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ORIGINAL ARTICLE

Comparison of quadriceps-sparing minimally invasive and medial parapatellar total knee arthroplasty: A 2-year follow-up study

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Background/Purpose: Quadriceps-sparing minimally invasive total knee arthroplasty (TKA) has been proposed to limit surgical dissection without compromising surgical outcome. We conducted a prospective and randomized study to compare the outcomes of patients who underwent quadriceps-sparing TKA with the outcomes of those who underwent standard medial parapatellar TKA, after a 2-year follow-up period.
Methods: Eighty primary TKA procedures that were to be performed in 60 osteoarthritis patients were randomly assigned to either a quadriceps-sparing (40 knees) or a standard medial parapatellar (40 knees) group. All surgeries were designed to set the prosthesis with a femoral component alignment of 7° valgus and a tibial component alignment that was perpendicular to the tibial shaft. Surgical time and tourniquet time were recorded. Outcome variables included knee function, as defined by a hospital for special surgery knee score; quadriceps muscle strength, which was measured by an isokinetic dynamometer; pain, as indicated on a visual analog scale; prosthetic position, which was measured on plain radiograph; and range of motion.
Results: Patients who underwent the 38 quadriceps-sparing and 37 standard TKA procedures completed the 2-year follow-up period without any infection or revision. The mean surgical time and tourniquet time were significantly longer in the quadriceps-sparing group. The mean peak quadriceps muscle strength, hamstring muscle strength, normalized muscle balance (hamstring/quadriceps ratio), pain score, function score, and range of motion were comparable in both groups at 2 months and 2 years. In the quadriceps-sparing group, both the femoral and the tibial components were significantly more varus-deviated from the expected position.

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Conclusion: Patients undergoing quadriceps-sparing and standard medial parapatellar TKA had comparable outcomes for quadriceps muscle strength, hamstring—quadriceps balance, and knee function; however, the quadriceps-sparing TKA was more time consuming surgically and resulted in a less accurate prosthesis position.

Introduction

Prosthetic total knee arthroplasty (TKA), which has been a promising surgery for osteoarthritis, has a good long-term functional outcome.[1—5] The conventional medial parapatellar arthrotomy method of TKA damages the extensor mechanism of the knee joint significantly and affects postoperative recovery and rehabilitation adversely.[5] Various minimally invasive arthrotomy techniques, which have been developed recently, involve smaller incisions and less soft tissue dissection that result in decreased quadriceps damage and postoperative pain, enhance early recovery and rehabilitation, and speed up the return to activities.[6—11] However, the overall advantages of such techniques have been debated because they result in less accurate positioning of prostheses and require longer operative times.[8,10,12]

One example of a minimally invasive TKA is a quadriceps-sparing arthrotomy that resembles the medial capsulotomy in unicompartmental arthroplasty.[13,14] This type of TKA has been reported to result in better and faster postoperative recoveries of quadriceps muscle strength, better short-term clinical and functional outcomes, and acceptable postoperative alignments compared to TKA that is performed by standard medial parapatellar arthrotomy.[12] Patellar insertion of the quadriceps muscle, or specifically, the m. vastus medialis obliquus, generally extends distally to the midpole of the patella.[15] The quadriceps-sparing arthrotomy, which starts from the proximal to the patellar midpole, does not avoid violating the muscle. We, therefore, hypothesized that such an arthrotomy would result in better preservation of the quadriceps muscle and provide faster recovery of muscle strength. In addition, a very limited operative field is currently utilized in the quadriceps-sparing TKA. Although special instruments can help overcome the technical difficulties, a number of complications, including malalignment of the limb, collateral ligament rupture, patellar tendon rupture, and postoperative arthrofibrosis, have been reported.[16—18] Among these complications, malalignment of the limb due to improper positioning of the prosthesis worst affects the long-term outcome.[8]

In this study, we hypothesized that quadriceps-sparing arthrotomy was not preferable to the standard medial parapatellar TKA arthrotomy with respect to postoperative recovery of quadriceps muscle strength, alignment of the limb, and clinical outcome.

