Arthroplasty Today 30 (2024) 101563

Contents lists available at ScienceDirect

Arthroplasty Today

journal homepage: http://www.arthroplastytoday.org/

Original Research

A Single Surgeon Experience of Selective Patellar Resurfacing During Primary Total Knee Arthroplasty

Catelyn A. Woelfle, BA, H. John Cooper, MD*

Department of Orthopedic Surgery, New York Presbyterian Hospital, Columbia University Irving Medical Center, New York, NY, USA

ARTICLE INFO

Article history:
Received 27 June 2024
Received in revised form
10 September 2024
Accepted 24 September 2024
Available online xxx

Keywords:
Total knee arthroplasty (TKA)
Revision total Knee arthroplasty
Patellar resurfacing
Reoperation
Secondary resurfacing

ABSTRACT

Background: Routine patellar resurfacing remains controversial in primary total knee arthroplasty (TKA). This study reports the experience of a high-volume arthroplasty surgeon who stopped routinely resurfacing patellae for a 3-year period.

Methods: All primary TKAs performed by a single surgeon between January 2018 and September 2022 with minimum 1-year follow-up were retrospectively reviewed. Data were analyzed between cohorts—nonresurfaced and resurfaced patellae—and between phases—universal and selective resurfacing. Outcomes included reoperation, patellar complications, and patient-related outcome measure scores.

Results: Five hundred four primary TKAs, with mean 24-month follow-up, were included. Patellar resurfacing was performed in 77% of the overall cohort, including 58% in the selective and 100% in the universal phases. Reoperation (7.6% vs 0.3%; $P < .001$) and patellar complications (8.4% vs 1.3%; $P < .001$) were higher in the nonresurfaced vs resurfaced cohort. Eight of the 9 reoperations in the nonresurfaced group were for secondary resurfacing, and all were female ($P = .017$). Mean 12-Item Short Form Health Survey Physical Health ($P = .037$) and Western Ontario and McMaster Universities Arthritis Index Pain scores ($P = .002$) were better in the resurfaced cohort. Selective resurfacing demonstrated a higher reoperation rate (3.3% vs 0.4%; $P = .022$) and worse Western Ontario and McMaster Universities Arthritis Index Pain ($P = .026$) and Knee Society Knee Functional scores ($P = .042$).

Conclusions: Cessation of routine patellar resurfacing led to inferior clinical results and an unacceptably high early reoperation rate, specifically among women. The generalizability of these findings may be limited due to surgeon-specific factors; however, we urge caution in surgeons who consider similar changes in practice.

Level of Evidence: Level III.

Introduction

The need for routine patellar resurfacing in primary total knee arthroplasty (TKA) continues to be controversial. Early studies from the 1970s showed most TKA designs had pain associated with a symptomatic patellofemoral joint [1-3]. Patellar resurfacing began in the 1980s, leading to immediate improvements in outcomes with reduced rates of anterior knee pain after surgery [4-9]. However, patellofemoral component design and quality quickly became an issue. The patella is a small surface but carries high load, greater than or equal to joint loads of the tibiofemoral joint [10,11]. Early patellofemoral prosthetic designs could not withstand these contact stresses and many had high failure rates [12-14]. With improvements in prosthetic design, these concerns regarding patellofemoral complications with patellar resurfacing have improved greatly over time [15,16].

In current practice, there is an abundance of literature surrounding the debate to resurface or to *not* resurface, and the risks and benefits of both approaches have been studied extensively. There is research supporting routine patellar resurfacing during primary TKA due to the risk of postoperative anterior knee pain when the patella is *not* resurfaced [6,17,18] as well as for lower rates of reoperation for secondary patellar resurfacing [19-23]. As one of

* Corresponding author. Department of Orthopedic Surgery, Columbia University Medical Center, 622 West 168th Street, PH 1149, New York, NY 10032, USA. Tel.: +1 914 787 2468.
E-mail address: hjc2008@columbia.edu

https://doi.org/10.1016/j.artd.2024.101563

many examples, Pakos et al. found that revision rates decreased by 4.6% and anterior knee pain decreased by 13.8% [24]. On the other hand, patellar resurfacing has been found to be an independent risk factor for postoperative patellar complications such as patellar maltracking, instability, fracture, component loosening, polyethene wear, soft-tissue impingement, and extensor mechanism disruption. [14,25-28]. Of these, patellar fracture is the most common complication studied and concern after patellar resurfacing [29-31].

Although there is research that *supports* universal resurfacing due to the benefit of decreased rate of anterior knee pain and reoperation, as well as research that *goes against* universal resurfacing due to the associated complications, many long-term studies report no clinical difference [32-34]. Routine patellar resurfacing has long been the predominant practice in the United States, although there has been a gradual annual decrease in patella resurfacing in this country from 96% in 2012 to 89% in 2022 [35]. Nevertheless, prevalence of resurfacing among TKA cases in many countries outside the United States are substantially lower, with the Australian Orthopaedic Association National Joint Replacement Registry reporting an 81% increase in the prevalence of resurfacing from 2007 to 2021, in which it was highest at 76% [35]. The need for routine patellar resurfacing continues to be debated without resolution, and due to the ongoing discussions many U.S. surgeons who routinely resurface have considered a change in practice to nonresurfacing or selective resurfacing, especially as studies have shown nonresurfacing may be a cost-effective strategy [36-38].

The purpose of the current study is to report the experience of a single surgeon who, for years, practiced universal patellar resurfacing during primary TKA, before deciding to adopt a strategy for selective resurfacing for a 3-year period, and then returned to universal resurfacing. The study reports on reoperation rates, patellar complications, and patient-reported outcome measures (PROMs).

Material and methods

Patient population

A retrospective consecutive review of all primary TKAs performed by a single fellowship-trained arthroplasty surgeon over a 5-year period, from January 2018 to September 2022, was performed. At the onset of the study, this surgeon had been in practice for more than 5 years and had established a mature high-volume arthroplasty practice.

The study period was divided into 3 phases based on surgical technique chosen for patellar resurfacing. The first (phase I), from January 2018 through March 2019, consisted of universal patellar resurfacing, which was consistent with the surgeon's entire practice prior to the study period. In April 2019, based a detailed review of the current literature at that time regarding management of the patella during primary TKA, [39] the decision was made to selectively resurface only patients with grade IV eburnated bone (phase II). In April 2022, the decision was made to return to universal patellar resurfacing based on a dissatisfaction with clinical outcomes (phase III).

Patient demographics, surgical data, and all postoperative complications were collected from retrospective chart review. Patients were excluded from the analysis if they failed to meet a minimum 1-year clinical follow-up. Approval from our institutional review board (IRB-AAAV1004) was obtained for this study prior to any data collection or analysis.

