The Journal of Arthroplasty 31 (2016) 2481–2486

Contents lists available at ScienceDirect

The Journal of Arthroplasty

journal homepage: www.arthroplastyjournal.org

Primary Arthroplasty

Semimembranosus Release for Medial Soft Tissue Balancing Does Not Weaken Knee Flexion Strength in Patients Undergoing Varus Total Knee Arthroplasty

Sung Won Jang, MD, In Jun Koh, MD, PhD, Man Soo Kim, MD, Ju Yeong Kim, MD,
Yong In, MD, PhD *

Department of Orthopaedic Surgery, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, Seoul, Korea

ARTICLE INFO

Article history:
Received 21 January 2016
Received in revised form
16 April 2016
Accepted 21 April 2016
Available online 30 April 2016

Keywords:
knee
arthroplasty
varus
semimembranosus
release

ABSTRACT

Background: The sequential medial release technique including semimembranosus (semiM) release is effective and safe during varus total knee arthroplasty (TKA). However, there are concerns about weakening of knee flexion strength after semiM release. We determined whether semiM release to balance the medial soft tissue decreased knee flexion strength after TKA.

Methods: Fifty-nine consecutive varus knees undergoing TKA were prospectively enrolled. A 3-step sequential release protocol which consisted of release of (1) the deep medial collateral ligament (dMCL), (2) the semiM, and (3) the superficial medial collateral ligament based on medial tightness. Gap balancing was obtained after dMCL release in 31 knees. However, 28 knees required semiM release or more after dMCL release. Isometric muscle strength of the knee was compared 6 months postoperatively between the semiM release and semiM nonrelease groups. Knee stability and clinical outcomes were also compared.

Results: No differences in knee flexor or extensor peak torque were observed between the groups 6 months postoperatively ($P = .322$ and $P = .383$, respectively). No group difference was observed in medial joint opening angle on valgus stress radiographs ($P = .327$). No differences in the Knee Society or Western Ontario and McMaster Universities Osteoarthritis Index scores were detected between the groups ($P = .840$ and $P = .682$, respectively).

Conclusion: These results demonstrate that semiM release as a sequential step to balance medial soft tissue in varus knees did not affect knee flexion strength after TKA.

Preoperative varus knee deformity with a tight medial gap is a common problem in total knee arthroplasty (TKA) candidates [1-3]. Inappropriate balancing of medial soft tissue in patients undergoing varus TKA can lead to early failure such as instability, wear, or loosening [4,5]. The medial stabilizing soft tissue structures consist of the deep medial collateral ligament (dMCL), the superficial medial collateral ligament (sMCL), the semimembranosus (semiM), the pes anserinus, the posteromedial capsule, and the posterior oblique ligament (POL), and so on (Fig. 1) [6,7]. Gradual subperiosteal release of the sMCL from its tibial attachment is traditionally used as the medial soft tissue balancing technique during varus TKA, but quantitative precise gap balancing is technically demanding using this technique [5,8-15].

Various algorithmic release techniques have been introduced including the semiM release (SR) as a sequential step, even though the correct method for defining the sequence, extent, and magnitude of medial soft tissue releases required during varus TKA remains ill defined [7]. Mullaji et al [16] suggested a medial gap balancing technique consisting of sequential release of the dMCL, semiM, pes anserinus, and sMCL. Matsumoto et al [17-19] suggested a step-by-step medial release sequence, involving release of the posteromedial capsule followed by the MCL, semiM, and pes anserinus. Yagishita et al [20] reported their step-by-step release technique, which consisted of release of the dMCL, semiM, and complete release of the sMCL 8-10 cm distal to the

---

No author associated with this paper has disclosed any potential or pertinent conflicts which may be perceived to have impending conflict with this work. For full disclosure statements refer to http://dx.doi.org/10.1016/j.arth.2016.04.022.