Patients and methods

This prospective and randomized clinical study, which was conducted in 2005, was approved by the Institutional Review Board of the authors' hospital and registered in the ClinicalTrials.gov registry (http://www.clinicaltrials.gov). Consecutive patients with primary osteoarthritis of the knee in whom prosthetic TKA was indicated were recruited from the senior author's clinic. Standing anteroposterior radiographs were taken to evaluate the severity of the arthritis and to measure the angle between the femoral axis and the tibial axis, which is known as the femorotibial angle. The inclusion criteria were advanced osteoarthritis with radiograph-evident narrowing of the joint gap, persistent symptoms after at least 6 months of conservative treatment, and patients' intention to receive a prosthetic TKA. We excluded knees with excessive deformity (femorotibial angle exceeding 15° varus or 10° valgus, or flexion contracture exceeding 15°), active infection, or previous surgery. A total of 68 patients were enrolled, and of them 60 patients (80 knees) were included to participate in the study.

Informed consent was obtained from all participating patients before the surgery, and computer-generated randomization was used to assign patients randomly to either the quadriceps-sparing (40 knees) or the standard medial parapatellar (40 knees) group. Patients were blind to the group assignment. Personal data, including age, gender, height, and weight, were recorded. Body mass index (BMI) was calculated as the body weight in kilograms divided by the square of the body height in meters. The preoperative baselines of the following parameters were measured. General knee function was evaluated by the Hospital for Special Surgery (HSS) knee score. The patients were requested to indicate their pain in their affected knees during daily activity using a 10-cm visual analog scale (VAS). The maximal range of motion of the knee joint was measured while the patients were seated. Isokinetic muscle tests were performed with a Cybex dynamometer (Biodex Medical Systems, Shirley, NY, USA) to detect the peak muscle torque of the quadriceps and hamstring muscles at low (60°/s) and high (180°/s) angular velocities during knee motion. The peak torque was defined as the maximal value measured in three repeats at either angular velocity. The ratio between the peak torques of the hamstring and the quadriceps muscles (H/Q ratio) at either velocity was calculated. All these parameters were also measured at the 2-month and 2-year postoperative follow-up examinations. The percentage recovery of muscle strength was calculated as the measured peak torques versus its preoperative baseline value. All measurements were performed by an independent orthopedic doctor and a study nurse, both of whom were blind to the surgical procedure.

Before the surgery, all patients were instructed to raise their affected leg with the knee fully extended while lying in bed (straight-leg-raising). All surgeries, which were routinely done under spinal anesthesia, resulted in the installation of a cemented modular posterior-stabilized prosthesis (NexGen LPS Flex; Zimmer, Inc., Warsaw, IN, USA). A universal 12 cm midline longitudinal skin incision was made with the knee in 60° flexion. For the quadriceps-sparing group, the attachment site of the quadriceps muscle around the superomedial corner of the patella was identified. The arthrotomy was started medial of the patella and just inferior to the muscle, extended 1 cm medial to the border of the patella and patellar tendon, and ended by the tibial tuberosity. The patella was retracted laterally but not everted, and specialized 4-in-1 quadriceps-sparing side-cutting instruments were used for femoral and tibial bone cuts from the medial side of the knee.[18] The arthrotomy was similar for the standard group, but it was extended about 4 cm farther proximally and longitudinally by cutting the quadriceps muscle. The patella was everted to dislocate laterally, and standard instruments were used for femoral and tibial bone cuts from the front. With either quadriceps-sparing or standard instruments, the femoral cut was set at 7° valgus with the intramedullary guide, whereas the tibial cut was set perpendicular to the tibial shaft by the extramedullary guide. The surgical time, tourniquet time, and amount of blood loss during the surgery were recorded.

All patients underwent the same postoperative protocol in the ward, including cryotherapy, pain control medication, and physiotherapy that was guided by one therapist who was blind to the surgical procedure. Pain control included the routine use of 200 mg of oral celecoxib during hospitalization, plus intermittent intravenous injections of 10 mg of morphine, as requested, with a minimal interval between doses of 4 hours during the initial 3 postoperative days. Patients were asked to do straight-leg-raising at 6, 24, and 48 hours after the surgery, and the earliest motion observed was used to define fast, intermediate, and delayed recovery of straight-leg-raising. On Postoperative Day 1 (the day following surgery), the drain tube was removed and bedside exercises, including quadriceps sets, ankle pumps, and gluteal sets, were started. The total blood loss was defined as the cumulative amount lost during surgery and collected by the drain. On Postoperative Day 2, exercises included active-assistive range of motion of the knee, strengthening of the quadriceps and hamstrings, terminal knee extension, transfer training, and ambulation training with a walker. During Postoperative Days 3–7, training for climbing stairs and other activities of daily life was added. The VAS pain scores on Postoperative Days 1 and 3 and the range of motion on Postoperative Day 7 were recorded. Patients were discharged on Postoperative Day 7 due to regulations of the National Health Insurance policy and instructed to use the walker until independent ambulation at 1 month after surgery.