Surgical technique

All cases utilized a medial parapatellar approach. Surgical technique for patellar resurfacing was performed as described in Held et al [39]. Peripheral osteophytes were initially removed with a rongeur. The patella was then everted, and the insertion points of the quadriceps and patellar tendons were visualized. Planned resection was determined by assessing patellar deformity and measuring native thickness using a caliper. A free-hand resection with an oscillating bone saw was then performed using haptic feedback. Patellar denervation at a depth of 2-3 mm was performed using circumferential electrocautery, and a partial lateral facetectomy was performed to remove 3-5 mm of the lateral facet that would extend beyond the margin of the patellar button. A template was used to determine sizing and positioning of the patellar component. All resurfaced patellae included in the study had round, 3-button, cemented, onlay polyethylene implants.

For nonresurfaced patellae, Held et al. [39] provided evidence supporting the benefits of circumferential denervation to reduce the likelihood of postoperative anterior knee pain and partial lateral facetectomy to reduce the likelihood of postoperative osteophyte formation to allow for secondary resurfacing. These techniques were applied to all nonresurfaced patellae.

In all cases, surgical protocol evaluated patellar tracking with trial components in place. In rare cases where patellar tracking was not concentric within the trochlear groove of the trial implant using a "no thumb" test, component rotation of the tibial and femoral trials was confirmed, and patellar maltracking was addressed with an inside-out lateral release.

Primary outcome

The primary outcome was reoperation for patellofemoral complications, including anterior knee pain, patellar loosening, extensor mechanism disruption, or patellar instability. Indications for reoperation are described as follows. The indication to reoperate for secondary patellar resurfacing in the nonresurfaced cohort was severe, activity-limiting anterior knee pain that was worse with flexion activities such as stairs in the setting of progressive patellar femoral osteoarthritis on serial radiographs. Patients were indicated when they failed to improve with activity modification and physical therapy focused on quadriceps strengthening. The indication to reoperate for extensor mechanism disruption was extensor lag greater than 20 degrees or lateral patellar instability.

Secondary outcomes

Secondary outcomes were (1) any patellofemoral complication, regardless of whether it required reoperation or was managed nonoperatively (eg, a patella fracture without loss of extensor mechanism) and (2) PROMs at 3 months and 12 months postoperatively. These PROMs included the 12-Item Short Form Health Survey (SF-12) Physical Health, SF-12 Mental Health, the Western Ontario and McMaster Universities Arthritis Index (WOMAC) Pain, WOMAC Stiffness, WOMAC Stiffness scores, and the Knee Society Knee Functional Score (KSKFS).

SF-12 Physical and Mental Health measures are both scored on 0-100 scales, with higher scores indicating better physical and mental functioning [40]. The KSKFS is also scored from 0-100, with better scores indicating better knee function [41]. There are different ways WOMAC has been measured, however, the current study uses the 0-96 scale derived from a 0-4 Likert Scale, which is the most common way reported in literature [42,43]. A total WOMAC score is the sum of the 3 subscales—Pain (0-20), Stiffness (0-8), and Function (0-68)—with a lower score indicating better symptoms. For the purposes of this study, the subscales were analyzed individually.

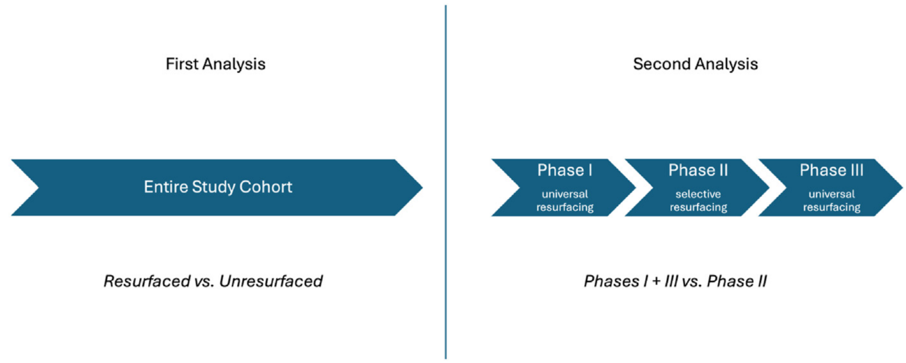

Figure 1. Statistical analysis schema.

Statistical analysis

The overall population was analyzed in 2 different ways (Fig. 1). In the first analysis, the overall sample across the entire study period was divided into 2 subgroups: patellae that *were* and were *not* resurfaced. Primary and secondary outcomes were compared between these 2 subgroups. In the second analysis, primary and secondary outcomes were evaluated between the periods of universal resurfacing (phases I and III) vs selective resurfacing (phase II).

Chi-squared tests for gender and independent samples *t* tests for age and body mass index (BMI) were conducted to determine if patient demographics were significant between the nonresurfaced and resurfaced cohorts and between the periods of universal resurfacing and period of selective resurfacing. Additional chi-squared tests were run to test if the frequency of complications or revisions were significantly different between primary TKAs with vs without patella arthroplasty and between periods of universal resurfacing and period of selective resurfacing. Another chi-squared test was run to determine if the rate of revision for secondary patellar resurfacing was significantly different between genders. An independent samples *t* test was also conducted to determine if there was a significant difference between the mean age of patients who required revision TKA vs who did not. Independent samples *t* tests were run to determine if PROM scores were different at 12 months postop between the nonresurfaced and resurfaced cohorts and between the periods of universal resurfacing and the period of selective resurfacing.

Results

A total of 605 primary TKAs were performed within the study period and 504 (83.3%) met the inclusion criteria of 1-year follow-up for analysis. The remainder were excluded as they were lost to follow-up before 1 year. Of the patients excluded, there were 13 from phase I, 62 from phase II, and 24 from phase III. Mean follow-up was 23.6 months, ranging from 12.0 months to 66.9 months.

Across the entire study period, patellar resurfacing was performed on 77% of the TKAs, while 23% were left unresurfaced (Table 1). The population demographics consisted of 35% male and 65% female. Gender was not statistically significant between the nonresurfaced (40% male vs 60% female) and resurfaced (34% male and 66% female) cohorts ($X^2 = 1.50$; df = 1; $P = .221$). Mean patient age was 67.3 years (range, 34-86 years) and was not significant between the nonresurfaced (mean = 67.5 years; range, 41-85) and resurfaced (mean = 66.8 years; range, 34-86) cohorts; t(502) = 0.495, $P = .310$. Additionally, the BMI was 33.6 kg/m^2 and was not significant between the nonresurfaced (mean = 33.2 kg/m^2; range, 20-39) and resurfaced (mean = 33.8 kg/m^2; range 19-41) cohorts; t(502) = 1.19; $P = .235$ (Table 1).

Regarding the 3 phases, there were 170 patients in phase I, 273 patients in phase II, and 61 patients in phase III (Table 1). The prevalence of patellar resurfacing during the periods of universal resurfacing (phase I and phase III) was 100%, compared to 58% during the period of selective resurfacing (phase II); $X^2 = 126$, df = 1, $P < .001$ (Fig. 2). Patient demographics between the periods of universal resurfacing and the period of selective resurfacing, gender (64% vs 66% female; $X^2 = 0.12$, df = 1, $P = .725$) , age (67.2 vs

Table 1
Patient demographics, patellar complications, and revisions by analysis.

