

# A Randomized, Controlled, Prospective Study Evaluating the Effect of Patellar Eversion on Functional Outcomes in Primary Total Knee Arthroplasty

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**Background:** Patellar mobilization technique during total knee arthroplasty has been debated, with some suggesting that lateral retraction, rather than eversion, of the patella may be beneficial. We hypothesized that patients with knees surgically exposed using patellar lateral retraction would have comparable outcomes with patients with knees surgically exposed using patellar eversion.

**Methods:** After an a priori power analysis, 120 patients with degenerative arthrosis were prospectively enrolled and were randomized to one of two patellar exposure techniques during the primary total knee arthroplasty: lateral retraction or eversion. The primary outcome measure was one-year, dynamometer-measured quadriceps strength. The secondary outcome measures evaluated during hospital stay included the ability to straight-leg raise, visual analog scale in pain, walking distance, and length of stay. The secondary outcome measures that were evaluated preoperatively and through a one-year follow-up included the Short Form-36 Physical Component Summary and Mental Component Summary scores, range of motion, quadriceps strength, and radiographic rate of patella baja and tilt.

**Results:** A mixed-model analysis of variance showed no significant differences between the two groups in the one-year outcome measures. At one year postoperatively, quadriceps strength was not different between groups ( $p = 0.77$ ), and the range of motion significantly improved ( $p < 0.01$ ) from preoperative values by a mean value (and standard deviation) of  $6^\circ \pm 17^\circ$ , with no significant difference ( $p = 0.60$ ) between groups. The Short Form-36 Physical Component Summary score and Mental Component Summary score significantly improved ( $p < 0.01$ ) for both study groups from preoperatively to one year postoperatively with no significantly different effects between groups (time  $\times$  group,  $p = 0.85$  for the Physical Component Summary score and  $p = 0.71$  for the Mental Component Summary score), and the scores were not different at one year after surgery. There were no significant differences between groups in the change in frequency of the radiographic patella baja ( $p = 0.99$ ) or the radiographic patellar tilt ( $p = 0.77$ ) from before surgery to one year after surgery.

**Conclusions:** Lateral retraction of the patella did not lead to superior postoperative results compared with eversion of the patella during total knee arthroplasty as evaluated using our primary outcome measure of one-year, dynamometer-measured quadriceps strength or our secondary outcome measures.

**Level of-Evidence:** Therapeutic Level II. See Instructions for Authors for a complete description of levels of evidence.

**Peer Review:** This article was reviewed by the Editor-in-Chief and one Deputy Editor, and it underwent blinded review by two or more outside experts. It was also reviewed by an expert in methodology and statistics. The Deputy Editor reviewed each revision of the article, and it underwent a final review by the Editor-in-Chief prior to publication. Final corrections and clarifications occurred during one or more exchanges between the author(s) and copyeditors.

Surgical exposure of the knee during total knee arthroplasty requires mobilization of the patella. Eversion of the patella by twisting it on the axis of the extensor mechanism can augment surgical exposure and has been a routine part of surgical technique<sup>1</sup>. Lateral retraction of the patella is an additional technique<sup>2</sup> whereby the patella is subluxed without eversion.

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## CONSORT 2010 Flow Diagram

