

# Patellofemoral arthroplasty: outcomes and factors associated with early progression of tibiofemoral arthritis

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## Abstract

**Purpose** The purpose of this study was to review the results of patellofemoral arthroplasty (PFA) performed by a single surgeon at a single institution in order to determine factors associated with clinical outcomes and progression of tibiofemoral degenerative joint disease.

**Methods** Sixty-one patients with isolated patellofemoral osteoarthritis were treated with a PFA by a single surgeon between 2003 and 2009. Fifty-nine patients were available for analysis with a mean follow-up of 4 years (range 2–6 years). Patients were evaluated by measuring range of motion and with the use of the Knee Society clinical rating system, the Tegner Activity Level Scale, and the UCLA Activity Score. In addition, preoperative radiographs were evaluated for patellofemoral and tibiofemoral compartment osteoarthritis and presence of trochlear dysplasia, and post-operative radiographs were reviewed for progression of tibiofemoral degenerative arthritis. Furthermore, multivariate statistical methods were applied to study factors that had potential to influence the final outcome.

**Results** There was no statistically significant association between age, gender, history of prior knee surgery, patellar height, patellofemoral osteoarthritis severity, patellar and femoral component size, or performance of lateral release with patient pain and function (as

measured by the Knee Society scores) or progression of tibiofemoral joint osteoarthritis at final follow-up. Increased preoperative body mass index (BMI) was associated with lower post-operative Knee Society function scores ( $p = 0.03$ ). Patients with preoperative trochlear dysplasia had significantly less radiographic evidence of tibiofemoral joint osteoarthritis progression compared with patients without trochlear dysplasia at final follow-up ( $p < 0.0001$ ).

**Conclusion** In this study, patients with preoperative radiographic evidence of trochlear dysplasia experienced less progression of tibiofemoral degenerative joint disease than patients without trochlear dysplasia at a mean follow-up of 4 years.

**Level of evidence** IV.

**Keywords** Patellofemoral arthroplasty · Patellofemoral osteoarthritis · Tibiofemoral arthritis

## Introduction

Patellofemoral arthroplasty (PFA) has been advocated for the treatment of isolated patellofemoral arthritis. It remains somewhat controversial, primarily due to less than satisfactory outcomes and relatively high reported failure rates for early implant designs [13]. Recent reports have yielded more favourable results, presumably due to improvements in implant design and surgical technique [1, 15, 16]. Nonetheless, medium- and long-term failure due to progression of tibiofemoral arthritis remains a concern, with up to 28 % of patients showing evidence of arthritis progression at 5-year follow-up [1]. Thus, proper indications and patient selection are paramount for the success of patellofemoral arthroplasty.

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The purpose of our study was to evaluate mid-term clinical results of PFA using a modern implant and to determine risk factors for progression of tibiofemoral arthritis.

## Materials and methods

Sixty-one patients with isolated patellofemoral osteoarthritis treated with PFA were retrospectively reviewed. The explicit inclusion criteria were patients presenting with a diagnosis of isolated patellofemoral osteoarthritis treated with a PFA by a single surgeon between 2003 and 2009. Patients were excluded for any of the following: preoperative history of inflammatory arthritis, post-septic arthritis, varus or valgus malalignment (mechanical axis  $<177^\circ$  or  $>183^\circ$ ) [12], or significant tibiofemoral arthritis as defined by a Kellgren and Lawrence grade of three or four.

The study was approved by our Institutional Review Board. The Avon patellofemoral prosthesis (Stryker Howmedica Osteonics, Mahwah, NJ, USA) was used in all 61 patients. The surgery was done by a single orthopaedic surgeon (DLD). A midline skin incision and medial parapatellar arthrotomy was used to expose the knee, being careful to limit the distal extent of the arthrotomy to avoid injury to the medial meniscus and/or inter-menisal ligament. Peripheral osteophytes were removed, and the anterior femur immediately adjacent to the most proximal extent of the trochlea was exposed. The trochlea was prepared to receive the appropriate sized trochlear component such that the distal aspect of the implant was flush with the articular cartilage both medially and laterally and the proximal aspect of the implant did not notch the anterior distal femur. The distal tip of the implant was placed just above the roof of the notch to prevent impingement in extension. Internal rotation of the trochlear component was avoided; however, the component was not excessively externally rotated to avoid compromise of lateral patellar stability [4]. The patella was then prepared so as to attempt to recreate the native patellar thickness and high point. Intraoperative assessment of patellar tracking was done during trialling and again after cementing the real components in place. The patella was reduced into the trochlea, and the knee was put through a range of motion test. Appropriate tracking was defined as a patella that remained centred in the trochlea through  $90^\circ$  flexion with no tendency for tilt or subluxation. If tracking was inadequate, the tourniquet was deflated and tracking was reassessed. If the patella continued to tilt or subluxate, then a lateral retinacular release was performed from the inside out, with care taken to preserve the superior lateral geniculate vessels.