Variable	*N*	First analysis by cohort			Second analysis by phase		
		Resurfaced	Not resurfaced	*P* value	Universal resurfacing (phases I and III)	Selective resurfacing (phase II)	*P* value
N (%)	504	386 (77)	118 (23)	—	231 (46)	273 (54)	—
Gender, n (%)							
Male	177 (35)	130 (34)	47 (40)	.221	83 (36)	94 (34)	.725
Female	327 (65)	256 (66)	71 (60)		148 (64)	179 (66)	
Age, mean (y)	67.3	66.8	67.5	.310	67.2	68.1	.210
BMI, mean (kg/m^2)	33.6	33.8	33.2	.235	34.0	33.6	.264
Patella complication, n (%)							
Yes	15 (3.0)	5 (1.3)	10 (8.4)	<.001	5 (2.2)	10 (3.7)	.324
No	489 (97)	381 (99)	108 (92)		226 (98)	263 (96)	
Revision, n (%)							
Yes	10 (2.0)	1 (0.3)	9 (7.6)	<.001	1 (0.4)	9 (3.3)	.022
No	494 (98)	385 (>99)	109 (92)		230 (>99)	264 (97)	

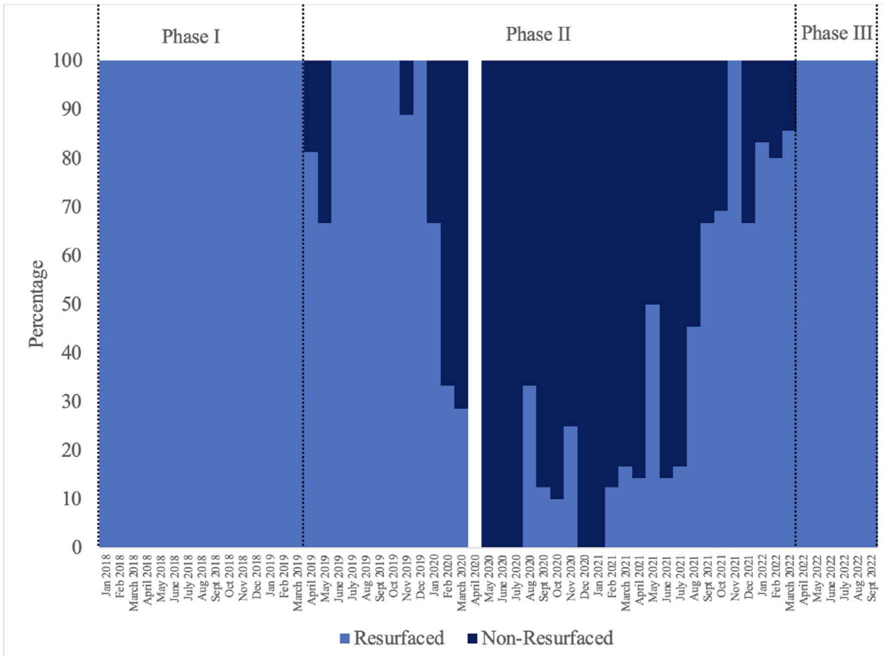

Figure 2. Prevalence of patellofemoral joint resurfacing across the study period by month. Universal routine resurfacing occurred in phase I (n = 170; January 2018-March 2019) and phase III (n = 61; April 2022-September 2022) with a 100% prevalence of resurfacing within a total of 21 months. Selective resurfacing included phase II (n = 273; April 2019-March 2022) with a 58% prevalence of resurfacing within a total of 36 months. Phases are separated by dashed lines. Note: No total knee arthroplasty cases were performed in April 2020 due to COVID-19.

68.1 years; ranges 34-86 vs 39-86; t[502] = 1.26, $P = .210$), and BMI (34.0 vs 33.6 kg/m^2; ranges 19- 41 vs 19-40; t[502] = 1.12, $P = .264$) did not differ significantly between the universal and selective resurfacing groups (Table 1).

Primary outcome—reoperation

Ten patients (2.0% of the entire sample) required reoperation for patellofemoral complications. Of the patients revised, 9 were in the nonresurfaced cohort. Eight of those 9 patients were indicated for anterior knee pain with progressive patellar osteoarthrosis and elected for secondary resurfacing after failing appropriate nonoperative treatment. The last revised patient in the nonresurfaced cohort was indicated for lateral patellar instability due to unrecognized early arthrotomy dehiscence. The patella was palpable and hypermobile on exam and tilted laterally. This patient also exhibited a 5-degree extensor lag. An arthrotomy repair, medial patellofemoral ligament reconstruction, and secondary resurfacing were performed during the revision. There was only 1 patient in the resurfaced cohort who was revised for patellar fracture. This patient was first treated nonoperatively initially treated nonoperatively with immobilization which led to successful bony healing but then later developed lateral patellar instability, subluxation, and eventual lateral patellar dislocation. This patient continued to feel unstable and fall, so revision TKA was required for patellar realignment with a lateral release and medial patellofemoral ligament reconstruction, which was successful in resolving pain and regaining appropriate patellofemoral tracking within the trochlear groove (Table 2).

Reoperation due to a patellar complication was required for 7.6% of patients who *were not* resurfaced vs 0.3% of all patients who *were* resurfaced during their primary TKA ($X^2 = 25.2$; df = 1; $P < .001$) (Table 1). The reoperation rate was also significantly higher during the period of selective resurfacing (phase II; 3.3%) compared to the periods of universal resurfacing (phase I and phase III; 0.4%) ($X^2 = 5.28$; $P = .022$) (Table 1).

Of patients who were not originally resurfaced, 8 patients (6.8%) elected for secondary resurfacing due to severe anterior knee pain that was did not improve with conservative treatment. Secondary resurfacing was performed at a mean of 20.4 months (range, 12-26 months). All 8 patients who underwent reoperation for secondary resurfacing were female, and a chi-squared test revealed a significant difference between genders for secondary resurfacing ($X^2 = 5.68$; df = 1; $P = .017$) (Table 3). There was no difference in age between patients who were indicated for secondary resurfacing (mean = 67.1 years; range, 60-76) and those who were not (mean = 67.5 years; range, 41-85); t(116) = 0.342; $P = .773$. There was also no difference in BMI between secondary resurfacing patients (mean = 34.9 kg/m^2; range, 23-39) vs nonresurfaced patients who did not have a secondary resurfacing (mean = 33.1 kg/m^2; range, 20-39); t(116) = 1.37; $P = .174$ (Table 3).

All 8 patients who underwent secondary resurfacing noted marked improvements in anterior knee pain during postoperative visits. One patient developed a superficial suture abscess at the distal pole of her incision 2 weeks postoperatively, which resolved with prophylactic antibiotics, and continued to progress as

Table 2
Types of patellar complications.