* Reprint requests: Yong In, MD, Department of Orthopaedic Surgery, Seoul St. Mary's Hospital, College of Medicine, The Catholic University of Korea, 222 Banpo-Daero, Seocho-Gu, Seoul, 137 701, Korea.

http://dx.doi.org/10.1016/j.arth.2016.04.022
0883-5403/

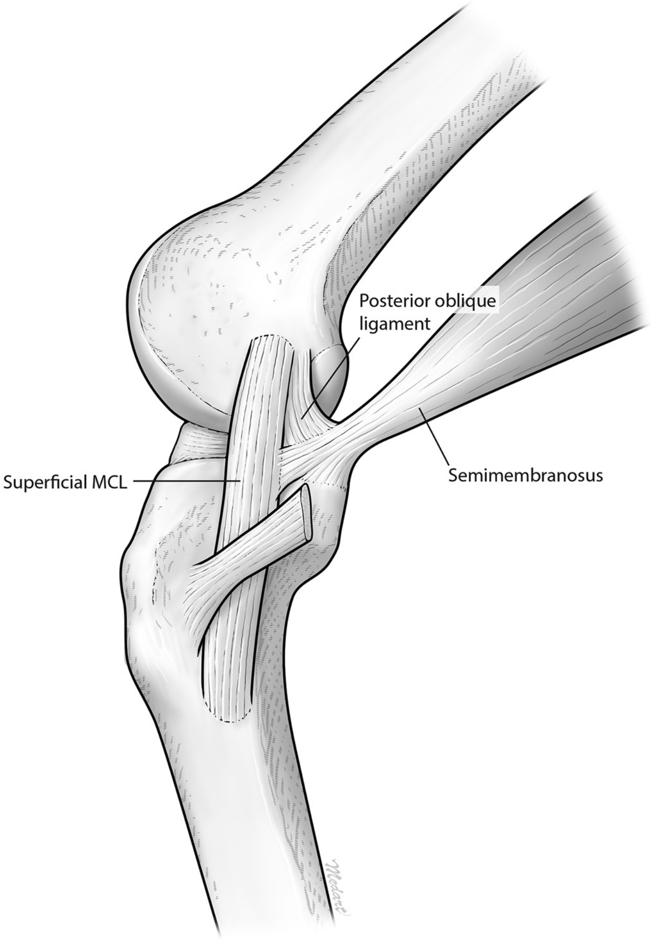

Fig. 1. Posteromedial corner of a right knee, demonstrating the tibial insertion of the semimembranosus. MCL, medial collateral ligament.

medial joint. Kim et al [21] reported that their three-step release technique, including SR as the second step, was efficacious and safe. However, the semiM muscle is not only a dynamic stabilizer but also an internal rotator and flexor of the knee [22]; thus, there are concerns about weakening flexion strength and causing residual instability after release of the semiM.

Although Matsumoto et al [23] reported that SR reduces tibial internal rotation and flexion angle after implantation of a cruciate-retaining (CR) type prosthesis, few data on flexion strength of the knee, stability, and the functional outcomes after SR are available for medial soft tissue balancing in varus TKA. The purpose of this study was to compare isometric flexor contraction torque, isometric extensor contraction torque, and the flexor/extensor ratio between patients who received SR for soft tissue balancing and those who did not during posterior-stabilized (PS) TKA for varus deformed knees. We hypothesized that isometric flexion peak torque in patients who underwent SR would be the same as those in patients who did not.

Material and Methods

Fifty-nine varus knees of 37 patients (33 women and 4 men) undergoing primary TKA from July 2013 to February 2014 were enrolled in this prospective cohort study. This study was approved by the Institutional Review Board of our hospital, and all patients provided informed consent. All knees showed varus alignment of the femorotibial angle >0° on preoperative standing anteroposterior radiographs. Exclusion criteria included patients who had previous knee surgery, inflammatory arthritis, flexion contracture >20°, history of neurologic impairment, and refusal to participate.

The mean preoperative femorotibial angle was varus 4.9° (range: varus, 0.1° to varus, 17.8°), and mean hip-knee-ankle axis was 169.4° (range, 152°-179°). Mean patient age was 70 years (range, 60-86 years), and mean body mass index was 27.3 kg/m^2 (range, 21.8-35.3 kg/m^2). The mean preoperative range of motion of the knee was 125.2° (range, 90°-135°). The diagnosis was Kellgren-Lawrence grade 4 osteoarthritis [24] in all knees.