Patients began progressive weight bearing on post-operative Day 1, and active range of motion was initiated within 24 h of surgery. Patients were typically discharged

on post-operative Day 2 or 3, after obtaining the ability to ambulate with a walker or crutches, ascend several stairs, and flex the knee  $90^\circ$  or more. Patients were asked to return for examination and radiographs at 3 months, 1, 2, and 5 years from surgery.

Patient variables reviewed included age, body mass index (BMI), work status, smoking history, prior ipsilateral knee surgery, presence or absence of trochlear dysplasia, patellar position, and severity of patellofemoral osteoarthritis. Surgical factors analysed included performance of a lateral release, patellar component size, and femoral component size.

Preoperative and post-operative clinical function was assessed with the Knee Society clinical rating system, the UCLA Activity Score, the Tegner Activity Level Scale, and overall post-operative satisfaction [7, 18, 21]. Knee Society pain and function scores were calculated from standardised questionnaires given prospectively to all patients just prior to surgery and at regular intervals thereafter. Preoperative and post-operative UCLA Activity Scores and Tegner Activity Levels were obtained retrospectively from patient records. Patient satisfaction was obtained post-operatively at 2 years following surgery and at regular intervals thereafter. Patients were asked to consider their post-operative knee pain and function as one of the following compared with their preoperative knee pain and function: worse, the same, somewhat better, or much better.

Preoperative and post-operative radiographic examination included a standing anterior-posterior (AP) radiograph of bilateral knees, a lateral radiograph, a merchant view of the patella, and a full-length standing hip-knee-ankle radiograph. All radiographs were evaluated by the senior author (DLD). The presence of trochlear dysplasia was assessed using the Dejour classification method [17]. Degenerative changes of the patellofemoral joint were assessed preoperatively using the Iwano classification system [9]. The tibiofemoral joint was evaluated preoperatively using the Kellgren–Lawrence classification system and again post-operatively to evaluate for progression of tibiofemoral degenerative joint disease [10]. Patellar position was determined using the Insall–Salvati Index [8]. Patellar tilt and subluxation were measured according to the technique of Gomes et al. [5]. Patellar tilt of more than  $5^\circ$  and subluxation of more than 1 mm were defined as important [2]. Mechanical axis was determined on digital long-standing hip to ankle X-rays utilising the angle created by a line drawn from the centre of the hip to the centre of the knee and a second line from the centre of the knee to the centre of the talus [6]. For radiographic evaluation purposes, patients with a mechanical axis less than  $180^\circ$  were considered to have varus alignment, while patients with a mechanical axis greater than  $180^\circ$  were considered to have valgus alignment.

There were 57 women and 4 men with a mean age of 56 years (SD 10.4) and a mean BMI of 30 kg/m<sup>2</sup> (SD 4.9). Of the 61 patients reviewed, 34 were employed at the time of the PFA (34 of 61 patients, 55 %), 15 were retired (15 of 61 patients, 25 %), and 12 were unemployed (12 of 61 patients, 20 %). Of the 12 unemployed patients, three were unemployed due to a primary complaint of ipsilateral “knee pain.” Only three patients were actively smoking cigarettes at the time of the PFA (3 of 61 patients, 5 %). Prior to patellofemoral arthroplasty, 20 patients had undergone a total of 37 ipsilateral knee surgeries (20 of 61 patients, 33 %).

Preoperative mean maximum knee flexion was 123° (SD 9.0). The preoperative mean Knee Society function score was 56 (SD 10.9). The preoperative mean Knee Society pain score was 51 (SD 7.4). The preoperative mean Knee Society stair climbing score was 27 (SD 6.7). The preoperative median Tegner activity level was two (range 0–4), and the preoperative mean UCLA Activity Score was 3.4 (SD 0.6).