Complication	*N*	Resurfaced	Not resurfaced
Patella fracture	6	5	1
Patellar instability	1	0	1
Anterior knee pain with progressive patellar OA	8	0	8
Total	15	5	10
Revision, n (%)			
Yes	10 (67)	1 (20)	9 (90)
No	5 (33)	4 (80)	1 (10)

OA, osteoarthritis.

Table 3
Rate of secondary patellar resurfacing by demographics.

Demographic	*N*	Secondary patellar resurfacing due to pain	No secondary resurfacing	*P* value
N (%)	118	8 (6.8)	110 (93)	-
Gender, n (%)				
Male	47 (40)	0 (0)	47 (43)	.017
Female	71 (60)	8 (100)	63 (57)	
Age, mean (y)	67.5	67.1	67.5	.733
BMI, mean (kg/m^2)	33.2	34.9	33.1	.174

expected. Another patient required a debridement, antibiotics, and implant retention (DAIR) procedure for an acute postoperative periprosthetic joint infection 6 weeks following revision for secondary resurfacing. The infection was successfully treated, and her anterior knee pain was almost completely resolved at 15 months following DAIR.

Secondary outcome—patellofemoral complications

Postoperative patellar complications were identified in 15 patients total (3.0% of the overall sample), with 5 patients whose patella *was* resurfaced during primary TKA and 10 patients whose patella was *not* resurfaced during primary TKA (Table 1). Of all patients with a postoperative patellofemoral complication, 10 (67%) required reoperation, as described above, while 5 (33%) were able to be managed nonoperatively. When examining all complications together regardless of need for reoperation, there were significantly more patellofemoral complications in the nonresurfaced (8.4%) vs resurfaced (1.3%) cohort (X^2 = 16.1; df = 1; P < .001) (Table 1). However, there was no significant difference in patellar complication rates between the phases of universal resurfacing (2.2%) and the phase of selective resurfacing (3.7%) (X^2 = 0.97; df = 1; P = .324 (Table 1).

Regarding specific patellofemoral complications, no patellar loosening was identified in any patients in the resurfaced cohort. Six patients—5 resurfaced and one nonresurfaced—suffered a postoperative periprosthetic patellar fracture (Table 2). None had complete disruption of the extensor mechanism, so all were treated with initial attempts at nonoperative management with immobilization. Conservative treatment with bracing followed by progressive return of range of motion was successful in 5 of these 6 patients with patellar fractures. The sixth patient, who was in the resurfacing cohort, was initially treated nonoperatively with immobilization, but then required revision as described previously.

Secondary outcome—patient reported outcome measures

SF-12 Physical Health scores were significantly lower at 1 year postop with the nonresurfaced (mean = 44.1; range, 15.0-59.7) cohort compared to the resurfaced (mean = 45.9; range, 15.5-61.4) cohort; t(502) = 2.09, P = .037 (Table 4). Similarly, WOMAC Pain scores showed were significantly lower in the nonresurfaced (mean = 4.3; range, 0-20) compared to the resurfaced cohort (mean = 3.1; range, 0-20) patients; t(502) = 3.07, P = .002 (Table 4). PROM scores did not differ significantly in nonresurfaced vs resurfaced patients in the following measures: SF-12 Mental Health (mean = 46.8 vs 46.2; range, 29.1-58.0 vs 14.0-65.7; t[502] = 0.81; P = .416), WOMAC Stiffness (mean = 2.6 vs 2.3; range, 0-8 vs 0-8; t[502] = 1.56; P = .119), WOMAC Function (mean = 15.5 vs 13.3; range, 0-67 vs 0- 66; t[502] = 1.43; P = .154), or KSKFS (mean = 72.1 vs 71.5; range, 5-100 vs 10-100 ; t[502] = 0.24; P = .811 (Table 4).

Regarding 12 months postoperative PROM scores by phases of resurfacing, WOMAC Pain scores also differed significantly between the universal and (2.6, range 0-20) and selective (3.2, range 0-20) phases; t(502) = 2.24; P = .026 (Table 5). Additionally, KSKFS scores differed significantly between universal (73.2, range 10-100) and selective (70.1, range 5-100) phases; t(502) = 2.03; P = .042 (Table 5). PROM scores did not differ between the universal and selective cohorts in the following measures: SF-12 Physical Health (46.1 vs 45.1; ranges 19.1-61.4 vs 15.0-59.7; t[502] = 1.40; P = .163), SF-12 Mental Health (45.9 vs 46.8; t[502] = 1.26; 29.1-64.9 vs 14.0-65.7 P = .209), WOMAC Stiffness (2.3 vs 2.4; ranges 0-to 8 vs 0-8; t[502] = 0.56; P = .576), and WOMAC Function (13.4 vs 14.1; ranges, 0-67 vs 0 to 67; t[502] = 0.60; P = .547) (Table 5).

Discussion

Routine patellar resurfacing during primary TKA continues to be controversial. Research has shown it is a safe and reproducible

Table 4
Average patient-related outcome measure (PROM) scores.

PROM	Prep-op	3 mo	12 mo	*P* value at 12 mo
SF-12 Physical Health (0-100)				
Resurfaced	38.3	43.4	45.9	.037
Not resurfaced	37.9	43.2	44.1	
SF-12 Mental Health (0-100)				
Resurfaced	48.9	47.7	46.2	.416
Not resurfaced	48.6	48.2	46.8	
WOMAC Pain (0-20)				
Resurfaced	11.3	4.9	3.1	.002
Not resurfaced	11.6	5.5	4.3	
WOMAC Stiffness (0-8)				
Resurfaced	4.6	3.3	2.3	.119
Not resurfaced	4.8	3.2	2.6	
WOMAC Function (0-68)				
Resurfaced	38.4	19.1	13.3	.154
Not resurfaced	38.3	20.7	15.5	
KSKFS (0-100)				
Resurfaced	50.2	63.8	71.5	.811
Not resurfaced	49.0	61.1	72.1	

Table 5
Patient-related outcome measure (PROM) scores at 12 mo by phases of resurfacing.

PROM	12 mo	*P* value at 12 mo
SF-12 Physical Health (0-100)		
Universal	46.1	.163
Selective	45.1	
SF-12 Mental Health (0-100)		
Universal	45.9	.209
Selective	46.8	
WOMAC Pain (0-20)		
Universal	2.6	.026
Selective	3.2	
WOMAC Stiffness (0-8)		
Universal	2.3	.576
Selective	2.4	
WOMAC Function (0-68)		
Universal	13.4	.547
Selective	14.1	
KSKFS (0-100)		
Universal	73.2	.042
Selective	70.1	

procedure, and improvements in resurfacing techniques have shown to improve outcomes [39,44]. Furthermore, advancements in patellar prothesis design have largely assuaged earlier concerns of premature component failure [34,45-47]. However, literature has not been able to clarify if the benefits of resurfacing outweigh the risks for revision and/or patellar complications following resurfacing, and there is an early trend in the United States where surgeons who previously practiced universal resurfacing are changing their practice to resurface less. This current study revealed that, in the context of a surgeon switching from universal resurfacing to selective resurfacing, patients who underwent resurfacing were more likely to fare better with significantly lower risk of early reoperation, significantly lower rates of patellar complications, and improved SF-12 Physical Health and WOMAC Pain scores at 1 year postoperatively. Furthermore, in periods of routine universal resurfacing, reoperation rates due to patellar complications were lower and WOMAC Pain and KSKFS scores were improved at 1 year postop, compared to that of a period which the surgeon opted for selective resurfacing based on severity of the degeneration in the patellofemoral joint.