At the 2-month follow-up examination, the length of the surgical scar was measured with knee flexion at 60°. Standing hip-to-ankle radiographs of the anteroposterior projection were taken to measure the position of the prosthesis, as described previously.[18] Briefly, the femoral component angle was the medial angle between the horizontal tangential line at the distal surface of the femoral component and the axis of the femur. The tibial component angle was the medial angle between the surface of the tibial component and the axis of the tibia. The bone cut during the surgery was fashioned to expect a 97° femoral component angle and a 90° tibial component angle. The deviation of the postoperatively measured angles from their expected values represented the accuracy of the bone cut.

Statistical analyses were done with SPSS software (SPSS Inc., Chicago, IL, USA) on a Microsoft Windows-based computer. Continuous variables, such as age, BMI, VAS pain score, and range of motion, were compared by independent-sample t tests between the two groups and by paired t tests within the same group. Nonparametric variables, such as the HSS knee score, were evaluated by the Mann–Whitney test. Categorical variables were analyzed with chi-square contingency tables. At least 37 patients were required to be able to determine a significant difference ($p < 0.05$) at a power of 0.8 between the two groups.

Results

No significant postoperative morbidity was reported in any patient. All patients completed the 2-month follow-up examination, but three patients (five knees) dropped out of the study after the surgery. Contact was lost with two of them (four knees), and the remaining one had an ipsilateral femoral intertrochanteric fracture 20 months after the surgery. Therefore, data from the 29 patients (38 knees, 95%) remaining in the quadriceps-sparing group and the 28 patients (37 knees, 93%) in the standard group were used in the statistical analysis. There were no infections or revisions in these patients before the final follow-up examination.

The preoperative baseline values for mean age, BMI, range of motion, VAS pain score, and HSS knee score were not significantly different between the two groups (Table 1). The mean surgical time and tourniquet time were significantly longer in the quadriceps-sparing group, but the mean blood loss was comparable between the two groups (Table 2). All patients were capable of straight-leg-raising at 48 hours post surgery; the promptness of the return to straight-leg-raising was comparable between the two groups (Table 3).

The mean VAS pain score did not differ significantly between the two groups at any time during the Postoperative Day 1, Day 3, 2-month, or 2-year follow-up

Table 1 Preoperative profiles of patients who completed the final follow-up examination.

	Quadriceps sparing	Medial parapatellar	p
Number of patients (male/female)	30 (3/27)	30 (3/27)	
Number of TKA	38	37	
Age (y)	69.7 ± 5.3	69.8 ± 5.4	0.87
Body mass index	28.6 ± 3.8	29.6 ± 3.5	0.26
Range of motion	$110.1 \pm 18.6°$	$110.7 \pm 19.5°$	0.90
VAS pain score (cm)	5.3 ± 2.2	5.5 ± 2.0	0.73
HSS knee score	64.3 ± 12.3	65.2 ± 12.4	0.78

BMI = body mass index; HSS = Hospital for Special Surgery; TKA = total knee arthroplasty; VAS = visual analog scale.

Table 2 Postoperative parameters of patients who completed the final follow-up examination.

	Quadriceps sparing	Medial parapatellar	*p*
Time consumption			
Tourniquet time (min)	58.7 ± 7.6	37.7 ± 8.4	<0.0001*
Operation time (min)	89.6 ± 9.3	66.9 ± 13.7	<0.0001*
Blood loss			
During surgery (mL)	163.2 ± 61.2	166.2 ± 79.1	0.85
Drain collection (mL)	470.3 ± 150.5	491.2 ± 136.3	0.53
Total (mL)	633.4 ± 158.1	657.4 ± 158.9	0.52
Blood transfusion (mL)	915 ± 275	945 ± 317	0.65
Length of surgical scar (cm)	12.2 ± 0.9	12.9 ± 0.8	<0.001*
Position of prosthesis			
Femoral component angle	95.9 ± 1.8°	97.4 ± 1.1°	<0.0001*
Tibial component angle	88.6 ± 1.3°	89.5 ± 0.9°	<0.01*