Of the 61 patients, 39 had radiographic evidence of trochlear dysplasia and 22 patients had no radiographic evidence of trochlear dysplasia as described by Tecklenburg et al. [17]. Of the 39 patients with radiographic evidence of trochlear dysplasia, 17 had type A dysplasia (17 of 39 patients, 44 %), 16 had type B dysplasia (16 of 39 patients, 41 %), 5 had type C dysplasia (5 of 39 patients, 13 %), and 1 had type D dysplasia (1 of 39 patients, 2 %). All patients in the study had preoperative radiographic evidence of patellofemoral osteoarthritis as described by Iwano et al. Of the 61 patients, 10 had stage 2 (moderate) degenerative changes (10 of 61 patients, 16 %), 23 had stage 3 (severe) degenerative changes (23 of 61 patients, 38 %), and 28 had stage 4 (very severe) degenerative changes (28 of 61 patients, 46 %). In terms of tibiofemoral osteoarthritis, no patient had preoperative radiographic evidence of moderate or severe osteoarthritis according to the Kellgren–Lawrence classification system—41 patients had normal tibiofemoral joint space (41 of 61 patients, 67 %), 16 patients had grade one (doubtful joint space narrowing) degenerative changes (16 of 61 patients, 26 %), and four patients had grade two (minimal joint space narrowing) degenerative changes (4 of 61 patients, 7 %). Of the 61 patients, 51 had preoperative patella alta (51 of 61 patients, 84 %) and 10 had normal patellar position (10 of 61 patients, 16 %) as measured by the Insall-Salvati index. With respect to alignment, there were a total of 22 patients with varus alignment, 21 patients with valgus alignment and 18 patients with neutral alignment. Of note, patients with trochlear dysplasia had a mean mechanical axis of 180.4°, while patients without trochlear dysplasia had a mean mechanical axis of 179.2° ( $p = 0.006$ ).

Lateral retinacular release was performed in 50 patients at the time of surgery (50 of 61 patients, 82 %). Of the 61

PFA procedures performed, 3 patients received an extra small femoral implant (3 of 61 patients, 5 %), 19 patients received a small femoral implant (19 of 61 patients, 31 %), 35 patients received a medium femoral implant (35 of 61 patients, 57 %), and four patients received a large femoral implant (4 of 61 patients, 7 %). In terms of patellar component size, 44 patients received a small patellar implant (44 of 61 patients, 71 %), 15 patients received a medium patellar implant (15 of 61 patients, 25 %), and two patients received a large patellar implant (2 of 61 patients, 4 %).

The average follow-up was 4 years (range 2–6). At the time of final follow-up, one patient had died from causes unrelated to the operation and one patient was lost to follow-up. This left 59 patients available for final analysis. This study was IRB approved by the Mayo Clinic College of Medicine (IRB #11-000732).

### Statistical methods

Association of risk factors with continuous differences in preoperative to post-operative outcome measures was estimated using linear regression. Outcomes that could be dichotomised, such as UCLA Activity Score, Tegner Activity Level, patient satisfaction, and progression of osteoarthritis were analysed using logistic regression, reported as odds ratios for common risk factors. Risk factors assessed included age, BMI, work status, smoking history, prior ipsilateral knee surgery, preoperative trochlear dysplasia, patellar position, severity of patellofemoral osteoarthritis, performance of lateral release, patellar component size, and femoral component size.  $p$  values less than or equal to 0.05 were considered statistically significant.

### Results

Maximum knee flexion improved from a mean preoperative value of 123° (SD 9.0) to a mean post-operative value of 125° (SD 6.1) ( $p = \text{n.s.}$ ). The Knee Society function score improved from a mean preoperative value of 56 (SD 10.9) to a mean post-operative value of 78 (SD 20.6) ( $p = 0.0001$ ). The Knee Society pain score improved from a mean preoperative value of 51 (SD 7.4) to a mean post-operative value of 90 (SD 13.6) ( $p = 0.0001$ ). The Knee Society stair climbing score improved from a mean preoperative value of 27 (SD 6.7) to a mean post-operative value of 39 (SD 10.2) ( $p = 0.0001$ ). Tegner activity level improved from a median preoperative level of two (range 0–4) to a median post-operative level of four (range 0–5) ( $p = 0.0001$ ). UCLA Activity Score improved from a mean preoperative score of 3.4 (SD 0.6) to a mean post-operative score of 5.8 (SD 1.8) ( $p = 0.0001$ ). A table summarising these results is included (Table 1).

