (Table 8).

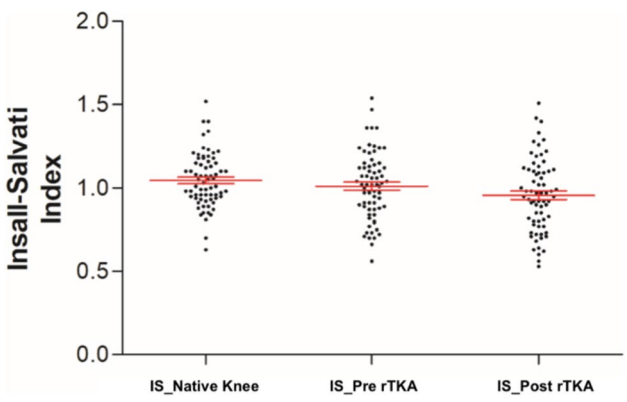

Fig. 4 Trajectory of the ISR values

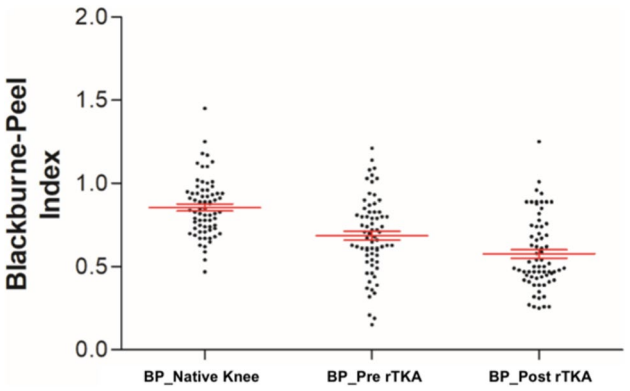

Fig. 5 Trajectory of the BP values

Table 7 Comparison of mean values of ISR between groups

Sample 1–Sample 2	*P* value
IS_Post rTKA–IS_Pre rTKA	**0.041**
IS_Post rTKA–IS_Native Knee	**0.001**
IS_Pre rTKA–IS_Native Knee	0.7

Table 8 Comparison of mean values of BPR between groups

Sample 1–Sample 2	*P* value
BP_Post rTKA–BP_Pre rTKA	**0.001**
BP_Post rTKA–BP_Native Knee	**0.000**
BP_Pre rTKA–BP_Native Knee	**0.000**

Discussion

This study of 114 rTKA patients observed a progressive reduction in patellar height post-surgery, suggesting a joint line rise. Postoperative patella baja (PB) and pseudopatella baja (PPB) progression increased, with significant PPB differences between stiffness and aseptic loosening/instability groups. Both groups showed a significant rise in PB and PPB cases after rTKA. No substantial association was found between preoperative range of motion (ROM) and PB or PPB. However, stiff knee patients with PPB displayed significantly lower ROM at the last follow-up. Subanalysis revealed a notable decrease in patellar positioning values, highlighting the impact of revision surgeries on patellar height.

Various techniques are used to measure patella height and diagnose patella baja (PB) in radiographs [29]. The Insall-Salvati ratio (ISR) reliably detects true PB by assessing patellar tendon shortening with good interobserver agreement [30, 31]. However, ISR is not effective in identifying pseudo-patella baja (PPB) as it doesn't consider the joint line position [15]. To distinguish PPB from PB, the joint line dependent Blackburne-Peel Ratio (BPR) is recommended due to its excellent reproducibility, even in prosthetic knees [15, 30, 32]. Additionally, BPR is helpful in revision cases to differentiate between PB and PPB [18].

In this study, we recorded the incidence of PB and PPB after total knee arthroplasty (TKA) in patients requiring revision due to aseptic reasons. The incidence was found to be 11.4% for both PB and PPB after primary TKA, aligning with existing literature except for one study that reported a higher PPB incidence (92%) [33]. Notably, the present study included patients only with failed aseptic TKAs requiring revision surgery, setting it apart from previous research. After revision TKA, we observed 24 cases of PB (21%) and 34 cases of PPB (29.8%). In the study by Han et al. [18], the respective percentages were 19.9% and 54.2%, indicating a significantly higher PPB incidence. This discrepancy was attributed to tibial joint line elevation caused by enlarged flexion or extension gaps with ligaments and capsular laxity [18, 34]. It's important to note that Han et al.'s study included both septic and aseptic revision cases, unlike the present study.