The length of the surgical scar and the position of the prosthesis were determined by plain roentgenograms at 2 months after surgery.
Asterisks indicate significant differences between groups.

examinations (Fig. 1), nor did the mean range of motion differ significantly at any time during the Postoperative Day 7, 2-month, or 2-year follow-up examinations (Fig. 2). Both groups exhibited similar results for the following factors. Although the mean range of motion did not change significantly from the preoperative baseline value to the 2-month follow-up examination, it increased significantly from the 2-month to the 2-year follow-up examination (Fig. 2). The mean HSS knee score did not differ significantly between the two groups at the 2-month and 2-year follow-up examinations (Fig. 3). In the two groups, the mean HSS knee scores increased significantly from the preoperative baseline value to the 2-month follow-up examination and also from the 2-month to the 2-year follow-up examination.

The mean percentage recovery of the peak torque of the quadriceps and hamstring muscles at either velocity did not differ significantly between the two groups at the 2-month and 2-year follow-up examinations (Fig. 4). Both groups showed a similar recovery of quadriceps torque. The low-velocity torque had about 90–95% recovery at 2 months and exceeded the baseline at 2 years, whereas the high-velocity torque exceeded the baseline at both follow-up examinations. The same course was noted for hamstring muscle torque. The low-velocity torque had about 97% recovery at 2 months and exceeded the baseline at 2 years, whereas the high-velocity torque exceeded the baseline value at both follow-up examinations.

At the 2-month follow-up examination, the H/Q ratio at either velocity in either group increased from its preoperative baseline. The changes were insignificant, except for a significant increase in the low velocity in the quadriceps-sparing group. At the 2-year follow-up examination, however, the H/Q ratios at both velocities in both groups were significantly lower than their corresponding preoperative baseline values (Fig. 5). Between the two groups, the H/Q ratio of either velocity was not significantly different for preoperative baseline values and at the 2-month and 2-year follow-up examinations.

At the 2-month follow-up examination, the surgical scars were significantly shorter in the quadriceps-sparing group.

Table 3 Promptness of return to straight-leg-raising after surgery.

	Quadriceps sparing	Standard
Fast	13 (34%)	8 (22%)
Intermediate	11 (29%)	13 (35%)
Delayed	14 (37%)	16 (43%)

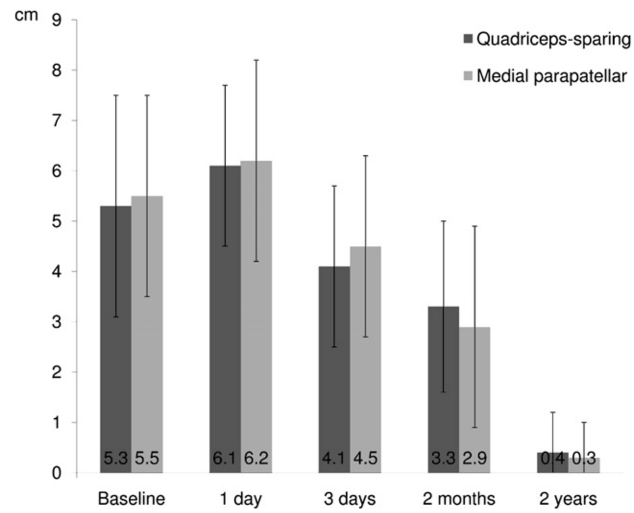

Figure 1 Pain scores by a 10-cm visual analog scale.