**Table 1** Results at time of final follow-up

Characteristics	Preoperative	Post-operative	<i>p</i> value
Maximal knee flexion (°)			
Mean (SD)	123.4 (8.98)	124.6 (6.11)	NS
Median (range)	125.0 (90, 135)	125.0 (105, 140)	
Knee society function score			
Mean (SD)	56.0 (10.94)	77.6 (20.62)	0.0001
Median (range)	60.0 (20, 70)	80.0 (15, 100)	
Knee society pain score			
Mean (SD)	51.4 (7.38)	89.9 (13.63)	0.0001
Median (range)	50.0 (37, 88)	95.0 (57, 100)	
Knee society stair climbing score			
Mean (SD)	26.9 (6.70)	38.8 (10.19)	0.0001
Median (range)	30.0 (0, 30)	40.0 (0, 50)	
Tegner activity level			
Mean (SD)	2.3 (0.91)	3.8 (1.22)	0.0001
Median (range)	2 (0, 4)	4.0 (0, 5)	
UCLA activity score			
Mean (SD)	3.4 (0.55)	5.8 (1.80)	0.0001
Median (range)	3 (2, 5)	6.0 (2, 9)	

There was no statistically significant association between patient age, gender, work status, smoking history, prior knee surgery, preoperative patellar height, severity of preoperative patellofemoral osteoarthritis, patellar and femoral component size, or need for a lateral retinacular release with patient pain and function at final follow-up as measured by the change in knee range of motion, post-operative patient satisfaction, and change in function, pain, and stair climbing components of the Knee Society score. Increased preoperative BMI was associated with less preoperative to post-operative improvement of Knee Society function scores ( $p = 0.03$ ) and Knee Society stair climbing scores ( $p = 0.05$ ). In addition, there was a trend towards less improvement of Tegner activity level with increased preoperative BMI ( $p = 0.09$ ). There was no statistically significant association between preoperative patient BMI and progression of tibiofemoral joint osteoarthritis, change in maximum knee flexion, change in Knee Society pain score, change in UCLA Activity Score, or post-operative patient satisfaction.

Patients with preoperative evidence of trochlear dysplasia had significantly less progression of tibiofemoral joint osteoarthritis at final follow-up compared with patients without preoperative evidence of trochlear dysplasia ( $p < 0.0001$ ). Of the 39 patients with evidence of preoperative trochlear dysplasia, only five patients demonstrated radiographic progression of tibiofemoral osteoarthritis at final follow-up (5 of 39 patients, 13 %). Lateral compartment progression was seen in all five patients. Of the 20 patients without evidence of preoperative trochlear dysplasia, 14 demonstrated

**Table 2** Radiographic progression of tibiofemoral osteoarthritis at final follow-up

		Trochlear dysplasia		
		Not Present (%)	Present (%)	Total (%)
Tibiofemoral osteoarthritis at final follow-up	Worse	14 (24)	5 (8)	19 (32)
	Same	6 (10)	34 (58)	40 (68)
	Total	20 (34)	39 (66)	59 (100)

radiographic progression of tibiofemoral osteoarthritis at final follow-up (14 of 20 patients, 70 %) (Table 2). Medial compartment progression was seen in 13 of these patients and lateral compartment progression in 1 patient. Examples of patients with and without evidence of degenerative arthritis progression are presented in Fig. 1. Of note, there was no statistically significant difference in length of follow-up between patients with and without preoperative trochlear dysplasia. In addition, there was no significant correlation between preoperative BMI and presence of trochlear dysplasia. Also of note, mechanical axis of those patients who showed evidence of progression of degenerative arthritis was  $178.8^\circ$  (SD 1.3) versus  $180.5^\circ$  (SD 1.4) in those who did not show evidence of arthritis progression ( $p < 0.001$ ).

There was no statistically significant association between presence of preoperative trochlear dysplasia and change in maximum knee flexion, change in Knee Society pain score, change in Knee Society function score, change in Knee Society stair climbing score, change in Tegner activity level, change in UCLA score, or post-operative patient satisfaction.

Kaplan–Meier survivorship of the 59 patients showed survival of 93 % with reoperation for any reason defined as the end point at 4 years post-operatively. There was survival of 97 % with conversion to total knee arthroplasty defined as the end point at 4 years post-operatively.