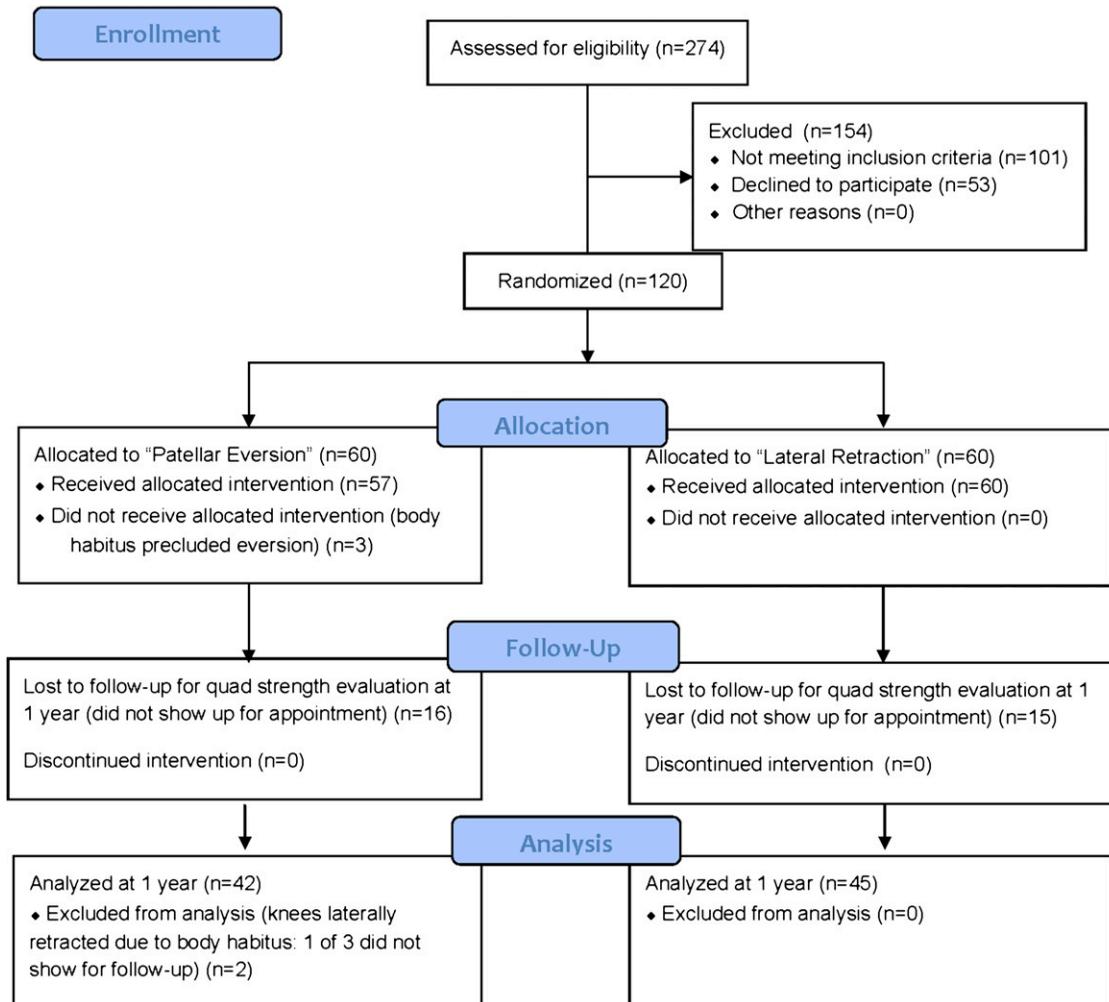


Fig. 1  
A Consolidated Standards of Reporting Trials (CONSORT) diagram showing patients who were approached, who provided consent, and who were available for one-year dynamometer quadriceps (quad) strength analysis.

Potentially, lateral retraction may offer the benefit of limiting stress on the extensor mechanism with the possible disadvantage of less optimal surgical exposure.

Theoretical reasons why everting the patella could be harmful and could result in poorer outcomes include quadriceps muscle damage due to torsion and increased tension<sup>2</sup>, damage to the patellar tendon<sup>3</sup> resulting in scarring and shortening, patella baja<sup>4,5</sup>, and decreased mechanical advantage of the extensor mechanism due to a less optimal position of the patella during the flexion and extension arc. Any of these theoretical consequences of eversion could result in decreased quadriceps strength, decreased range of motion, slower physical therapy progress that might be evidenced by decreased walking distance or increased length of hospital stay, increased postoperative pain, or decreased patient function and satisfaction.

We hypothesized that patients with knees surgically exposed during total knee arthroplasty using patellar lateral retraction would have comparable outcomes to patients with knees surgically exposed using patellar eversion.

### Materials and Methods

Institutional review board approval was granted for a prospective randomized study of 120 total knee replacements. The sample size was based on the ability to detect a clinically important difference in postoperative quadriceps strength between groups. On the basis of the typical intersubject variability in quadriceps strength after total knee arthroplasty<sup>6,7</sup>, it was estimated that with sixty patients per group, there was 80% power to detect a between-group difference in quadriceps strength of >20% at a significance level of  $p < 0.05$ . This estimated detectable difference increases to 26% with a loss to follow-up of ten patients per group.

Eligibility criteria for study participation included all patients indicated for primary total knee arthroplasty with degenerative joint disease. Patients

were excluded from the study if they had had ipsilateral total knee replacement, knee arthrotomy, osteotomy at or about the knee, or preoperative angular deformity of  $>20^\circ$ .