The findings from this study are consistent with many prior studies in that routine patellar resurfacing demonstrates a lower rate of reoperation [19-24]. The National Institute for Health Care Excellence conducted an evidence review in 2020 that included 28 studies and over 25,000 primary TKAs. They revealed no clinical benefit in resurfaced vs nonresurfaced patellae in most PROMs; however, they identified a higher risk of revision TKA for secondary resurfacing due to anterior knee pain presenting in patients who were not resurfaced primarily [36]. The authors discussed about the decision making involved in patellar resurfacing. The authors report that only 35%-40% of primary TKAs analyzed in their review include resurfacing and was based on surgeon's discretion [36], similar to the selective resurfacing phase in our study. Our results echo the findings of our study, as we revealed significantly higher reoperation rates both in the nonresurfaced cohort *and* overall during the phase of selective resurfacing.

The findings from this study are also consistent with much of the existing literature in that it demonstrated that routine patellar resurfacing is also associated with some degree of improved PROMs. PROMs are increasingly being implemented in different areas in health care, with one of the major areas being elective surgeries. They aim to give a clear assessment of symptoms on both sides without misinterpretation and can be used to optimize care [48,49]. PROMs are not only used to evaluate and improve patient-related care but could be a good resource for health-care funding and general transparency around surgical and clinical outcomes [48,49]. Some studies find no difference in PROMs between resurfacing vs *not* resurfacing [50,51], while others do [36]. Robertsson et al. reported that, in a sample of over 27,000 primary TKAs, resurfaced patients are generally more satisfied with TKA outcomes [52], which is supported by the results of the current study which identified an overarching clinical difference with patellar resurfacing. Improved SF-12 Physical Health and WOMAC Pain scores at the 1 year postoperative period were seen in patients who had patellar resurfacing vs whose patellae were retained during primary TKA. The observed mean difference in SF-12 Physical Health scores between these 2 cohorts (1.8) was equal to the minimal clinically important difference (MCID) identified for patients following TKA [53]. While the observed mean difference in WOMAC Pain scores between the cohorts (1.2) was statistically significant, it was under the MCID threshold (11) identified in TKA [54]. Additionally, improved WOMAC Pain and KSKFS scores were also found in phases of routine universal vs selective resurfacing. These observed mean differences, 1.5 and 3 respectively, were also smaller than the reported MCIDs for TKA patients, 11 and 6 respectively [54,55]. While some of these statistically significant differences were under their respective MCIDs, the authors still believe the PROM results potentially hold meaning due to the inconsistent definitions surrounding and measuring MCID after TKA.

The current study revealed a 7.6% revision rate due to patellar complications in the unsurfaced cohort and 0.3% in the resurfaced cohort. These findings are comparable to prior research, including a 2018 meta-analysis of 22 studies which showed a 6.9% unsurfaced vs 1.0% resurfaced reoperation rates for patella complications [20]. Likewise, our study found a 6.8% rate of secondary resurfacing alone for anterior knee pain, which was also comparable to prior research. Parvizi et al., a 14 study-meta-analysis, revealed a secondary resurfacing rate of 8.7% [23].

The success of secondary resurfacings has shown to be less effective than doing it during primary TKA [56,57]. Van Jonbergen et al. found only 64% of patients were happy with secondary resurfacing [58]. However, our results compare favorably with 100% of patients satisfied with the decision for secondary resurfacing, even the patient who required a DAIR for an acute periprosthetic joint infection resulting from the secondary resurfacing procedure. This universal improvement with secondary resurfacing is a strong indicator that the nonresurfaced patella was the pain generator in this series and strengthens the decision for universal resurfacing in the age-old debate regarding whether or not to routinely resurface in all primary TKA cases. While anterior knee pain can occur with or without resurfacing [59], the need for secondary resurfacing is still common once everything is ruled out [58,60,61]. Secondary resurfacing has also shown better outcomes when the revision is sooner after primary TKA vs later but overall was still not successful as those who got had the resurfacing during primary TKA [62]. Thus, the risk of *not* resurfacing during primary TKA could be seen as more meaningful and preventative if the solution to the complication is less likely to get patients to the same clinical level as those who were resurfaced primarily. With the increased risk of revision due to secondary resurfacing, cost analyses have shown resurfacing the patella during primary TKA as cost-effective in the long-term [36-38]. While the individual patella prosthesis itself adds an additional cost to the primary procedure, revision operations are expensive and the additive cost of secondary resurfacings at the rates seen today outweighs the small added cost of individual patellar prosthesis.

The decision to selectively resurface has been guided in part by literature but ultimately is left up to the subjective discretion of the surgeon. Outerbridge grade IV patellae are more predicative and have 21.5 times greater revision rates for secondary resurfacing due to postoperative anterior knee pain when compared to grades I, II, and III [63], which has been the threshold for the patellae that are selected to be resurfaced. However, one surgeon's discretion of grade IV is on a case-to-case basis and cannot be exactly replicated between surgeons. The 2020 review from the National Institute for Health Care Excellence revealed a 35%-40% prevalence of selective resurfacing [36], whereas the current study showed a 58% prevalence of resurfacing during the selective phase and might have yielded further worsened outcomes had fewer patellae been resurfaced. Furthermore, the surgeon's opinion on resurfacing literature and overall experience with resurfacing affects this decision as well [36]. Some surgeons gravitate to resurface more to reduce the risk of revision, whereas others selectively follow some of the long-term research which demonstrates no clinical differences between resurfacing and not [32-34] and gravitate toward not resurfacing to prevent patellar complications, and save time, money, and health-care resources during the primary operation [39]. Thus, studies like these are vital in continuing the debate over resurfacing so more congruent conclusions can be drawn.

It is also worth discussing the risk of patellar fracture associated with patellar resurfacing. Some studies report low fracture rates, as low as under 1% [29], after patellar resurfacing, while others found higher fracture rates, such as 9% [30], and many associate this complication to the resurfacing [31]. The suggested reasoning for fracture involves the increased strain on the native patella which has decreased in thickness after patellar resurfacing [64]. Additionally, some research has identified a causal relationship between fracture and the lateral release technique during TKA [65]. Nondisplaced fractures are commonly treated nonoperatively through knee immobilization and radiographic monitoring, whereas displaced fractures are risk factors for further complications such as extensor mechanism disruption and patellar instability which require operative treatments [66,67]. Interestingly, while our patellar fracture rate was low (1.2%), we found fractures in both resurfaced and nonresurfaced patellae. All but one of the fractures was able to be managed nonoperatively.

