Predicting Patellar Failure After Total Knee Arthroplasty

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Published online: 19 August 2008
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Abstract We identified patient and surgeon factors associated with patellar component failure in a series of 8530 TKAs performed in 5640 patients using the same posterior cruciate ligament-retaining TKA with all-polyethylene patellar components between January 1983 and December 2003. Patellar failure was defined as loosening, fracture, or patellar revision. All infections were excluded. Statistical analysis using Kaplan-Meier and Cox regression was used to determine the risk of patellar failure. Followup averaged 7.0 years (range, 2–22 years). Patellar component loosening occurred in 4.8% of TKAs (409 knees). Patellar fracture was identified in 5.2% of TKA (444 knees). Twenty-five patellae were revised (0.3%). TKA performed with a lateral release and patients with a body mass index of greater than 30 kg/m² were at the greatest risk of patellar loosening and fracture, respectively. Male gender, preoperative varus alignment of greater than 5°, and large patellar component size also predicted a higher risk of patellar fracture. Medial patellar component position, tibial component thickness of

greater than 12 mm, preoperative valgus alignment of 10° or more, and preoperative flexion of 100° or more predicted patellar loosening. An awareness of these factors that predict patellar failure after TKA may help determine the relative indications for TKA and influence surgical technique, especially when using this prosthesis.

Level of Evidence: Level IV, prognostic study. See the Guidelines for Authors for a complete description of levels of evidence.

Introduction

Complications related to the extensor mechanism in the patella (patellofemoral instability, fracture, loosening, wear, clunk, tendon rupture, and avascular necrosis) are among the most common causes of failure of a TKA [1, 4, 7, 8, 15, 17, 19, 27, 33] and may account for up to 50% of all revision operations [1]. In some of these cases, patellar component revision may be indicated. Unfortunately, isolated patellar revisions have been associated with substantial complication rates up to 45% [5, 22]. To avoid these complications, some surgeons may choose simply not to resurface the patella. However, not resurfacing the patella has generally been associated with more anterior knee pain, more weakness, and more revision operations [6, 12, 23, 24, 27]. Historically, several factors have been associated with patellar failure, including patient factors (osteoarthritis [11], obesity [11], and increased postoperative flexion [15, 35]), surgeon factors (increasing the relative patellar thickness [13, 15, 32] and performing a lateral retinacular release [4, 21, 29, 32]), and prosthetic factors (the use of metal-backed patellae [3, 30, 34] and the use of a large central peg [10, 19, 28, 31]). Because of this dilemma, selected patellar resurfacing may be desirable.

The research institution of the authors has received funding from Biomet Inc, Warsaw, IN; Zimmer, Inc, Warsaw, IN; Stryker Orthopaedics, Mahway, NJ; and St Francis Hospital, Mooresville, IN. Each author certifies that his or her institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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To address this controversy, we asked the following questions: what common preoperative (patient) factors are associated with patellar failure after TKA? What common intraoperative (surgeon) factors are associated with patellar component failure after TKA? And, what are the relative risks of each of these factors (if any)? An awareness of factors that may predict patellar component failure after TKA may influence the surgical technique when considering whether or not to resurface the patella.

Materials and Methods

We retrospectively reviewed the records of 7016 patients who underwent 10,884 primary TKAs between January 1983 and December 2003. We excluded patients who had less than 2 years of followup, a previous extensor mechanism realignment, a metal-backed patella, any uncemented component, posterior stabilized knee design, or subsequent infection. This left 5640 patients with 8531 primary cemented cruciate-retaining TKAs. All data including radiographic data were prospectively recorded and then retrospectively reviewed for this report. The average age at operation was 70 years. Sixty percent of patients were female. The diagnosis was osteoarthritis in 96%. Average followup was 7.0 years (standard deviation, 3.5 years; range, 2–22 years) (Table 1). Four hundred sixty-two patients (584 knees) were lost to followup after their 2-year followup and their status could not be determined.