During the period from March 2009 to April 2011, informed consent was obtained from 120 patients. On the basis of a computerized randomization schedule allocating 120 patients into two groups of sixty, each patient who gave consent was prospectively randomized to receive one of two patellar mobilization techniques during surgery: lateral retraction or eversion. See Figure 1 for the number of patients who were approached, the number of patients who refused to participate, the number of patients who were excluded, and the number of patients who were available for follow-up. The Appendix shows a comparison of patient demographic characteristics. There were no significant differences between groups in patient preoperative medical conditions including hypertension, hypercholesterolemia, diabetes mellitus, and coronary artery disease ( $p = 0.49$  to  $0.82$ ).

All arthroplasties were performed by three arthroplasty-fellowship-trained orthopaedic surgeons (J.R., A.R., and M.A.) using surgical techniques based on that of Ranawat<sup>8</sup>. All patients had spinal anesthesia, received a periarticular anesthetic (marcaine) and analgesic (morphine) cocktail injection, and had pneumatic thigh tourniquets used with times up to 120 minutes. All implanted devices were posterior-stabilized tricompartmental total knee replacements (Sigma, DePuy Orthopaedics, Warsaw, Indiana; LEGION, Smith & Nephew, Memphis, Tennessee; and Vanguard, Biomet, Warsaw, Indiana) placed through a medial parapatellar approach. All knees were surgically exposed with medial tibial subperiosteal dissection and by applying anterior tibial translation with tibial external rotation. Patients randomized to the eversion group had patellae everted during the flexion portions of the surgery. Patients randomized to the retraction group had patellae everted only for the patellar resurfacing, which was done with the knee in extension. Multimodal postoperative pain management and accelerated physical therapy were performed as previously described<sup>9</sup>. All other aspects of surgery including anticoagulation were standardized as per arthroplasty protocols at our institution.

Because quadriceps strength is a clinically important outcome that can be reproducibly measured, we powered our study with quadriceps strength at one year postoperatively as the primary outcome measure. Quadriceps strength was measured isometrically using a Biodex dynamometer (System 2; Biodex, Shirley, New York) with the patient's knee in  $60^\circ$  of flexion. The secondary outcome measures were evaluated during patient hospitalization (ability to straight-leg raise, visual analog scale [VAS] pain score, walking distance, length of stay), and over the year following surgery (Short Form-36 [SF-36] scores, range of knee motion, VAS pain score, and rate of patella baja or patellar tilt). For this study, we defined the ability to straight-leg raise as elevation of the heel at 15.24 cm (6 inches) with the foot dorsiflexed and the knee fully extended without extension lag. The SF-36 outcome survey has been verified and has been used widely in the literature, including in the evaluation of surgical outcomes of total knee arthroplasty, for which the Physical Component Summary (PCS) score may be particularly useful<sup>10</sup>. To address the potential for a disparity in the frequency of patella baja or patellar tilt between groups before and after surgery, we performed a radiographic analysis based on previously published studies<sup>4,5</sup>. Radiographic evaluation was performed by two independent orthopaedic surgery fellows (one of whom [P.R.] was an author in this study) who were blinded to the patellar mobilization method. The Insall-Salvati ratio was calculated on the preoperative and one-year postoperative radiographs according to the original description by Insall and Salvati<sup>11</sup>. For this study, patella baja was defined as an Insall-Salvati ratio of  $<0.8$ .

All collaborating investigators of the study were blinded to each other's data until the conclusion of the data acquisition period of the study. All study patients were blinded to their patellar mobilization randomization group until after the one-year follow-up.

Data analysis was performed using standard statistical software (SPSS, version 21; IBM, Armonk, New York). The effect of surgical technique on short-term and one-year outcome measures was assessed with mixed-model analysis of variance with surgical technique as a between-subjects factor and time as a within-

subjects factor. Between-group differences at particular time intervals were assessed using the least significant difference method. As different numbers of patients were available at each follow-up interval, data were analyzed separately for time periods of preoperatively to six weeks, six weeks to three months, and three months to one year. This method of analysis maximized the sample size for analysis of changes over time. The results are reported as the mean and the standard deviation. In the Results section and in the figures, time effect refers to the change in the dependent variable between the respective time intervals (preoperatively, six weeks, three months, and one year). Time  $\times$  group refers to whether the change in the dependent variable differed between treatment groups.