PB is caused by patellar tendon shortening, and various perioperative factors contribute to this condition after TKA, such as fat pad excision, patellar eversion-induced tendon injury, and tendon stripping from the tibial tubercle or scarring from trauma or previous surgery [3, 4, 14, 15, 35, 36]. Our study showed a significant increase in PB cases after rTKA in both stiff and non-stiff patient groups, likely due to previous surgeries and interventions causing patellar tendon scarring or injury [4]. Revision surgery can be demanding, involving patellar eversion or peeling techniques, which can lead to patella scarring and adhesions.

The patella plays a crucial role in knee biomechanics, extending the lever arm of the extension mechanism and strengthening the quadriceps by 30–50% [1]. Patella height is vital as it influences joint reaction force throughout the knee's flexion–extension cycle [37]. PPB is described as a surgical complication after TKA, where the patella tendon is not shortened, but the femorotibial joint line is elevated during surgery, either due to femoral over-resection/undersizing or the use of a large polyethylene insert to regain knee stability in cases with excessive soft tissue release [15, 19]. Joint line elevation is common after TKA and rTKA, impacting patello-femoral biomechanics and post-operative stability [18, 38, 39]. In our study, patients who underwent rTKA for instability and loosening (Group 2) showed significantly more PPB cases after rTKA than the stiffness group (Group 1). This suggests that attempting to correct instability may lead to joint line alterations, potentially due to the use of thicker polyethylene inserts, a decision recognized for its contribution to joint line elevation [1, 15, 19, 40]. Clinical

outcomes have been associated with an elevation of the joint line exceeding 5mm in up to 79% of cases undergoing revision total knee arthroplasty (rTKA) [18, 41, 42].

PB has significant implications on patello-femoral joint mechanics, resulting in reduced postoperative range of motion, anterior knee pain, impingement, and polyethylene tibial insert wear [4, 6, 9, 14, 20, 21, 28, 43]. It is essential to distinguish between PB and PPB since their causes and treatments differ [4, 28]. Some studies indicate that PPB negatively affects knee function after TKA. Kazemi et al. found a significant association between decreased range of motion (ROM) and PPB presence [4]. Chonko et al. reported that PPB caused by joint line elevation after TKA can lead to decreased ROM and other complications [6]. Additionally, Flören et al. linked PPB to reduced flexion at 1-year follow-up [14], and Dos-Santos et al. observed a significant association between PPB and flexion contracture [3]. To avoid ROM limitations and functional issues, Behrend et al. suggest avoiding a reduction in BPR [5]. However, some studies did not find significant ROM effects due to PPB. Aguirre-Pastor et al. reported no general association between PPB and clinical outcomes, while patients with PB had worse outcomes than those with PPB or normal patellar height [15]. Bugelli et al. reported no significant ROM differences between patients with normal patellar height and those with PPB [1], and Etchebehere et al. noted that although patellar height decreased after TKA, it did not affect ROM or extension lag at 1 year [44]. The clinical relevance of joint line elevation might be related to the amount of elevation found [5]. Porteous et al. showed that a joint line elevation of less than 5 mm had no influence on clinical outcomes [42]. In conclusion, besides patellar tendon shortening causing PB, a change in joint line position leading to PPB can affect functional results, including ROM in a prosthetic knee [4].

In this study, significant ROM differences were observed only in Group 1 patients with PPB after rTKA, specifically in those who had undergone rTKA for stiff TKA. However, the presence of PB did not appear to significantly affect ROM before or after rTKA. Revision TKA due to stiffness may require excessive releases resulting in to joint elevation and PPB, compromising ROM. On the other hand, the non-stiff group showed no notable ROM differences before and after rTKA, regardless of PB or PPB presence, consistent with Bugelli et al. [1] and Aguirre-Pastor et al.'s [15] findings on PPB. Interestingly, the presence of PB did not significantly affect pre- and postoperative ROM.