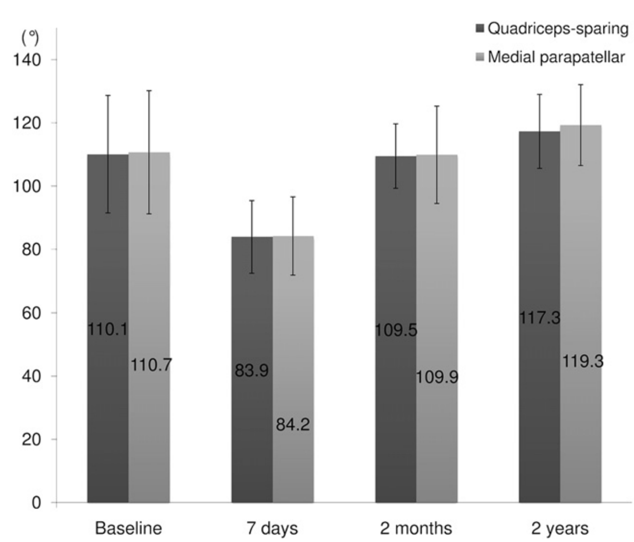

Figure 2 Range of motion.

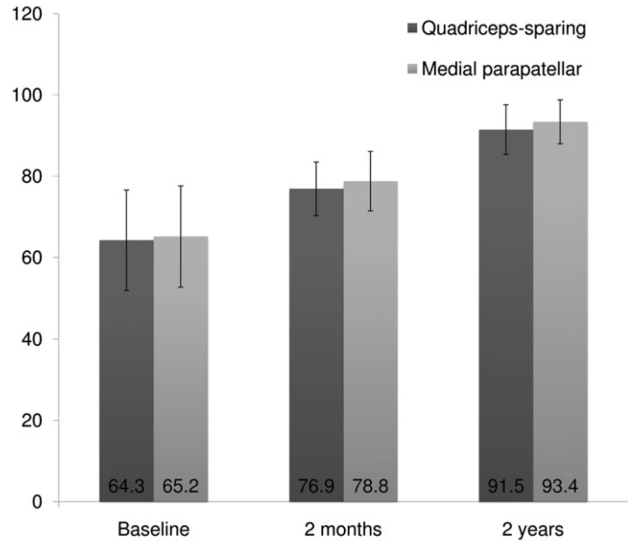

Figure 3 Hospital for Special Surgery knee score.

The position of the prosthesis was significantly less accurate in the quadriceps-sparing group. Both the deviation of the mean femoral component angle from the expected 97° and the deviation of the mean tibial component angle from the expected 90° were larger in the quadriceps-sparing group (Table 2). The femoral components in three knees and the tibial component in one knee of the quadriceps-sparing group had varus deviation equal to or greater than 4°.

Discussion

Quadriceps muscle strength, which is a critical factor in the functional results after TKA, correlates with knee scores positively.[19] However, 1 month after the surgery, the strength may decrease as much as 62%,[20] primarily due to lost voluntary muscle activation and, to a lesser extent, due to muscle atrophy. Various techniques of minimally invasive arthrotomy have been introduced to preserve the quadriceps muscle and tendon in TKA. Although quadriceps-sparing arthrotomy has been reported to result in a quicker and better recovery of quadriceps muscle power,[11,14] few studies in the literature have provided quantitative evidence by isokinetic studies. A previous study reported that the decrease of quadriceps strength from the preoperative baseline was 50% by standard arthrotomy and 30% by quadriceps-sparing arthrotomy at 2 weeks after TKA, and concluded that the quadriceps-sparing technique did less damage to the quadriceps by minimizing the quadriceps incision and patellar eversion.[21]