Our protocol is registered with Clinicaltrials.gov (#NCT01777009).

### Source of Funding

There was no external funding source for this study.

### Results

Sixty patients were randomized to be mobilized with patellar eversion, but three patients had a body habitus that precluded patellar eversion and lateral retraction was used at surgery. These three patients were excluded from subsequent analysis. Sixty patients were randomized to be mobilized with patellar lateral retraction and were all mobilized according to randomization.

Tourniquet times ranged from twenty-four to 120 minutes. The mean tourniquet time (and standard deviation) was  $67.9 \pm 22.5$  minutes for the eversion group and  $70.2 \pm 20.0$  minutes for the retraction group ( $p = 0.57$ ).

Complications included eight pulmonary emboli as diagnosed with spiral computed tomography (CT): seven in the eversion group and one in the lateral retraction group. These patients presented with tachycardia, required an increased length of stay for attainment of the therapeutic international normalized ratio, and were treated medically with three months of postoperative anticoagulation with warfarin using an enoxaparin bridge. There were no mortalities. Pulmonary emboli incidence was significantly different between groups ( $p = 0.03$ ).

Two patients in the eversion group had partial avulsions of the patellar tendon insertion, which did not require repair or deviation from our standard techniques or protocols. The ability to straight-leg raise, quadriceps strength, knee motion, and SF-36 scores were not significantly different from patients without partial avulsions. Eight patients in the eversion group and six patients in the lateral retraction group were recommended for or underwent manipulation under anesthesia for postoperative stiffness, with no significant difference between groups ( $p = 0.57$ ). Three patients in the eversion group and one patient in the lateral retraction group underwent or were recommended for scar excision for painful crepitus, with no significant difference between groups ( $p = 0.36$ ). One patient in the eversion group underwent both-component revisions for stiffness, with no significant difference between groups ( $p = 0.49$ ). Two patients in the eversion group had delayed skin healing, with no significant difference between groups ( $p = 0.24$ ). Four patients in the eversion group and five patients in the lateral retraction group reported anterior knee pain or retropatellar pain during their postoperative

visits, with no significant difference between groups ( $p = 0.99$ ).

### Short-Term Outcomes

The mean length of stay (and standard deviation) was significantly shorter ( $p = 0.03$ ) for the retraction group ( $4.0 \pm 1.4$  days) compared with the eversion group ( $4.8 \pm 2.6$  days). VAS pain scores, walking distance, and ability to perform a straight-leg raise were not significantly different between treatment groups (see Table I). VAS pain scores and walking distances improved from twenty-four to forty-eight hours and from forty-eight to seventy-two hours ( $p < 0.05$ ) with no difference between groups ( $p = 0.63$  to  $0.96$ ). One patient in the retraction group and six patients in the eversion group were not evaluated for straight-leg raise within seventy-two hours for reasons relating to research physical therapist availability.

### Radiographic Outcomes

The Insall-Salvati ratio was lower in the eversion group (preoperatively and postoperatively) (see Table II), but changes from preoperatively to postoperatively were not different between groups ( $p = 0.25$ ). The rate of patella baja was not significantly different between groups preoperatively (0.23) and at one year postoperatively (0.99). Patellar tilt was not different between groups but tended to be greater in the retraction group at one year. Tilt tended to be lower postoperatively compared with preoperatively in the eversion group ( $p = 0.10$ ) and was not different between preoperatively and postoperatively for the retraction group ( $p = 0.21$ ). The change in tilt from preoperatively to postoperatively was not different between groups ( $p = 0.77$ ).

### One-Year Outcomes

#### Pain

VAS pain scores were measured at rest and after a full range of knee motion. The average VAS scores at rest improved significantly ( $p < 0.001$ ) from preoperatively (6.0 points) to six weeks (3.4 points) and continued to improve from six weeks to three months and from three months to one year. Improvements in pain at rest were not significantly different between groups ( $p = 0.20$  to  $0.93$ ). Patients had a mean minimal resting knee pain (and standard deviation) of  $1.1 \pm 1.7$  points at one year.

The average pain after a knee range of motion did not change from preoperatively to six weeks ( $p = 0.95$ ) but did improve from six weeks to three months ( $p < 0.001$ ), with further improvement from three months to one year ( $p < 0.001$ ). Improvements in pain after a range of motion were not significantly different between groups ( $p = 0.22$  to  $0.76$ ). Patients had a mean minimal pain (and standard deviation) of  $1.9 \pm 2.2$  points after range of motion at one year.