The significant impact on ROM in patients with stiff knees and PPB after rTKA supports Han et al.'s [18] findings, suggesting that restoring the femoral joint line is the critical factor affecting postoperative knee ROM after rTKA. PPB has been associated with elevated joint lines while maintaining a normal patellar tendon length [28]. In our study, this condition led to decreased ROM in stiff patients after rTKA, indicating that the acquired joint line elevation was the primary reason for the continued decrease in ROM, not stiffness.

In a subanalysis of 69 patients with three consecutive knee X-rays (native—post TKA—post rTKA), we investigated the trajectory of both the ISR and the BPR. We observed a progressive decrease in the average values of ISR and BPR. Specifically, the decrease in BPR values was significant between all surgical operations. There was a significant decrease in ISR after rTKA, but no significant difference between the native knee status and the after primary TKA status. Overall, these findings indicate a trend of decreasing values for both ratios that assess the position of the patella. Meneghini et al. also reported a decrease in patellar tendon length in 50% of patients after TKA using ISR, but only 10% of them were identified as patients with PB [45]. The progressive reduction in BPR following successive surgeries could indirectly indicate a surgically induced elevation of the joint line. Surgeons need to recognize that with each subsequent surgical procedure there is a potential risk of compromising the patella height.

Limitations

The whole cohort is consisted of patients that underwent an aseptic TKA revision procedure and subsequently the incidence of PB and PPB cannot be compared with the incidence of PB and PPB in general. Furthermore, a retrospective Xray investigation has been conducted for this study. Accuracy of measurement may be influenced and be under observer's subjective opinion for the exact reference points. Although we tried to restrict this weakness with the use of two observers, the limitation must be noted. Furthermore, Xrays are taken in a supposedly 30° flexion position of the knee, a position that cannot be completely verified. Another limitation of this study is that the length of follow-up for patients examined varied and no correlation between follow-up, presence of PB or PPB and clinical outcomes has been investigated.

Conclusions

This research investigated PB and PPB incidences in aseptic rTKAs. After primary TKA, PB and PPB were low (both 11.4%), but increased after rTKA (21% and 29.8% respectively). Comparing the outcomes of aseptic primary TKAs and rTKAs, patients who underwent rTKA due to stiffness displayed a higher prevalence of PB, particularly after the revision procedure. Conversely, the non-stiffness group had a significantly higher incidence of PPB,

especially after rTKA. This finding suggests that joint line compromise may need to be considered when correcting instability or loosening while preserving the integrity of the patellar tendon. In these cases, elevation of the joint line is commonly resulted due to severe widening of the joint gabs, requiring thicker PE inserts to regain knee stability. Regarding range of motion (ROM), it was significantly affected only in patients with stiff knees who developed PPB after rTKA. Regarding the natural trajectory of the Insall-Salvati Ratio (ISR) and Blackburne-Peel Ratio (BPR) over consecutive surgeries, a significant decrease in ISR and BPR was observed. This decrease may indirectly indicate joint line elevation.

This information is of utmost importance to healthcare providers as it offers valuable insights into the potential risks and outcomes associated with rTKA, enabling more informed surgical decision-making and improved patient care.

Acknowledgements Research reported in this publication was supported by the Stavros Niarchos Complex Joint Reconstruction Center at Hospital for Special Surgery. The content is solely the responsibility of the authors and does not necessarily represent the official views of the Center

This study was supported through the generosity of the Anna-Maria and Stephen Kellen Foundation and Marina Kellen French.

TKAF Consortium: Thomas Bauer, Eric Bogner, Mathias Bostrom, Michael Cross, Mark Figgie, Steven Haas, Lionel Ivashkiv, Seth Jerabek, Kethy Jules-Elysee, Meghan Kirksey, Matthew Koff, Maxwell Konnaris, Samantha Lessard, David Mayman, Alexander McLawhorn, Piali Mukherjee, David Oliver, Miguel Otero, Douglas Padgett, Tania Pannellini, Giorgio Perino, Alessandra Pernis, Hollis Potter, Scott Rodeo, Brennan Rourke, Tannin Schmidt, Thomas Sculco, Purva Singh, Kathleen Tam, Chloe Verwiel, Geoffrey Westrich, Timothy Wright, Mark Youssef

Author contributions DAF contributed to study idea and reference research, wrote, reviewed, and edited the manuscript. MB contributed to idea, performed analysis and edited the manuscript. AN contributed to intellectual content, performed the analysis and edited the manuscript. IG contributed to intellectual content and reviewed the manuscript. WP contributed to intellectual content and reviewed the manuscript. GT contributed to intellectual content and reviewed the manuscript. PKS contributed to study idea and reviewed the manuscript.