All implants were of a posterior cruciate ligament-retaining type and included an all-polyethylene patellar component with a central peg. Five surgeons (MAR, EMK, PMF, JBM, MEB) implanted the TKAs using a standard medial parapatellar approach. Between 1983 and 1993, the

posterior condylar axis (PCA) was used to determine femoral component rotation in all TKAs. Between 1995 and 2003, the transepicondylar axis (TEA) was used to determine femoral component rotation in all TKAs. In 1994, both techniques were used. The decision to perform a lateral retinacular release was based on whether any patellar maltracking, pull, or tilt was present using the rule of “no touch.” All components (AGC[®]; Biomet Inc, Warsaw, IN) in all knees were cemented.

Patients began full weightbearing on the first postoperative day. Range of motion was started on the second postoperative day. All patients received the same postoperative physical therapy regimen.

Patients were followed at 8 weeks, 6 months, 1 year, and every 2 to 3 years thereafter using the Knee Society clinical scoring system [14]. Radiographs were obtained using the Knee Society standard protocol [9], which included a 100-cm (40-inch) standing anteroposterior radiograph, a 60° patellar (sunrise view) radiograph, and a 45° lateral radiograph. We (MAR, EMK, PMF, JBM, MEB) evaluated the radiographs for patellar loosening and patellar fracture. Patellar loosening was defined as any global radiolucency or component migration on any anteroposterior, lateral, or sunrise view radiograph. Patellar fracture was defined as any fracture of the cement mantle or the patella or both. Patellar fracture was diagnosed radiographically, independent of symptoms.

Preoperative (patient) factors evaluated included gender, age at operation, body mass index (BMI) at operation, diagnosis, alignment, Knee Society knee score, function score, and pain score, and knee flexion. Intraoperative (surgeon) factors studied included patellar component size (small, 31 mm; medium, 34 mm; or large, 37 mm), lateral retinacular release (yes or no), PCA or TEA, patellar position (medial, central, or lateral), patellar thickness preresection, patellar thickness postresection, and tibial component thickness (metal and polyethylene).

Patellar component survival was determined with the Kaplan-Meier method [16] using patellar component loosening, patellar fracture, and patellar revision as end points. Patellar revision was defined as revision for any patellofemoral complication. Survival curves comparing all variables for each patient and surgeon factor studied were tested for the greatest statistical differences in survivorship. (This method is called “recursive partitioning.” Thus, initially BMI > 30 and > 35 were NOT used as arbitrary cutoffs but, rather, the statistical results determined the where the cutoff for the greatest difference in survival was found with respect to BMI; in this case 30.) The Cox hazard ratio was used to determine the relative risk of each risk factor (if any). All statistical models were analyzed for power with the significance level equal to 0.025 and a power equal to 0.80 (that is, the probability of a Type 2

Table 1. Demographic data

Demographic	Value
Number of TKAs	8531
Number of patients	5640
Age (years)*	70 ± 9.0 (38–92)
Gender	
Female	3384 (60%)
Male	2256 (40%)
Diagnosis	
Osteoarthritis	8224 (96.4%)
Rheumatoid arthritis	230 (2.7%)
Osteonecrosis	73 (0.85%)
Other	4 (0.05%)
Body mass index (kg/m ²)*	30 ± 5.6 (22–38)
Followup (years)*	7.0 ± 3.5 (2–22)

*Values are expressed as average ± standard deviation, with range in parentheses.

beta error less than or equal to 0.20). Statistical analysis was performed with the aid of the SAS[®] software (SAS Institute Inc, Cary, NC).