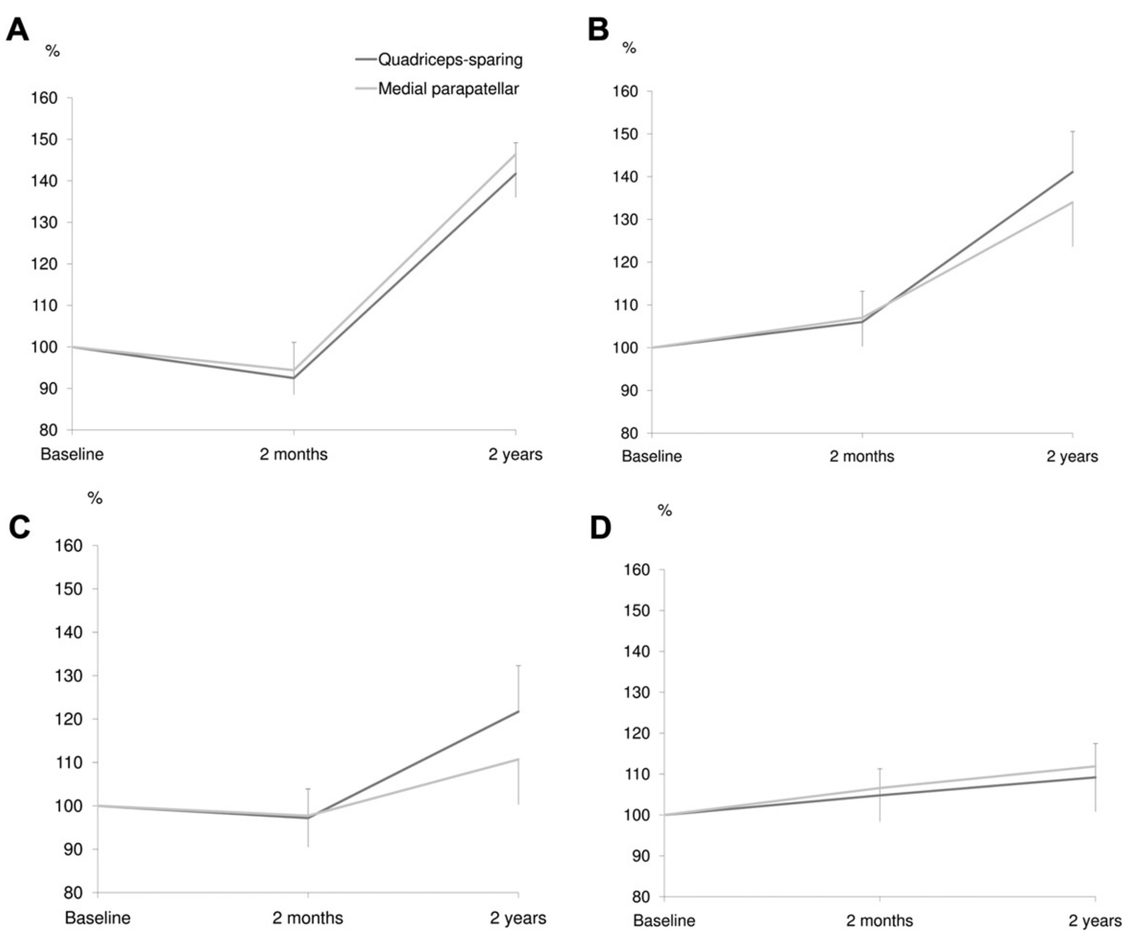

Figure 4 Percentage recovery of muscle torques after the surgery: quadriceps at (A) low and (B) high velocities and hamstring at (C) low and (D) high velocities.

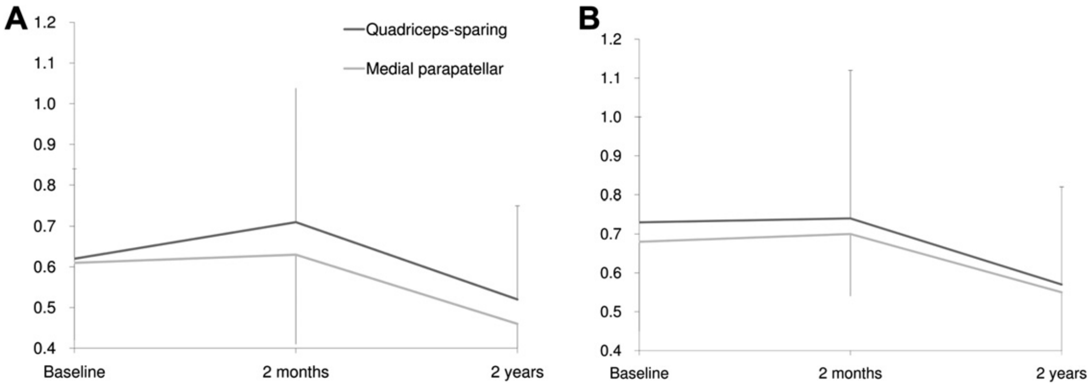

Figure 5 Change of hamstring/quadriceps (H/Q) ratio at (A) low and (B) high velocities.

However, we believe that the observation of muscle power may be biased by a number of factors, including pain and inadequate adaptation at 2 weeks post surgery. Instead, we suggested that the short-term condition of muscle strength should be evaluated at 2 months post surgery. In our study, quadriceps strength decreased by approximately 10%, and there was no significant difference between the two groups, indicating that the initial loss of quadriceps strength was comparable in the quadriceps-sparing and standard arthrotomies.