Funding The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declarations

Conflict of interest The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Peter K. Sculco, MD, reports relationships with DePuy, Zimmer Biomet, Intellijoint Surgical and Lima Corporate, outside the submitted work. The other authors report no potential conflicts of interest.

Informed consent Informed consent was waived from all patients included in this study.

References

1. Bugelli G et al (2018) Pseudo-patella baja: a minor yet frequent complication of total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 26(6):1831–1837. https://doi.org/10.1007/s00167-017-4828-8
2. Schwartz AM, Farley KX, Guild GN, Bradbury TL (2020) Projections and epidemiology of revision hip and knee arthroplasty in the United States to 2030. J Arthroplasty 35(6S):S79–S85. https://doi.org/10.1016/j.arth.2020.02.030
3. Dos-Santos G, Gutierres M, Leite MJ, Barros AS (2021) Pseudo-patella baja after total knee arthroplasty: radiological evaluation and clinical repercussion. Knee 33:334–341. https://doi.org/10.1016/j.knee.2021.10.017
4. Kazemi SM et al (2011) Pseudo-Patella Baja after total knee arthroplasty. Med Sci Monit 17(5):CR92–CR296. https://doi.org/10.12659/MSM.881770
5. Behrend H, Graulich T, Gerlach R, Spross C, Ladurner A (2019) Blackburne–Peel ratio predicts patients' outcomes after total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 27(5):1562–1569. https://doi.org/10.1007/s00167-018-5016-1
6. Chonko DJ, Lombardi AV, Berend KR (2004) Patella baja and total knee arthroplasty (TKA): etiology, diagnosis, and management. Surg Technol Int 12:231–238
7. Petersen W et al (2014) Patellofemoral pain syndrome. Knee Surg Sports Traumatol Arthrosc 22(10):2264–2274. https://doi.org/10.1007/s00167-013-2759-6
8. Shervin D (2015) Anterior knee pain following primary total knee arthroplasty. WJO 6(10):795. https://doi.org/10.5312/wjo.v6.i10.795
9. Blackburne J, Peel T (1977) A new method of measuring patellar height. J Bone Jt Surg Br 59(2):241–242. https://doi.org/10.1302/0301-620X.59B2.873986
10. Braun S et al (2022) The Corpus Adiposum Infrapatellare (Hoffa's Fat Pad)—the role of the infrapatellar fat pad in osteoarthritis pathogenesis. Biomedicines 10(5):1071. https://doi.org/10.3390/biomedicines10051071
11. Gallagher J, Tierney P, Murray P, O'Brien M (2005) The infrapatellar fat pad: anatomy and clinical correlations. Knee Surg Sports Traumatol Arthrosc 13(4):268–272. https://doi.org/10.1007/s00167-004-0592-7
12. Grelsamer RP (2009) Patella baja after knee arthroplasty surgery. is it really patella baja? Semin Arthroplasty 20(3):183–186. https://doi.org/10.1053/j.sart.2009.09.007
13. Lum ZC, Saiz AM, Pereira GC, Meehan JP (2020) Patella baja in total knee arthroplasty. J Am Acad Orthop Surg 28(8):316–323. https://doi.org/10.5435/JAAOS-D-19-00422
14. Flören M, Davis J, Peterson MGE, Laskin RS (2007) A Mini-midvastus capsular approach with patellar displacement decreases the prevalence of patella baja. J Arthroplasty 22(6):51–57. https://doi.org/10.1016/j.arth.2007.05.008
15. Aguirre-Pastor A, Ortolá DJ, Lizaur-Utrilla A, Rosa MA, Lopez-Prats FA (2020) Is pseudo-patella baja really a serious complication of total knee arthroplasty? J Arthroplasty 35(2):557–562. https://doi.org/10.1016/j.arth.2019.09.031
16. Gatha N, Clarke H, Fuchs R, Scuderi G, Insall J (2010) Factors affecting postoperative range of motion after total knee arthroplasty. J Knee Surg 17(04):196–202. https://doi.org/10.1055/s-0030-1248221
17. Grelsamer RP, Meadows S (1992) The modified Insall-Salvati ratio for assessment of patellar height. Clin Orthop Relat Res 282:170–176
18. Han H-S, Yu CH, Shin N, Won S, Lee MC (2019) Femoral joint line restoration is a major determinant of postoperative range of motion in revision total knee arthroplasty. Knee Surg Sports