Results

Patellar loosening was identified in 4.8% (409 patellae) of the entire study group. Of the preoperative (patient) factors studied, differences in Kaplan-Meier survivorship were identified with respect to gender, BMI, coronal alignment, and flexion (Table 2). Failure for patella loosening was greater in patients with a BMI of greater than 30 kg/m². Coronal knee alignment, which averaged 0° (range, 20° varus to 40° valgus) in the entire study group, was a factor associated with patellar loosening if the preoperative alignment measured 10° of valgus or more. Flexion, which averaged 107° (range, 5°–130°) in the entire study group, was also a factor in patella loosening for knees with 100° of flexion or more preoperatively. Patellar fracture was greater in men, in patients with a BMI of 30 kg/m² or more, and in knees with a preoperative alignment of 5° or more of varus. Twelve-year survival for loosening in patients with a BMI of 30 to 35 kg/m² was 0.8921 versus 0.8320 for patients with a BMI of greater than 35 kg/m². Patellar fractures occurred in 5.2% of all TKAs (444 knees). There were no known cases of trauma and all fractures were believed to be due to osteonecrosis. Knee score (average, 42; range, 0–80), function score (average, 44; range, 0–71), and pain score (average, 10; range, 0–45), along with age and diagnosis, were not preoperative risk factors for patella component failure. Twelve-year survival for patellar fracture in patients with a BMI of 30 to 35 kg/m² was 0.8746 versus 0.8611 for patients with a BMI of greater than 35 kg/m². Twenty-five patellae were revised

(0.3%); six were replaced with another cemented patellar component and 19 patella prostheses were excised. No preoperative variable studied was a risk factor for patellar revision. Furthermore, 12-year survival for patellar revision in patients with a BMI of 30 to 35 kg/m² was 0.9900 versus 0.9987 for patients with a BMI of greater than 35 kg/m².

Of the intraoperative (surgeon) factors studied, differences in Kaplan-Meier survivorship were identified with respect to patellar size, lateral retinacular release, patellar position, and tibial component thickness (Table 3). Lateral retinacular release (34% of all TKAs, 2901 TKAs) was associated with a greater risk of patellar loosening. Patellar loosening was also greater in knees with a medially positioned patellar button (84% medial, 1% central, 15% lateral). Tibial component thickness averaged 11 mm (range, 8–16 mm) for all TKAs. Patellar loosening was greater for tibial components 12 mm thick or greater. While a small patellar component was used in 24% (2047 TKAs) and a medium patellar component was used in 71% (6057 TKAs), failure for patella fracture was greater in knees implanted with a large (37-mm) patella (5% of all TKAs, 427 knees). The methodology used for femoral component rotation (PCA, 46%; TEA, 54%) was not associated with an increased risk of patellar failure. Furthermore, the preresection patellar thickness (average, 18 mm; range, 10–35 mm) or the postresection patellar thickness (average, 10 mm; range, 5–20 mm) were also not associated with patellar failure. No intraoperative variable examined was a risk factor for patellar component revision.

Patients with a BMI of greater than 30 kg/m² had more than 6 times the risk for patellar component loosening and 1.7 times the risk of patellar component fracture compared to patients with a BMI of 30 kg/m² or less (Tables 4, 5). Performing a lateral retinacular release placed the patella at a 3.8 times risk for loosening and a 2.7 times risk for patella fracture as compared to not performing a lateral

Table 2. Kaplan-Meier survival according to preoperative variable

Preoperative variable	Patellar loosening	Patellar fracture	Patellar revision
Gender	0.8781	0.0027*	0.2715
Age	0.2086	0.1911	0.6044
Body mass index	0.0023 [†]	0.0017 [†]	0.7866
Diagnosis	0.3570	0.8389	0.2463
Alignment	0.0206 [‡]	0.0206 [§]	0.6642
Knee score	0.4144	0.8585	0.7653
Function score	0.8262	0.1252	0.4265
Pain score	0.6897	0.7038	0.5834
Flexion	0.0203	0.9154	0.3421

*Failure greater in males; [†]failure greater for body mass index of 30 kg/m² or more; [‡]failure greater for 10° valgus or more; [§]failure greater for 5° varus or more; ^{||}failure greater for 100° of flexion or more.