#### Quadriceps Strength

The average quadriceps strength declined from preoperatively to six weeks (time effect,  $p < 0.001$ ) with no significant difference between groups (time  $\times$  group,  $p = 0.51$ ). Quadriceps strength improved from six weeks to three months ( $p < 0.001$ ), with a greater improvement seen in the eversion group (49%) compared with the retraction group (31%) (time  $\times$  group,  $p = 0.04$ ). Quadriceps strength continued to improve from three months to one year (time effect,  $p < 0.001$ ), at which time there was no significant difference between groups (time  $\times$  group,  $p = 0.77$ ). Quadriceps strength was not different between groups at one year ( $p = 0.62$ ) (Fig. 2).

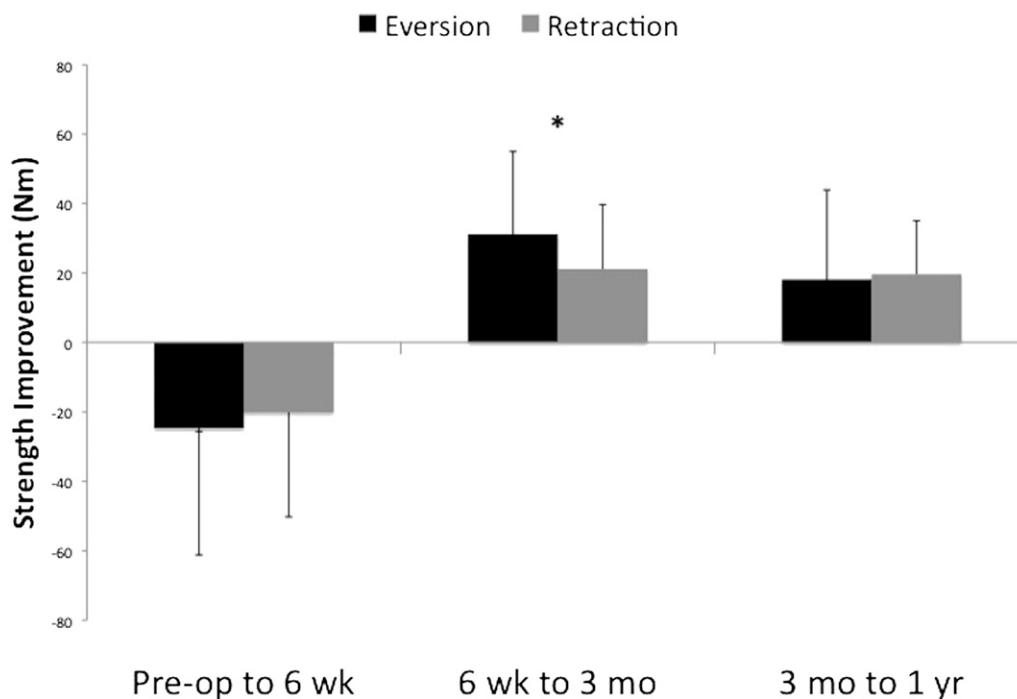


Fig. 2

A bar graph showing the quadriceps strength improvement for eighty-nine patients from preoperatively to six weeks (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.51$ ), for seventy-nine patients from six weeks to three months (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.04$ ), and for seventy-six patients from three months to one year (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.62$ ). The asterisk denotes significance. The error bars denote the standard deviation.

TABLE I Short-Term Outcomes

Outcomes	Eversion (N = 51)	Retraction (N = 59)	P Value
Length of stay* (d)	4.8 ± 2.6	4.0 ± 1.4	0.03
Discharge day 3†	42%	48%	0.71
Average VAS pain score in the first forty-eight hours* (points)	4.6 ± 2.1	4.5 ± 2.1	0.88
Walking distance* (ft)			
At twenty-four hours	21 ± 18	29 ± 53	0.4
At forty-eight hours	64 ± 54	61 ± 70	0.83
At seventy-two hours	109 ± 61	80 ± 65	0.08
Straight-leg raise within seventy-two hours‡	30 (59%)	40 (68%)	0.33

\*The values are given as the mean and the standard deviation. †The values are given as the percentage. ‡The values are given as the number of patients, with the percentage in parentheses.