Revision was performed in two patients (2 of 59 patients, 3 %). Both patients had progression of tibiofemoral joint osteoarthritis and were revised to a total knee arthroplasty; one patient was revised at 50 months following surgery and the other was revised at 63 months following surgery. Reoperations were performed in two additional patients (2 of 59 patients, 3 %). One patient had ipsilateral knee stiffness treated with arthroscopic debridement and manipulation, and one patient had a medial meniscus tear treated with arthroscopic partial meniscectomy.

## Discussion

We report a single surgeon series of PFA performed for isolated patellofemoral arthritis using a modern implant. The

**Fig. 1** **a, b** Preoperative X-rays for a patient without trochlear dysplasia performed in 2006. **c** At 4-year follow-up, this patient shows evidence of progression of medial compartment degenerative arthritis. **d, e** Preoperative X-rays for a patient with trochlear dysplasia and PFA performed in 2007. **f** At 4-year follow-up, this patient exhibits no evidence of progression of degenerative arthritis



most important findings of our study include significant improvement in Knee Society pain and function Scores, stair climbing scores, and both Tegner and UCLA Activity Scores at a mean 4-year follow-up. Patients with trochlear dysplasia demonstrated significantly less progression of tibiofemoral degenerative arthritis when compared to patients without trochlear dysplasia. Survivorship at a mean of 4 years was 97 %.

Strengths of the study include the use of a single implant by a single surgeon using a standardised technique, with radiographic review and near-complete follow-up. Limitations include the retrospective study design and the fact that long-term data are not yet available for this patient cohort.

Clinically, patients in this cohort exhibited significant improvement in standard outcome measures of pain, function, and activity. Given these results, we suggest that PFA represents a viable alternative to total knee arthroplasty (TKA) for patients with isolated patellofemoral arthritis. We previously published a comparative study of PFA versus TKA in this patient population and found similar early outcomes with respect to pain relief, but less morbidity and improved function and Activity Scores in the PFA

group [3]. The ideal candidate for PFA, however, remains a subject of some debate. In the current study, patients with higher preoperative BMI demonstrated significantly less improvement in Knee Society function and stair climbing scores. It is possible that PFA patients with increased BMI exhibit lower post-operative functional improvement due to increased co-morbidities that may affect function. It is unclear, however, whether TKA would afford these patients improved function when compared to PFA. Based on our above-noted comparative study, we feel this is unlikely. With respect to arthritis progression, we were unable to show that increased BMI was independently correlated with progression of tibiofemoral arthritis at mid-term follow-up. However, with longer follow-up, this might indeed be a concern. It has been suggested that patients with a BMI over 30 kg/m<sup>2</sup> may have a higher rate of revision than non-obese patients [11, 19].

The presence of trochlear dysplasia was associated with significantly less progression of tibiofemoral arthritis at follow-up. Whereas seventy per cent of patients without trochlear dysplasia demonstrated progression of tibiofemoral arthritis, only thirteen per cent of those with trochlear

dysplasia demonstrated progression. Other authors have suggested improved outcomes in patients with preoperative trochlear dysplasia [11]. However, we are aware of only one other study that has documented less radiographic progression of tibiofemoral arthritis in patients with trochlear dysplasia undergoing modern PFA [14, 20]. Despite evidence for progression of tibiofemoral arthritis in our cohort of patients without trochlear dysplasia, very few patients had required revision to TKA at mid-term follow-up. It is evident that radiographic findings do not always correlate with clinical outcome. Nonetheless, caution should be exercised when considering PFA for patients with patellofemoral arthritis without trochlear dysplasia, and these patients should be counselled that PFA may represent an “interim” procedure for them. This is particularly relevant in younger patients for whom PFA has been recommended.

With respect to alignment, patients with significant varus or valgus deformity were excluded from consideration for patellofemoral arthroplasty. However, we did measure the mechanical axis in order to determine whether subtle variations in patient morphotype might impact progression of degenerative arthritis. We did find that patients with trochlear dysplasia were more likely to exhibit valgus alignment than patients without trochlear dysplasia. Likewise, those patients that showed no progression of degenerative arthritis also were more likely to exhibit slight valgus alignment on preoperative radiographs. Although statistically significant, it is difficult to determine whether these differences in mechanical axis are clinically significant. It is certainly possible, however, that patients with preoperative evidence of varus alignment without trochlear dysplasia might be at particular risk for progression. Further study is warranted in order to reach a definitive conclusion regarding the effect of patient morphotype on degenerative arthritis progression.