Table 3. Kaplan-Meier survival according to intraoperative variable

Intraoperative variable	Patellar loosening	Patellar fracture	Patellar revision
Patellar size	0.5423	0.0330*	0.6325
Lateral release	< 0.0001 [†]	< 0.0001 [†]	0.6683
PCA/TEA	0.4592	0.3508	0.1073
Patellar position	0.0005 [‡]	0.6985	0.1073
Preresection thickness	0.4636	0.5888	0.5943
Postresection thickness	0.4240	0.6012	0.5898
Tibial component thickness	0.0050 [§]	0.7091	0.3009

*Failure greater in large (37-mm) patellae; [†]failure greater for knees with lateral release; [‡]failure greater for medial patellar position; [§]failure greater for tibial component thickness of 12 mm or greater; PCA = posterior condylar axis; TEA = transepicondylar axis.

Table 4. Relative risk for loosening

Variable	Cox hazard ratio	p value
Body mass index > 30 kg/m ²	6.3	0.0018
10° preoperative valgus or more	2.0	0.0164
Flexion > 100°	2.1	0.0089
Lateral release	3.8	0.0001
Medial patellar position	2.7	0.0014
Tibial component > 12 mm	2.2	0.0025

Table 5. Relative risk for fracture

Variable	Cox hazard ratio	p value
Body mass index > 30 kg/m ²	1.7	0.0001
Male gender	1.9	0.0001
5° preoperative varus or more	1.6	0.0060
Lateral release	2.7	0.0001
Large patellar size	1.4	0.0334

Table 6. Kaplan-Meier survival: patellar loosening over time

Time (years)	Probability	95% confidence interval	Number failed
1	0.9925	0.9900, 0.9944	45
3	0.9841	0.9806, 0.9870	94
5	0.9704	0.9654, 0.9746	158
7	0.9543	0.9476, 0.9602	211
10	0.9350	0.9257, 0.9433	248
12	0.8897	0.8837, 0.9136	280
15	0.8809	0.8597, 0.8992	288
17	0.8594	0.9251, 0.8874	291

retinacular release. Furthermore, patient factors such as 10° of preoperative valgus or more and preoperative flexion of greater than 100° and surgeon factors such as a medial patellar position and use of a tibial component 12 mm thick or greater placed the patellar at more than 2 times the risk for loosening, whereas patient factors such as male gender and 5° of preoperative varus or more were associated with a 1.9 and 1.6 times risk of patella fracture, respectively. Finally, the use of a large patellar component placed the patella at a 1.4 times risk of patella fracture.

The 17-year survival probabilities for failure as patellar loosening, fracture, and revision were 0.8594, 0.9025, 0.9525, respectively (Tables 6, 7, 8).

Discussion

What common preoperative (patient) factors are associated with patellar failure after TKA? What common

Table 7. Kaplan-Meier survival: patella fracture over time

Time (years)	Probability	95% confidence interval	Number failed
1	0.9872	0.9841, 0.9898	77
3	0.9733	0.9689, 0.9771	159
5	0.9605	0.9549, 0.9653	219
7	0.9472	0.9404, 0.9533	264
10	0.9297	0.9204, 0.9380	297
12	0.9188	0.9070, 0.9291	307
15	0.9091	0.8932, 0.9226	311
17	0.9025	0.8811, 0.9202	312

Table 8. Kaplan-Meier survival: patellar revision over time

Time (years)	Probability	95% confidence interval	Number failed
1	1.0000	1.0000, 1.0000	0
3	0.9990	0.9978, 0.9995	6
5	0.9978	0.9961, 0.9988	11
7	0.9975	0.9955, 0.9986	12
10	0.9960	0.9931, 0.9977	15
12	0.9948	0.9902, 0.9972	16
15	0.9892	0.9761, 0.9951	18
17	0.9892	0.9761, 0.9951	18

intraoperative (surgeon) factors are associated with patellar component failure after TKA? And, what are the relative risks of each of these factors? If any of these factors are predictive of patellar component failure after TKA, knowledge of these factors may influence the surgical technique when considering whether or not to resurface the patella. We identified patient and surgeon factors associated with patellar component failure in a series of 8530 TKAs performed in 5640 patients using the same posterior cruciate ligament-retaining TKA with all-polyethylene patellar components.