### Knee Range of Motion

There was a loss of passive knee motion from preoperatively to six weeks (time effect,  $p < 0.001$ ) with no significant difference between groups (time  $\times$  group,  $p = 0.30$ ). Range of motion improved from six weeks to three months (time effect,  $p < 0.001$ ) with no significantly different effects between groups (time  $\times$  group effect,  $p = 0.24$ ). Continued improvements were seen in the range of motion from three months to one year (time effect,  $p < 0.001$ ), and again these effects were not significantly different between groups (time  $\times$  group,  $p = 0.54$ ). At one year, the

mean range of motion (and standard deviation) for both groups was improved by  $6^\circ \pm 17^\circ$  from preoperative values ( $p < 0.01$ ) (Fig. 3).

### SF-36 Scores

SF-36 PCS and Mental Component Summary (MCS) scores were not different between eversion and retraction groups at one year after surgery. PCS scores did not change from preoperatively to six weeks postoperatively (time effect,  $p = 0.25$ )

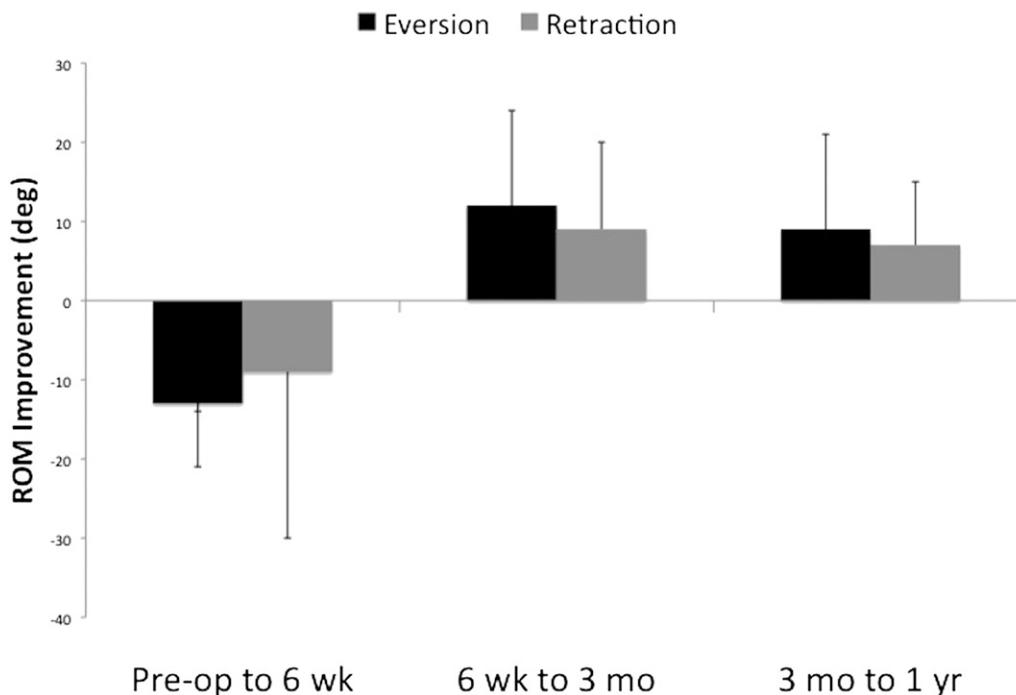


Fig. 3

A bar graph showing the knee range of motion (ROM) improvement for eighty-nine patients from preoperatively to six weeks (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.30$ ), for seventy-nine patients from six weeks to three months (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.24$ ), and for seventy-five patients from three months to one year (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.54$ ). The error bars denote the standard deviation.

TABLE II Radiographic Outcomes

Outcome	Eversion (N = 53)	Retraction (N = 56)	P Value
Insall-Salvati ratio*			
Preoperatively	1.10 ± 0.17	1.17 ± 0.16	0.02
At one year postoperatively	1.10 ± 0.17	1.21 ± 0.19	0.01
Patella baja†			
Preoperatively	2	0	0.23
At one year postoperatively	2	3	0.99
Patellar tilt*			
Preoperatively	3.17° ± 2.89°	3.80° ± 3.43°	0.30
At one year postoperatively	2.25° ± 2.56°	3.11° ± 2.63°	0.09

\*The values are given as the mean and the standard deviation. †The values are given as the number of patients.