Interestingly, all patients who underwent secondary resurfacing (8) were female in the current study. Scheuer et al. [68] also produced results suggesting there may be a greater risk of anterior knee pain leading to secondary resurfacing in females following primary TKA without resurfacing. While there is not much prior research supporting female gender as a risk factor, Robertsson et al. reported that females are generally less satisfied with TKA outcomes [52]. Thus, the authors suggest that gender may play a role in postsurgical anterior knee pain in nonresurfaced patients and should be taken into consideration when deciding on whether to resurface or not.

There are several strengths to the current study. Our findings reinforce the predominant opinion that patellar resurfacing during primary TKA is beneficial to improve outcomes and reduce risk of reoperation for secondary resurfacing [39]. Likewise, the secondary resurfacing improved anterior knee pain in all patients who underwent this revision operation, which contributes to the argument for universal resurfacing in the age-old debate regarding whether or not to routinely resurface. A comparative trial of both universal resurfacing phases *and* selective patellar resurfacing phase by a single surgeon allows for an objective trial of both techniques. While common patellar complications that have identified resurfacing as a risk factor in previous literature [14,25-31] were found in the current study, the frequency of both overall patellar complications and revisions due to those complications were significantly higher in the nonresurfaced cohort. These findings support previous research that also find the benefits outweigh the risks for patellar resurfacing [6,17-24]. Furthermore, the 6 PROMs used have high validity and are commonly seen in literature measuring clinical outcomes in TKA. Thus, the significant differences in the SF-12 Physical Health, WOMAC Pain, and KSKFS scales identified in this study may be generalizable and reveal new outlooks on clinical considerations.

The authors acknowledge this study's limitations. First, preoperative radiographic interpretation of the severity of patellofemoral osteoarthritis was not included and may have altered the results if the cohorts had different degrees of patellar arthritis. Additionally, while the average follow-up was almost 2 years postop, the PROMs used were only available at 1 year postop consistently for all patients included in the analysis due to incomplete 2-year data, as it is not routinely collected at our institution. This study would be further strengthened by an analysis of a longer follow-up period. While most secondary resurfacing occurs in the early years following primary TKA, it is likely still prevalent beyond 2 years postop. Additionally, this is a single-surgeon series and surgical variables inherent to this surgeon's primary TKA technique and considerable subjectivity in judging grade IV eburnated bone may limit generalizability to other surgeons. Furthermore, anterior knee pain following TKA can be multifactorial and the decision for a secondary resurfacing is often left to surgeon discretion. The nature of individualized judgments regarding postoperative anterior knee pain further limits the study's generalizability.

Conclusions

When an experienced, high-volume arthroplasty surgeon that had previously universally resurfaced patellae during primary TKA undertook a multiyear trial of selective patellar resurfacing, patients experienced inferior clinical results and an unacceptably high reoperation rate within 2 years following primary TKA, specifically among women. The idea that selective resurfacing would lead to similar clinical outcomes as universal resurfacing was not borne out during this transition, leading to disappointing clinical results and a reversion back to universal resurfacing. Furthermore, secondary resurfacing improved anterior knee pain in all patients who underwent this revision operation, strengthening the surgeon's justification for universal resurfacing. However, the discussed limitations of the study design may restrict the generalizability of this study. The reasons for these findings are not clear from this study, and may be related to surgeon-specific factors, but we would urge caution in high-volume surgeons who are considering a similar change in practice from universal resurfacing to selective resurfacing. Future research should continue to study long-term surgical and clinical outcomes of patellar resurfacing to allow for greater unanimity in the literature.

Conflicts of interest

C.A. Woelfle is a Polaris consultant; H.J. Cooper serves in the 3M speakers bureau, is a DePuy, 3M, Zimmer-Biomet, Canary, and Polaris consultant, receives stock or stock options from Polaris and research support from Smith & Nephew, is a *Journal of Bone and Joint Surgery* AM, and is a American Academy of Orthopaedic Surgeons, Eastern Orthopaedic Association Board member.

For full disclosure statements refer to https://doi.org/10.1016/j.artd.2024.101563.

CRediT authorship contribution statement

Catelyn A. Woelfle: Writing – review & editing, Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **H. John Cooper:** Writing – review & editing, Visualization, Project administration, Methodology, Investigation, Conceptualization.

References

[1] Insall JN, Ranawat CS, Aglietti P, Shine J. A comparison of four models of total knee-replacement prostheses. J Bone Joint Surg Am 1976;58:754–65.
[2] Mochizuki RM, Schurman DJ. Patellar complications following total knee arthroplasty. J Bone Joint Surg Am 1979;61:879–83.
[3] Ranawat CS, Insall J, Shine J. Duo-condylar knee arthroplasty: hospital for special surgery design. Clin Orthop Relat Res 1976:76–82.
[4] Aglietti P, Insall JN, Walker PS, Trent P. A new patella prosthesis. Design and application. Clin Orthop Relat Res 1975:175–87.
[5] Insall J, Tria AJ, Scott WN. The total condylar knee prosthesis: the first 5 years. Clin Orthop Relat Res 1979:68–77.