## Conclusion

In conclusion, PFA yields satisfactory outcomes in patients with isolated patellofemoral arthritis. With longer follow-up, there is concern for progression of tibiofemoral arthritis, particularly in patients who do not demonstrate trochlear dysplasia on preoperative radiographs. Additionally, patients with higher BMI likely demonstrate less functional improvement following PFA, despite achieving significant improvement in pain.

## References

- Ackroyd CE, Newman JH, Evans R, Eldridge JD, Joslin CC (2007) The Avon patellofemoral arthroplasty: five year survivorship and functional results. *J Bone Joint Surg Br* 89:310–315
- Bindelglass DF, Cohen JL, Dorr LD (1993) Patellar tilt and subluxation in total knee arthroplasty. Relationship to pain, fixation, and design. *Clin Orthop Relat Res* 286:103–109
- Dahm DL, Al-Rayashi W, Dajani K, Shah JP, Levy BA, Stuart MJ (2010) Patellofemoral arthroplasty versus total knee arthroplasty in patients with isolated patellofemoral arthritis. *Am J Orthop* 39:487–491
- Farr J 2nd, Barrett D (2008) Optimizing patellofemoral arthroplasty. *Knee* 15:339–347
- Gomes LS, Bechtold JE, Gustilo RB (1988) Patellar prosthesis positioning in total knee arthroplasty. A roentgenographic study. *Clin Orthop Relat Res* 236:72–81
- Hsu RW, Himeno S, Coventry MB, Chao EY (1990) Normal axial alignment of the lower extremity and load-bearing distribution of the knee. *Clin Orthop Relat Res* 255:215–227
- Insall JN, Dorr LD, Scott RD, Scott WN (1989) Rationale of the knee society clinical rating system. *Clin Orthop Relat Res* 248:13–14
- Insall J, Salvati E (1971) Patella position in the normal knee joint. *Radiology* 101:101–104
- Iwano T, Kurosawa H, Tokuyama H, Hoshikawa Y (1990) Roentgenographic and clinical findings of patellofemoral osteoarthritis. With special reference to its relationship to femorotibial osteoarthritis and etiologic factors. *Clin Orthop Relat Res* 252:190–197
- Kellgren JH, Lawrence JS (1957) Radiological assessment of osteo-arthritis. *Ann Rheum Dis* 16:494–502
- Leadbetter WB, Kolisek FR, Levitt RL, Brooker AF, Zietz P, Marker DR, Bonutti PM, Mohnt MA (2009) Patellofemoral arthroplasty: a multi-centre study with minimum 2-year follow up. *Int Orthop* 33:1597–1601
- Leadbetter WB (2008) Patellofemoral arthritis: rationale and outcomes in younger patients. *Orthop Clin North Am* 39:363–380
- Mihalko WM, Boachie-Adjei Y, Spang JT, Fulkerson JP, Arendt EA, Saleh KJ (2007) Controversies and techniques in the surgical management of patellofemoral arthritis. *J Bone Joint Surg Am* 89:788–802
- Nicol SG, Loveridge JM, Weale AE, Ackroyd CE, Newman JH (2006) Arthritis progression after patellofemoral joint replacement. *Knee* 13:290–295
- Odumanya M, Costa ML, Parsons N, Achten J, Dhillon M, Krikler SJ (2010) The Avon patellofemoral joint replacement: five year results from an independent centre. *J Bone Joint Surg Br* 92:56–60
- Starks I, Roberts S, White SH (2009) The avon patellofemoral joint replacement: independent assessment of early functional outcomes. *J Bone Joint Surg Br* 91:1579–1582
- Tecklenburg K, Dejour D, Hoser C, Fink C (2006) Bony and cartilaginous anatomy of the patellofemoral joint. *Knee Surg Sports Traumatol Arthrosc* 14:235–240
- Tegner Y, Lysholm J (1985) Rating systems in the evaluation of knee ligament injuries. *Clin Orthop Relat Res* 198:43–49
- Van Jonbergen HP, Werkman DM, Van Kampen A (2010) Long term outcomes of patellofemoral arthroplasty. *J Arthroplasty* 25:1066–1071
- Williams DP, Pandit HG, Athanasou NA, Murray DW, Gibbons CL (2013) Early revisions of the femoro-patella vialla joint replacement. *J Bone Joint Surg Br* 95:793–797
- Zahiri CA, Schmalzried TP, Szuszczewicz ES, Amstutz HC (1998) Assessing activity in joint replacement patients. *J Arthroplasty* 13:890–895