Minimally invasive TKA has also been promoted for rapid postoperative recovery of quadriceps strength, which is weaker at 3 months than at the preoperative level, yet is 17% stronger at 6 months and 30% stronger at 1 year.[22] We had a similar finding, and, in addition, we observed 40% increased strength at 2 years. However, our comparative study revealed a similar recovery after standard arthrotomy, indicating that factors other than the type of arthrotomy performed might contribute to the recovery of muscle strength.

The H/Q ratio normally ranges from 0.50 to 0.80,[23,24] and, due to the weakness of the quadriceps, may remain elevated for months or even years after standard medial parapatellar TKA.[25–27] This held true in our findings at 2 months post surgery, but the elevation was insignificant with an H/Q ratio in the normal range. Furthermore, for both groups in our study, the H/Q ratio at 2 years dropped to a value that was significantly lower than the preoperative baseline and the 2-month postoperative value, indicating that the increase of quadriceps muscle torque was greater than the increase of hamstring muscle torque. This might have been due to more intensive postoperative rehabilitation on the quadriceps than on the hamstrings. TKA for varus knee usually requires an extensive release of the posteromedial structure, including part of the hamstring muscle. The hamstring muscle may be damaged during the procedure; hence, we suggest that the training of this muscle should be included in the postoperative rehabilitation. The H/Q ratio was not significantly different between the two groups at any time. We assumed that the hamstring and quadriceps muscle torques were also affected by the lost proprioception from the sacrificed cruciate ligaments. The muscle torque may be affected more by the change of proprioception than by the surgical damage.

Proper alignment of the lower limb after TKA is also critical for faster functional recovery and long-term survival of the prostheses.[28–31] Although several retrospective studies show that minimally invasive techniques yield comparable postoperative alignments with standard techniques,[6–10,12] others have debated that minimally invasive techniques may increase the risk of component malposition.[14,17,18,32] In our study, both the femoral and the tibial component angles were significantly smaller in the quadriceps-sparing group, which was probably due to the side-cutting technique. These two smaller angles together constituted a more varus alignment of the lower limb that might jeopardize the longevity of the prosthetic knee. A long and stiff saw blade may provide a more accurate bone cut than a side-cutting instrument and, thus, less malposition of the prosthesis.[8,18] In our study, malposition of more than 4° from the expected prosthesis position occurred in four knees (one tibial and three femoral components) in the quadriceps-sparing group. All four patients had a higher BMI than the average of the group, indicating that accurate prosthesis installation with the quadriceps-sparing technique might be more difficult in obese patients due to the limited operative field. Careful screening of patients may be important to ensure correct installation of the prosthetic knee with minimally invasive techniques.

The advantages of quadriceps-sparing arthrotomy for the immediate postoperative outcomes are also controversial. Although a faster return of straight-leg-raising and a larger range of motion at 2 weeks have been reported with quadriceps-sparing arthrotomy compared to standard arthrotomy,[17] other studies show no significant difference in these parameters.[14,18,32,33] We also observed comparable immediate postoperative results between these two arthrotomies for some factors, including pain score, range of motion, and return of straight-leg-raising. Disadvantages of the quadriceps-sparing technique include a longer surgical time and an unfavorable learning curve.[12,14,17,18,32–34] Our findings were consistent with this. The mid-term outcomes at 2 years, including the HSS knee score and range of motion, were comparable between the two arthrotomies in our study.

In general, our findings regarding postoperative recovery of muscle power after quadriceps-sparing TKA were compatible with previous studies[14,32]; we added an evaluation of muscle power with objective and quantitative parameters in order to affirm the results further. The limitation of this study was the absence of a quantitative assessment of muscle within the 2-month postoperative period in order to evaluate the proposed short-term benefits of quadriceps-sparing TKA.[21] A determination of muscle power by the Cybex dynamometer was very difficult, if not impossible, for the TKA patients within this period because of postoperative pain. Thus, because of ethical concerns, we waited until 2 months after the surgery to take the measurement. We concluded that the quadriceps-sparing TKA did not give a better postoperative outcome than the standard TKA in the short- and mid-term of up to 2 years.

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