Traumatol Arthrosc 27(7):2090–2095. https://doi.org/10.1007/s00167-019-05361-1
19. Thornton-Bott P, Unitt L, Johnstone D, Sambatakakis A (2005) Pseudo-patella baja following soft tissue balancing in total knee arthroplasty. Ann R Coll Surg Engl 87:484–484
20. Weale AE, Murray DW, Newman JH, Ackroyd CE (1999) The length of the patellar tendon after unicompartmental and total knee replacement. J Bone Jt Surg Br 81-B(5):790–795. https://doi.org/10.1302/0301-620X.81B5.0810790
21. Yoshii I, Whiteside LA, White SE, Milliano MT (1991) Influence of prosthetic joint line position on knee kinematics and patellar position. J Arthroplasty 6(2):169–177. https://doi.org/10.1016/S0883-5403(11)80013-6
22. Chen AF, Tetreault MW, Levicoff EA, Fedorka CJ, Rothenberg AC, Klatt BA (2014) Increased incidence of patella baja after total knee arthroplasty revision for infection. Am J Orthop (Belle Mead NJ) 43(12):562–566
23. Kirschbaum S, Weynandt C, Fuchs M, Perka C, Gwinner C (2022) Major shortening of the patellar tendon during septic two-stage knee arthroplasty revision using static spacers. J Arthroplasty. https://doi.org/10.1016/j.arth.2022.03.082
24. Ahmad CS, Kwak SD, Ateshian GA, Warden WH, Steadman JR, Mow VC (1998) Effects of patellar tendon adhesion to the anterior tibia on knee mechanics. Am J Sports Med 26(5):715–724. https://doi.org/10.1177/03635465980260051901
25. Mariani PP, Del Signore S, Perugia L (1994) Early development of patella infera after knee fractures. Knee Surg, Sports traumatol, Arthroscopy 2(3):166–169. https://doi.org/10.1007/BF01467919
26. Paulos LE, Wnorowski DC, Greenwald AE (1994) Infrapatellar contracture syndrome: diagnosis, treatment, and long-term followup. Am J Sports Med 22(4):440–449. https://doi.org/10.1177/036354659402200402
27. Insall J, Salvati E (1971) patella position in the normal knee joint. Radiology 101(1):101–104. https://doi.org/10.1148/101.1.101
28. Grelsamer RP (2002) Patella baja after total knee arthroplasty: Is it really patella baja? J Arthroplasty 17(1):66–69. https://doi.org/10.1054/arth.2002.28728
29. Igoumenou VG, Dimopoulos L, Mavrogenis AF (2019) Patellar height assessment methods: an update. JBJS Rev 7(1):e4–e4. https://doi.org/10.2106/JBJS.RVW.18.00038
30. Cabral F, Sousa-Pinto B, Pinto R, Torres J (2017) Patellar height after total knee arthroplasty: comparison of 3 methods. J Arthroplasty 32(2):552-557.e2. https://doi.org/10.1016/j.arth.2016.07.013
31. Xu B, Xu W, Lu D, Sheng H, Xu X, Ding W (2017) Application of different patella height indices in patients undergoing total knee arthroplasty. J Orthop Surg Res 12(1):191. https://doi.org/10.1186/s13018-017-0694-9
32. Seil R, Müller B, Georg T, Kohn D, Rupp S (2000) Reliability and interobserver variability in radiological patellar height ratios. Knee Surg Sports Traumatol Arthrosc 8(4):231–236. https://doi.org/10.1007/s001670000121
33. Seo J-G et al (2015) Prevention of pseudo-patella baja during total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 23(12):3601–3606. https://doi.org/10.1007/s00167-014-3257-1