with higher values in the retraction group (group effect,  $p = 0.045$ ). PCS scores improved from six weeks to three months postoperatively (time effect,  $p < 0.001$ ) with no significantly different effects between eversion and retraction groups (time  $\times$  group,  $p = 0.54$ ). PCS scores continued to improve from three months to one year (time effect,  $p < 0.001$ ) with no significantly different effects between groups (time  $\times$  group,  $p = 0.85$ ). The mean one-year follow-up PCS score (and standard deviation) was  $47 \pm 8.5$  points for the

eversion group and  $50.0 \pm 8.5$  points for the retraction group ( $p = 0.14$ ) (Fig. 4).

The SF-36 MCS score improved from preoperatively to one year ( $p < 0.01$ ). For the eversion group, the mean score (and standard deviation) was  $47.3 \pm 14.6$  points preoperatively and  $52.5 \pm 9.1$  points at one year postoperatively, and for the retraction group, the mean score (and standard deviation) was  $48.9 \pm 12.6$  points preoperatively and  $53.0 \pm 10.0$  points at one year postoperatively, with no

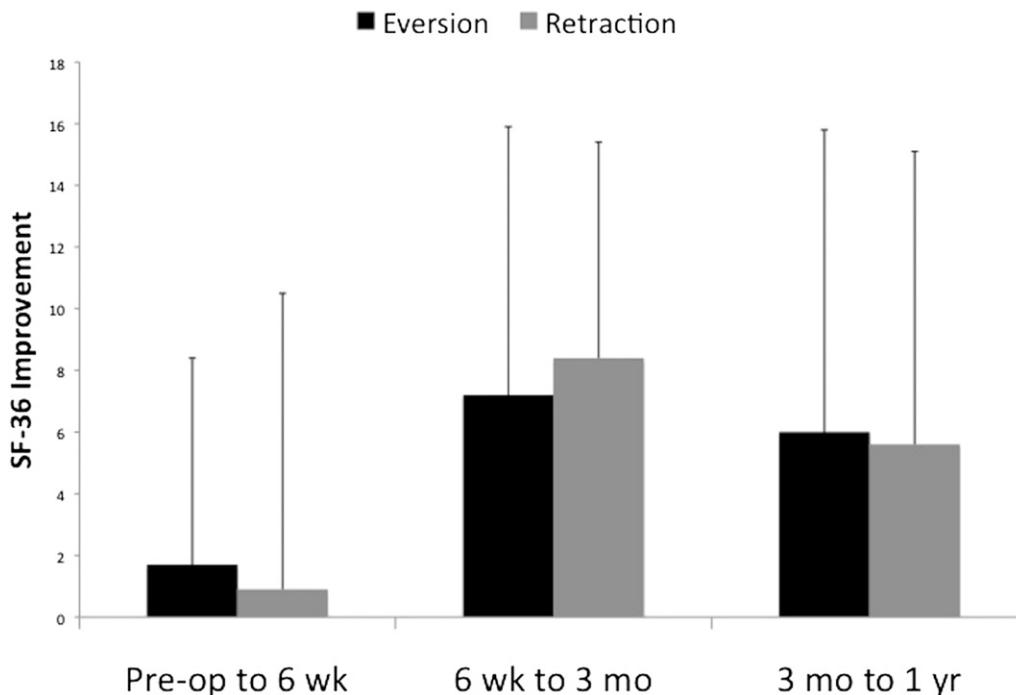


Fig. 4

A bar graph showing the SF-36 PCS score improvement for fifty-six patients from preoperatively to six weeks (time effect,  $p = 0.25$ ; time  $\times$  group,  $p = 0.045$ ), for sixty patients from six weeks to three months (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.54$ ), and for seventy-four patients from three months to one year (time effect,  $p < 0.001$ ; time  $\times$  group,  $p = 0.85$ ). The error bars denote the standard deviation.

significantly different effect between groups (time  $\times$  group,  $p = 0.71$ ).

### Discussion

Lateral retraction of the patella did not lead to superior postoperative results compared with eversion of the patella during total knee replacement surgery as evaluated using our primary outcome measure of one-year, dynamometer-measured quadriceps strength or our secondary outcome measures (range of motion, rate of radiographic patella baja or tilt, or SF-36 scores).