Our results are limited by the use of a single implant design. The use of an all-polyethylene patellar component with peripheral pegs or a different implant may, therefore, lead to results different from ours. Extrapolation of these data to other knee designs should be done with caution. Because a single design was used, however, these results are not compromised by an additional variable. Another limitation of this study relates to large statistical reviews in general. While relative risks of patellar failure were identified in this study, the absolute risks of patellar component failure are relatively small. This fact may make it difficult for the surgeon to make rational decisions about whether to resurface the patella or not. Yet, a much smaller database would make a statistical determination of these relative risks more suspect.

Specific patient factors such as gender, BMI, coronal alignment, and preoperative flexion were all important factors in patellar component failure. Healy et al. [11] in a study evaluating 211 TKAs reported obesity (mean weight, 190 pounds or greater) was associated with an increased incidence of patellofemoral problems. Both uncemented and metal-backed patellar components were used. In contrast to our report, Healy et al. [11] reported osteoarthritis associated with patellar component failure as compared to other diagnoses. Windsor et al. [35] noted patients with postoperative knee flexion of greater than 95° had an increased risk of patellar fracture. Insall et al. [15] reported the average flexion in TKA with patellar fracture was “slightly greater” than in knees without patellar fractures. No statistical comparison was performed. In our study, flexion was not associated with patellar fracture. Our study is the first, to our knowledge, to report preoperative flexion of 100° or more as a risk factor for patellar component failure (loosening).

Of the intraoperative variables studied, surgeon-related factors such as performing a lateral retinacular release, patellar component position, and tibial polyethylene thickness were factors associated with patellar component failure. The deleterious effects of lateral retinacular release as it relates to patellar complications, including osteonecrosis, patella fractures, and loosening, are well documented [4, 21, 29, 32]. In our study, lateral retinacular release was associated with a 2.7 times risk of patella fracture and a 3.8 times risk of patellar loosening. These findings are consistent with these previous reports. However, this is the first report to relate medial patellar component position and tibial component thickness of 12 mm or greater as risk factors for patellar component loosening. Although the use of the TEA to determine femoral component rotation resulted in a diminished use of lateral retinacular releases intraoperatively, the placement of the patellar component (medial, central, lateral) remained relatively consistent throughout this study. Traditionally, the patellar button may be medialized on the host patella. This surgical technique was adopted, theoretically, to decrease the rate of lateral release and the stress of the patellar component articulation with the lateral flange of the femoral component. However, previous studies have reported a medialized component may increase patellar tilt and increased patellofemoral contact pressures with a medial position as opposed to central position of the patella [20]. Furthermore, a medial patellar position may be associated with either asymmetric patellar resection or patellar tilt, both of which may be associated with patellofemoral instability [1]. Nevertheless, patellar tilt, subluxation, and asymmetric resurfacing may still be associated with a good clinical result [25, 26]. Further study is needed to determine why a medial patellar component position was associated with patellar component failure. With respect to tibial component thickness, however, we

speculate a thicker tibial component may be associated with instability of the posterior cruciate ligament, due to a more inferior resection level, which may increase patellofemoral femoral contact stresses, especially with stair descent. Patellar failure has been associated with both excessive patellar resection [1] and increased patellar thickness (minimal patellar resection) [13, 29]. In our study, the pre-resection and postresection thicknesses were not associated with patellar component failure. Although the range of postresection patellar thickness was variable (5–20 mm), the average was 10 mm. The use of a patellar component with a large central peg has been associated with an increased risk of patellar fracture [1, 10, 19, 28]. Such a large central peg hole increases the anterior patellar strain more so than smaller peripheral holes [1]. Nevertheless, the central-pegged all-polyethylene patellar component in this study has been associated with an overall excellent survivorship. Keating et al. [18] reported on 4278 cemented TKAs with a 15-year survivorship (standard case scenario) of 92%. Failure was defined as patellar component revision and/or loosening [18]. Defining failure as revision of the patellar component resulted in a 15-year survivorship of 99% [18].