34. Wyss TF, Schuster AJ, Münger P, Pfluger D, Wehrli U (2006) Does total knee joint replacement with the soft tissue balancing surgical technique maintain the natural joint line? Arch Orthop Trauma Surg 126(7):480–486. https://doi.org/10.1007/s00402-006-0171-0
35. Gwyn R, Kotwal RS, Holt MD, Davies AP (2016) Complete excision of the infrapatellar fat pad is associated with patellar tendon shortening after primary total knee arthroplasty. Eur J Orthop Surg Traumatol 26(5):545–549. https://doi.org/10.1007/s00590-016-1775-x
36. Noyes FR, Wojtys EM, Marshall MT (1991) The early diagnosis and treatment of developmental patella infera syndrome. Clin Orthop Relat Res 265:241–252
37. Rogers BA, Thornton-Bott P, Cannon SR, Briggs TWR (2006) Interobserver variation in the measurement of patellar height after total knee arthroplasty. J Bone Jt Surg Am 88-B(4):484–488. https://doi.org/10.1302/0301-620X.88B4.16407
38. Martin JW, Whiteside LA (1990) The influence of joint line position on knee stability after condylar knee arthroplasty. Clin Orthop Relat Res 259:146–156
39. Schwab JH (2006) Patellar complications following distal femoral replacement after bone tumor resection. J Bone Jt Surg Am 88(10):2225. https://doi.org/10.2106/JBJS.E.01279
40. Sharma V, Tsailas PG, Maheshwari AV, Ranawat AS, Ranawat CS (2008) Does patellar eversion in total knee arthroplasty cause patella baja? Clin Orthop Relat Res 466(11):2763–2768. https://doi.org/10.1007/s11999-008-0347-8
41. Laskin RS (2002) Joint line position restoration during revision total knee replacement. Clin Orthop Relat Res 404:169–171. https://doi.org/10.1097/00003086-200211000-00029
42. Porteous AJ, Hassaballa MA, Newman JH (2008) Does the joint line matter in revision total knee replacement? J Bone Jt Surg Br 90-B(7):879–884. https://doi.org/10.1302/0301-620X.90B7.20566
43. Koshino T, Ejima M, Okamoto R, Morii T (1990) Gradual low riding of the patella during postoperative course after total knee arthroplasty in osteoarthritis and rheumatoid arthritis. J Arthroplasty 5(4):323–327. https://doi.org/10.1016/S0883-5403(08)80091-5
44. Etchebehere M, Lin PP, Moon BS, Yu J, Li L, Lewis VO (2016) Patellar height decreasing after distal femur endoprosthesis reconstruction does not affect functional outcome. J Arthroplasty 31(2):442–445. https://doi.org/10.1016/j.arth.2015.09.009
45. Meneghini RM, Ritter MA, Pierson JL, Meding JB, Berend ME, Faris PM (2006) The effect of the Insall-Salvati ratio on outcome after total knee arthroplasty. J Arthroplasty 21(6):116–120. https://doi.org/10.1016/j.arth.2006.04.014

Authors and Affiliations

Dimitrios A. Flevas[1] · Marco Brenneis[1,2] · TKAF Consortium · Allina Nocon[1] · Ioannis Gkiatas[3] · Wali Pirzada[1] · Georgios Tsakotos[4] · Peter K. Sculco[1]

✉ Dimitrios A. Flevas
flevasd@hss.edu

[1] Hospital for Special Surgery, Stavros Niarchos Foundation Complex Joint Reconstruction Center, 535 East 70th Street, New York, NY 10021, USA

[2] Department of Orthopedics (Friedrichsheim), University Hospital Frankfurt, Goethe University, Frankfurt, Main, Germany

[3] Department of Orthopaedic Surgery, University of Ioannina, Ioannina, Greece

[4] Department of Anatomy, School of Medicine, National and Kapodistrian University of Athens, Athens, Greece