We found a significantly increased length of stay for the patients in the eversion group compared with the patients in the retraction group. This result is attributable to a disproportionate number of patients developing pulmonary emboli in the eversion group, although our rate of pulmonary emboli in both groups was elevated compared with published norms. The rates of symptomatic pulmonary emboli diagnosed by spiral CT in patients who underwent primary total knee arthroplasty and received a multimodal venous thromboembolism prophylaxis regimen similar to ours range from 0.49%<sup>12</sup> to 1.2%<sup>13</sup>. Increasing rates of pulmonary emboli have been associated with more sensitive detection modalities<sup>14</sup>, such as those used in the current study. To our knowledge, no study has shown a higher incidence of pulmonary emboli with patellar eversion. It is unlikely that the increased rate of pulmonary emboli seen in our patients in the eversion group is due to the eversion per se; rather, it appears to be only an association. There was no significant difference in the pulmonary emboli rate between operating surgeons contributing patients to this study.

Walter et al.<sup>15</sup> reported that patients with patellar eversion achieved a straight-leg raise on average 8.9 hours later than patients mobilized with patellar lateral retraction, and that this difference in time to return of straight-leg raise reached significance. The clinical importance of a difference of a few hours in the return of straight-leg raise is, of course, debatable. Arnout et al.<sup>16</sup> evaluated the ability of patients to straight-leg raise at day 4, grading effort on a 4-point scale, and found no significant difference between groups. Dalury et al.<sup>17</sup> evaluated patients' ability to straight-leg raise at one, two, three, and ten days postoperatively and found no significant difference between groups in the proportion of patients able to straight-leg raise at any time point. We found no significant difference in the proportion of patients able to straight-leg raise by seventy-two hours postoperatively between the eversion and retraction groups.

Walter et al.<sup>15</sup> did not report longer-term quadriceps strength measurements. Arnout et al.<sup>16</sup> measured isokinetic leg extension strength using a Biodex machine at six months and found no difference between groups at that time. Dalury et al.<sup>17</sup> tested quadriceps strength with a handheld dynamometer preoperatively and at six and twelve weeks postoperatively, and with a seated knee extension machine at six months postoperatively, and found a significant improvement in both groups at each time interval after an initial decline at six weeks, but no difference between groups. We found similar significant findings in our study, with an initial decline in strength at six weeks, followed by a steady increase in strength to one year, with no

difference between groups. We observed a significantly greater improvement in strength in the eversion group (49% versus 31%) from six weeks to three months, although this rate equalized from three months to one year.

On the basis of the data in this study, we cannot posit discrete anatomic criteria to be used in making the decision to mobilize the patella with lateral retraction or eversion in the exposure for total knee arthroplasty. Two patients mobilized with eversion demonstrated partial avulsions at the patellar tendon insertion. We suggest that it may be more beneficial to mobilize patients such as these with the lateral retraction technique, at least during parts of the case. Eversion may have benefits in certain instances as well. This study showed a significant advantage in the gain of quadriceps strength from six weeks to three months postoperatively in patients in the eversion group compared with those in the retraction group ( $p = 0.04$ ). Patellar tilt tended to be greater in the retraction group at one year ( $p = 0.09$ ), and tilt tended to improve more with the eversion technique ( $p = 0.10$ ).

We are unable to recommend one patellar mobilization method over the other definitively. We recommend continuously evaluating in real time the risks and benefits of a chosen patellar mobilization method, with confidence that changing from one to the other during the case should not have any untoward effect on the patient's recovery. All patients in this study were exposed by standard medial parapatellar arthrotomy with subperiosteal elevation of the medial collateral ligament and anterior tibial subluxation with external rotation, which will greatly affect the magnitudes and directions of forces on the extensor mechanism and its insertion.

In this randomized, prospective, blinded study designed with an a priori power analysis, we found no significant detriment to eversion of the patella compared with lateral retraction of the patella during total knee arthroplasty with regard to dynamometer-measured quadriceps strength at one year. We believe that there is a balance between the extent of surgical exposure allowing accurate placement of components and optimal cement fixation and the attempts to preserve the soft-tissue envelope surrounding the knee. At times, exposure during total knee arthroplasty may be augmented by eversion of the patella, and in our experience, this has not led to inferior postoperative outcomes compared with lateral retraction of the patella.

### Appendix

 A table showing patient demographic characteristics with insignificant differences is available with the online version of this article as a data supplement at [jbj.org](http://jbj.org). ■

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