Recognizing patients with greater risk factors for patellar component failure may help determine the relative indications for both TKA and patella resurfacing. A lower risk of patellar failure may be achieved by avoiding patellar resurfacing in patients who are obese (6.3 times risk), male (1.9 times risk), with 10° or more of preoperative genu valgus (2 times risk) or 5° or more of preoperative genu varus (1.6 times risk), and greater than 100° of preoperative knee flexion (2.1 times risk). Further, the risk of patellar failure may be lowered by avoiding the use of a lateral retinacular release (3.8 times risk), medializing the patellar component (2.7 time risk), the use of a larger patellar component (1.4 times risk), and the use of a tibial component of 12-mm thickness or greater (2.7 times risk).

The failure rate of the all-polyethylene patellar component used in study was approximately 5%, with a patellar revision rate of 0.3%. If one concludes leaving the patella unresurfaced results in a patellar revision rate (secondary resurfacing) of approximately 10%, as reported by Barrack et al. [2], then all-polyethylene resurfacing certainly results in lower revision rates than not resurfacing the patella.

Acknowledgments The authors thank Philip M. Faris, MD, Kenneth Davis, MD, and Matt Brunsman, for their assistance with this study.

References

1. Ayers DC, Dennis DA, Johanson NA, Pellegrini VD Jr. Instructional course lectures, the American Academy of Orthopaedic Surgeons: common complications of total knee arthroplasty. *J Bone Joint Surg Am.* 1997;79:278–311.