[6] Ranawat CS. The patellofemoral joint in total condylar knee arthroplasty. Pros and cons based on five- to ten-year follow-up observations. Clin Orthop Relat Res 1986:93–9.
[7] Freeman M, Todd R, Bamert P, Day W. ICLH arthroplasty of the knee: 1968–1977. J Bone Joint Surg Br 1978;60-B:339–44. https://doi.org/10.1302/0301-620X.60B3.681410.
[8] Schindler OS. The controversy of patellar resurfacing in total knee arthroplasty: ibisne in medio tutissimus? Knee Surg Sports Traumatol Arthrosc 2012;20:1227–44. https://doi.org/10.1007/s00167-012-1985-7.
[9] Nizard RS, Biau D, Porcher R, Ravaud P, Bizot P, Hannouche D, et al. A meta-analysis of patellar replacement in total knee arthroplasty. Clin Orthop Relat Res 2005:196–203. https://doi.org/10.1097/01.blo.0000150348.17123.7f.
[10] Matthews LS, Sonstegard DA, Henke JA. Load bearing characteristics of the patello-femoral joint. Acta Orthop Scand 1977;48:511–6. https://doi.org/10.3109/17453677708989740.
[11] Schindler OS. Basic kinematics and biomechanics of the patellofemoral joint part 2: the patella in total knee arthroplasty. Acta Orthop Belg 2012;78:11–29.
[12] Bayley JC, Scott RD, Ewald FC, Holmes Jr GB. Failure of the metal-backed patellar component after total knee replacement. J Bone Joint Surg Am 1988;70:668–74.
[13] Hsu HP, Walker PS. Wear and deformation of patellar components in total knee arthroplasty. Clin Orthop Relat Res 1989:260–5.
[14] Lombardi AV Jr, Engh GA, Volz RG, Albrigo JL, Brainard BJ. Fracture/dissociation of the polyethylene in metal-backed patellar components in total knee arthroplasty. J Bone Joint Surg Am 1988;70:675–9.
[15] Collier JP, Sperling DK, Currier JH, Sutula LC, Saum KA, Mayor MB. Impact of gamma sterilization on clinical performance of polyethylene in the knee. J Arthroplasty 1996;11:377–89. https://doi.org/10.1016/s0883-5403(96)80026-x.
[16] Wilhelm SK, Henrichsen JL, Siljander M, Moore D, Karadsheh M. Polyethylene in total knee arthroplasty: where are we now? J Orthop Surg 2018;26:2309499018808356. https://doi.org/10.1177/2309499018808356.
[17] Waters TS, Bentley G. Patellar resurfacing in total knee arthroplasty: a prospective, randomized study. J Bone Joint Surg Am 2003;85:212–7.
[18] Maney AJ, Koh CK, Christopher M, Young SW. Usually, selectively, or rarely resurfacing the patella during primary total knee arthroplasty: determining the best strategy. J Bone Joint Surg Am 2019;101:412–20. https://doi.org/10.2106/JBJS.18.00389.
[19] Hunt LP, Matharu GS, Blom AW, Howard PW, Wilkinson JM, Whitehouse MR. Patellar resurfacing during primary total knee replacement is associated with a lower risk of revision surgery. Bone Joint J 2021;103-B:864–71. https://doi.org/10.1302/0301-620X.103B5.BJJ-2020-0598.R2.
[20] Longo UG, Ciuffreda M, Mannering N, D'Andrea V, Cimmino M, Denaro V. Patellar resurfacing in total knee arthroplasty: systematic review and meta-analysis. J Arthroplasty 2018;33:620–32. https://doi.org/10.1016/j.arth.2017.08.041.
[21] Pilling RW, Moulder E, Allgar V, Messner J, Sun Z, Mohsen A. Patellar resurfacing in primary total knee replacement: a meta-analysis. J Bone Joint Surg Am 2012;94:2270–8. https://doi.org/10.2106/JBJS.K.01257.
[22] Li S, Chen Y, Su W, Zhao J, He S, Luo X. Systematic review of patellar resurfacing in total knee arthroplasty. Int Orthop 2011;35:305–16. https://doi.org/10.1007/s00264-010-1109-2.
[23] 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;438:191–6. https://doi.org/10.1097/01.blo.0000166903.69075.8d.
[24] Pakos EE, Ntzani EE, Trikalinos TA. Patellar resurfacing in total knee arthroplasty. A meta-analysis. J Bone Joint Surg Am 2005;87:1438–45. https://doi.org/10.2106/JBJS.D.02422.
[25] Schiavone Panni A, Cerciello S, Del Regno C, Felici A, Vasso M. Patellar resurfacing complications in total knee arthroplasty. Int Orthop 2014;38:313–7. https://doi.org/10.1007/s00264-013-2244-3.
[26] 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;75:674–81. https://doi.org/10.2106/00004623-199305000-00006.
[27] Wright J, Ewald FC, Walker PS, Thomas WH, Poss R, Sledge CB. Total knee arthroplasty with the kinematic prosthesis. Results after five to nine years: a follow-up note. J Bone Joint Surg Am 1990;72:1003–9.
[28] Meding JB, Fish MD, Berend ME, Ritter MA, Keating EM. Predicting patellar failure after total knee arthroplasty. Clin Orthop Relat Res 2008;466:2769–74. https://doi.org/10.1007/s11999-008-0417-y.
[29] Ortiguera CJ, Berry DJ. Patellar fracture after total knee arthroplasty. J Bone Joint Surg Am 2002;84:532–40.
[30] Ogon M, Hartig F, Bach C, Nogler M, Steingruber I, Biedermann R. Patella resurfacing: no benefit for the long-term outcome of total knee arthroplasty. Arch Orthop Trauma Surg 2002;122:229–34. https://doi.org/10.1007/s00402-001-0364-5.
[31] Grace JN, Sim FH. Fracture of the patella after total knee arthroplasty. Clin Orthop Relat Res 1988;230:168–75.
[32] Burnett RS, Haydon CM, Rorabeck CH, Bourne RB. The John insall award :patella resurfacing versus nonresurfacing in total knee arthroplasty: results of a randomized controlled clinical trial at a minimum of 10 Years' followup. Clin Orthop Relat Res 2004;428:12–25. https://doi.org/10.1097/01.blo.0000148594.05443.a3.
[33] Feller JA, Bartlett RJ, Lang DM. Patellar resurfacing versus retention in total knee arthroplasty. J Bone Joint Surg Br 1996;78-B:226–8. https://doi.org/10.1302/0301-620X.78B2.0780226.
[34] Gustke KA, Simon P, Meheux CJ. Metal-Backed patella implants in knee arthroplasty: can the past predict the future? J Arthroplasty 2023;38:S131–6. https://doi.org/10.1016/j.arth.2023.02.013.
[35] American Joint Replacement Registry (AJRR). 2023 Annual report. Rosemont, IL: American Academy of Orthopaedic Surgeons (AAOS); 2023. https://www.aaos.org/registries/publications/ajrr-annual-report/.
[36] National Guideline Centre (UK). Evidence review for patella resurfacing: joint replacement (primary): hip, knee and shoulder: evidence review L. London: National Institute for Health and Care Excellence (NICE); 2020 (NICE Guideline, No. 157.), https://www.ncbi.nlm.nih.gov/books/NBK561419/.
[37] Parsons T, Al-Jabri T, Clement ND, Maffulli N, Kader DF. Patella resurfacing during total knee arthroplasty is cost-effective and has lower re-operation rates compared to non-resurfacing. J Orthop Surg Res 2021;16:185. https://doi.org/10.1186/s13018-021-02295-8.
[38] Weeks CA, Marsh JD, MacDonald SJ, Graves S, Vasarhelyi EM. Patellar resurfacing in total knee arthroplasty: a cost-effectiveness analysis. J Arthroplasty 2018;33:3412–5. https://doi.org/10.1016/j.arth.2018.07.001.
[39] Held MB, Gazgalis A, Sarpong NO, Geller JA, Shah RP, Cooper HJ. Management of the patella during total knee arthroplasty. JBJS Rev 2021;9:e21.00054. https://doi.org/10.2106/JBJS.RVW.21.00054.
[40] Ware J, Kosinski M, Turner-Bowker D, Gandek B. How to score SF-12 items. SF-12 v2: How to Score Version 2 of the SF-12 Health Survey 29-38. https://www.researchgate.net/publication/291994160_How_to_score_SF-12_items; 2002. [Accessed 3 June 2024].
[41] The 2011 knee society knee scoring System©, The Knee Society. www.kneesociety.org/assets/2011KSS%20Support%20Materials.pdf; 2012. [Accessed 3 June 2024].
[42] Copsey B, Thompson JY, Vadher K, Ali U, Dutton SJ, Fitzpatrick R, et al. Problems persist in reporting of methods and results for the WOMAC measure in hip and knee osteoarthritis trials. Qual Life Res 2019;28:335–43. https://doi.org/10.1007/s11136-018-1978-1.
[43] Woolacott NF, Corbett MS, Rice SJC. The use and reporting of WOMAC in the assessment of the benefit of physical therapies for the pain of osteoarthritis of the knee: findings from a systematic review of clinical trials. Rheumatology 2012;51:1440–6. https://doi.org/10.1093/rheumatology/kes043.
[44] Benazzo F, Perticarini L, Jannelli E, Ivone A, Ghiara M, Rossi SMP. Controversy: supporting patellar resurfacing in total knee arthroplasty - do it. EFORT Open Rev 2020;5:785–92. https://doi.org/10.1302/2058-5241.5.190075.
[45] Wood DJ, Smith AJ, Collopy D, White B, Brankov B, Bulsara MK. Patellar resurfacing in total knee arthroplasty: a prospective, randomized trial. J Bone Joint Surg Am 2002;84:187–93. https://doi.org/10.2106/00004623-200202000-00004.
[46] Laskin RS, Bucknell A. The use of metal-backed patellar prostheses in total knee arthroplasty. Clin Orthop Relat Res 1990;260:52–5.
[47] Hedley AK. Minimum 5-year results with duracon press-fit metal-backed patellae. Am J Orthop (Belle Mead NJ) 2016;45:61–5.
[48] Williams K, Sansoni J, Morris D, Grootemaat P, Thompson C. Patient-reported outcome measures: literature review. Sydney: ACSQHC. https://www.safetyandquality.gov.au/sites/default/files/migrated/PROMs-Literature-Review-December-2016.pdf; 2016. [Accessed 3 June 2024].
[49] Ackerman IN. The changing landscape of patient outcome assessment. J Physiother 2017;63:1–3. https://doi.org/10.1016/j.jphys.2016.11.003.
[50] Ko YI, Yang JH, Choi CH. Comparison of clinical outcomes after total knee arthroplasty with and without patellar resurfacing in the same patients. Clin Orthop Surg 2022;14:361–9. https://doi.org/10.4055/cios20289.
[51] Kaseb MH, Tahmasebi MN, Mortazavi SJ, Sobhan MR, Nabian MH. Comparison of clinical results between patellar resurfacing and non-resurfacing in total knee arthroplasty: a Short term evaluation. Arch Bone Jt Surg 2018;6:124–9.
[52] Robertsson O, Dunbar M, Pehrsson T, Knutson K, Lidgren L. Patient satisfaction after knee arthroplasty: a report on 27,372 knees operated on between 1981 and 1995 in Sweden. Acta Orthop Scand 2000;71:262–7. https://doi.org/10.1080/000164700317411852.
[53] Clement ND, Weir D, Holland J, Gerrand C, Deehan DJ. Meaningful changes in the Short Form 12 physical and mental summary scores after total knee arthroplasty. Knee 2019;26:861–8. https://doi.org/10.1016/j.knee.2019.04.018.
[54] Clement ND, Bardgett M, Weir D, Holland J, Gerrand C, Deehan DJ. What is the minimum clinically important difference for the WOMAC index after TKA? Clin Orthop Relat Res 2020;478:922. https://doi.org/10.1097/CORR.0000000000000444.
[55] Khow YZ, Liow MHL, Goh GS, Chen JY, Lo NN, Yeo SJ. Defining the minimal clinically important difference for the knee society score following revision total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2022;30:2744–52. https://doi.org/10.1007/s00167-021-06628-2.
[56] Parvizi J, Mortazavi SMJ, Devulapalli C, Hozack WJ, Sharkey PF, Rothman RH. Secondary resurfacing of the patella after primary total knee arthroplasty: does the anterior knee pain resolve? J Arthroplasty 2012;27:21–6. https://doi.org/10.1016/j.arth.2011.04.027.
[57] Spencer SJ, Young D, Blyth MJG. Secondary resurfacing of the patella in total knee arthroplasty. Knee 2010;17:187–90. https://doi.org/10.1016/j.knee.2009.08.003.