2. Barrack RL, Wolfe MW, Waldman DA, Milicic M, Bertot AJ, Myers L. Resurfacing of the patella in total knee arthroplasty: a prospective, randomized, double-blind study. *J Bone Joint Surg Am.* 1997;79:1121–1131.
3. Bayley JC, Scott RD. Further observations on metal-backed patellar component failure. *Clin Orthop Relat Res.* 1988;236:82–87.
4. Berend ME, Ritter MA, Keating EM, Faris PM, Crites BM. The failure of all-polyethylene patellar components in total knee replacement. *Clin Orthop Relat Res.* 2001;388:105–111.
5. Berry DJ, Rand JA. Isolated patellar component revision of total knee arthroplasty. *Clin Orthop Relat Res.* 1193;286:110–115.
6. Bourne RB, Burnett RS. The consequences of not resurfacing the patella. *Clin Orthop Relat Res.* 2004;428:166–169.
7. Boyd AD Jr., Ewald FC, Thomas WH, Poss R, Sledge CB. Long-term complications after total knee arthroplasty with or without resurfacing of the patella. *J Bone Joint Surg Am.* 1993;75:674–681.
8. Brick GW, Scott RD. The patellofemoral component of total knee arthroplasty. *Clin Orthop Relat Res.* 1988;231:163–178.
9. Ewald FC. The Knee Society total knee arthroplasty roentgenographic evaluation and scoring system. *Clin Orthop Relat Res.* 1989;248:9–12.
10. Goldstein SA, Coale E, Weiss AP, Grossnickle M, Meller B, Matthews LS. Patellar surface strain. *J Orthop Res.* 1986;4:372–377.
11. Healy WL, Wasilewski SA, Takei R, Oberlander M. Patellofemoral complications following total knee arthroplasty. *J Arthroplasty.* 1995;10:197–201.
12. Holt GE, Dennis DA. The role of patellar resurfacing in total knee arthroplasty. *Clin Orthop Relat Res.* 2003;416:76–83.
13. Hsu HC, Luo ZP, Rand JA, An KN. Influence of patellar thickness on patellar tracking and patellofemoral contact characteristics after total knee arthroplasty. *J Arthroplasty.* 1996;11:69–80.
14. Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. *Clin Orthop Relat Res.* 1989;248:13–14.
15. Insall JN, Lachiewicz PF, Burstein AH. The posterior stabilized condylar prosthesis: a modification of the total condylar design. *J Bone Joint Surg Am.* 1984;82:1317–1323.
16. Kaplan EL, Meier P. Nonparametric estimation from incomplete observations. *J Am Stat Assoc.* 1953;53:457–481.
17. Keating EM, Haas G, Meding JB. Patella fracture after total knee replacements. *Clin Orthop Relat Res.* 2003;416:93–97.
18. Keating EM, Meding JB, Faris PM, Ritter MA. Long-term followup of nonmodular total knee replacements. *Clin Orthop Relat Res.* 2002;404:34–39.
19. Larson CM, McDowell CM, Lachiewicz PF. One-peg versus three-peg patellar component fixation in total knee arthroplasty. *Clin Orthop Relat Res.* 2001;392:94–100.
20. Laskin RS. The Genesis total knee prosthesis: a 10-year followup study. *Clin Orthop Relat Res.* 2001;388:92–102.
21. McMahon MS, Scuderi GR, Glashow JL, Scharf SC, Meltzer LP, Scott WN. Scintigraphic determination of patellar viability after excision of infrapatellar fat pad and/or lateral retinacular release in total knee arthroplasty. *Clin Orthop Relat Res.* 1990;260:10–16.
22. Ortiguera CJ, Berry DJ. Patellar fracture after total knee arthroplasty. *J Bone Joint Surg Am.* 2002;84:532–540.
23. Pakos EE, Ntzani EE, Trikalinos TA. Patellar resurfacing in total knee arthroplasty: a meta-analysis. *J Bone Joint Surg Am.* 2005;87:1438–1445.
24. Parvizi J, Rapuri VR, Saleh KJ, Kuskowski MA, Sharkey PF, Mont MA. Failure to resurface the patella during total knee arthroplasty may result in more knee pain and secondary surgery. *Clin Orthop Relat Res.* 2005;438:191–196.
25. Ranawat CS. The patello-femoral joint in total condylar knee arthroplasty: pros and cons based on five to ten year follow up observations. *Clin Orthop Relat Res.* 1986;205:93–99.
26. Rand JA. Patellar resurfacing in total knee arthroplasty. *Clin Orthop Relat Res.* 1990;260:110–117.
27. Rand JA. The patellofemoral joint in total knee arthroplasty. *J Bone Joint Surg Am.* 1994;76:612–620.
28. Rand JA, Gustilo RB. Technique of patellar resurfacing in total knee arthroplasty. *Tech Orthop.* 1988;3:57–66.
29. Ritter MA, Pierce MJ, Zhou H. Patellar complications (total knee arthroplasty). *Clin Orthop Relat Res.* 1999;367:149–157.
30. Rosenberg AG, Andriacchi TP, Barden R, Galante JO. Patellar component failure in cementless total knee arthroplasty. *Clin Orthop Relat Res.* 1988;236:106–114.
31. Scott RD, Turoff N, Ewald FC. Stress fracture of the patella following duopatellar total knee arthroplasty with patellar resurfacing. *Clin Orthop Relat Res.* 1982;170:147–151.
32. Scuderi G, Scharf SC, Meltzer LP, Scott WN. The relationship of lateral releases to patella viability in total knee arthroplasty. *J Arthroplasty.* 1987;2:209–214.
33. Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM. Why are total knee arthroplasties failing today? *Clin Orthop Relat Res.* 2002;404:7–13.
34. Stulberg SD, Stulberg BN, Hamati Y, Tsao A. Failure mechanisms of metal-backed patellar components. *Clin Orthop Relat Res.* 1988;236:88–105.
35. Windsor RE, Scuderi GR, Insall JN. Patellar fractures in total knee arthroplasty. *J Arthroplasty.* 1989;4(Suppl):S63–S67.