[58] van Jonbergen HP, Boeddha AV, M van Raaij JJ. Patient satisfaction and functional outcomes following secondary patellar resurfacing. Orthopedics 2016;39:e850–6. https://doi.org/10.3928/01477447-20160509-05.
[59] Petersen W, Rembitzki IV, Brüggemann GP, Ellermann A, Best R, Koppenburg AG, et al. Anterior knee pain after total knee arthroplasty: a narrative review. Int Orthop 2014;38:319–28. https://doi.org/10.1007/s00264-013-2081-4.
[60] Thomas C, Patel V, Mallick E, Esler C, Ashford RU. The outcome of secondary resurfacing of the patella following total knee arthroplasty: results from the Trent and Wales Arthroplasty Register. Knee 2018;25:146–52. https://doi.org/10.1016/j.knee.2017.10.004.
[61] Fuchs S, Skwara A, Tibesku CO, Rosenbaum D. Retropatellar contact characteristics before and after total knee arthroplasty. Knee 2005;12:9–12. https://doi.org/10.1016/S0968-0160(02)00045-5.
[62] Karnezis IA, Vossinakis IC, Rex C, Fragkiadakis EG, Newman JH. Secondary patellar resurfacing in total knee arthroplasty: results of multivariate analysis in two case-matched groups. J Arthroplasty 2003;18:993–8. https://doi.org/10.1016/S0883-5403(03)00286-9.
[63] Rodríguez-Merchán CE, Gómez-Cardero P. The Outerbridge classification predicts the need for patellar resurfacing in TKA. Clin Orthop Relat Res May 2010;468:1254–7. https://doi.org/10.1007/s11999-009-1123-0.
[64] Reuben JD, McDonald CL, Woodard PL, Hennington LJ. Effect of patella thickness on patella strain following total knee arthroplasty. J Arthroplasty 1991;6:251–8. https://doi.org/10.1016/s0883-5403(06)80172-5.
[65] Scuderi G, Scharf SC, Meltzer LP, Scott WN. The relationship of lateral releases to patella viability in total knee arthroplasty. J Arthroplasty 1987;2:209–14. https://doi.org/10.1016/s0883-5403(87)80039-6.
[66] Govil G, Tomar L, Dhawan P. Peri-prosthetic trans-patellar fractures after Total knee Arthroplasty: a case series and review of literature. Arthroplasty 2020;2:35. https://doi.org/10.1186/s42836-020-00050-8.
[67] Chalidis BE, Tsiridis E, Tragas AA, Stavrou Z, Giannoudis PV. Management of periprosthetic patellar fractures: a systematic review of literature. Injury 2007;38:714–24. https://doi.org/10.1016/j.injury.2007.02.054.
[68] Scheurer P, Reininga IH, van Jonbergen HP, van Raay JJ. Secondary patellar resurfacing following total knee arthroplasty. Int Orthop 2015;39:1301–6. https://doi.org/10.1007/s00264-015-2684-z.