All surgeries were performed by a single senior surgeon (one of the authors) under general anesthesia using a PS knee prosthesis (LOSPA; Corentec Inc, Seoul, Korea). A pneumatic tourniquet was inflated to 300 mmHg. A subvastus approach was used in all cases. Three-step algorithmic release technique was applied, which consisted of (1) dMCL release, (2) SR, and (3) multiple needle puncturing of the sMCL until equal rectangular space was achieved [21]. After medial meniscectomy, the dMCL was released at the meniscocapsular junction. A periosteal elevator was inserted at the midmedial portion, and the release was performed from the dMCL to the anteromedial capsule with a knife. The anterior cruciate ligament and posterior cruciate ligament (PCL) were removed before cutting bone. Then, the distal femur was cut 6° of valgus to the anatomic axis. An intramedullary alignment guide system was used for the femoral cuts and an extramedullary system for the tibial cut. External rotation of the femur was determined using the anteroposterior axis, the posterior condylar axis, and the transepicondylar axis. The tibia was cut to about 10-mm thickness from the lateral tibial plateau perpendicularly to the mechanical axis of the tibia. The flexion and extension gaps were evaluated using a spreader device (Aesculap, Tuttlingen, Germany). When the mediolateral gap difference was within 2 mm, the flexion and extension gaps were considered balanced. The distal femur was recut when the extension gap was tight.

Of the 59 varus TKAs, equal medial and lateral gaps were obtained after step 1 release (dMCL release) in 31 knees. However, the remaining 28 knees had a trapezoidal unbalanced extension or flexion gap after the first step of the release procedure, so semiM or sMCL release was required. The expansion of the semiM was cut with a # 10 blade and released completely with a periosteal elevator from tibial insertion including the posteromedial capsule in flexion position. Twenty-four of 28 knees were balanced after the step 2 release (SR); however, 4 knees remained tight on the medial side even after step 2 release. Thus, step 3 release (sMCL release) was applied. The sMCL was punctured with multiple 18 G spinal needles after trial placement of the femoral component until the intended trial tibial and polyethylene components were inserted. The needle puncturing was performed in a gentle manner by palpating the taut portion of the sMCL. All 4 knees obtained appropriate gap balance after the step 3 release. All patellae were resurfaced, and all components were cemented. An intraarticular suction drain was inserted and removed within 48 hours after the surgery. All patients were discharged from the hospital 1 week postoperatively.

The knees were grouped into 2 groups according to the medial release steps, such as the semiM nonrelease group (SNR) and the SR group. In other words, the SNR group included knees balanced after step 1 release (31 knees), and the SR group contained knees requiring step 2 release or more (28 knees). Clinical and radiographic assessments were performed preoperatively and 6 weeks, 3 months, and 6 months postoperatively. The primary outcome variable was isometric flexion peak torque 6 months postoperatively. The secondary outcome variables were knee stability measured on valgus and varus stress radiographs using a Telos Stress Device (Telos, Marburg, Germany) and functional outcomes based on the Knee Society score and the Western Ontario and McMaster Universities Osteoarthritis Index score [25,26].

In all cases, flexion and extension strength of the knee (maximal isometric contraction) were measured using a dynamometer (Primus RS; BTE Technologies, Denver, CO) preoperatively and 6 months postoperatively (Fig. 2). A single rehabilitation medicine physician measured peak contraction torque. Patients warmed up on a bicycle for 5 minutes before testing. The patients were seated on the dynamometer with their pelvis and thighs secured. The anatomic axis of the knee was aligned with the axis of the dynamometer. A force transducer was secured around the ankle 5 cm above the lateral malleolus. A belt harness was placed around the patient's chest and both thighs for stabilization. The patients were instructed to provide maximum effort throughout the test using visual and verbal feedback. A set of 2 maximal isometric contractions (4 seconds each) at each measurement time point with knee positioned at 60° flexion was performed. Isometric dynamometer testing at 60°/second is the safest and most reproducible method to test muscle strength [27-29]. Two peak torque measurement values for extension and flexion were taken. We calculated the highest peak force by multiplying the averaged data from the 2 trials, normalized to body mass (Nm/kg). Maximum values were registered and used to calculate the flexion power to extension power (F/E) ratio.

Fig. 2. Isometric muscle strength test.

Table 1
Comparison of Preoperative Demographics.

	SNR Group[a] (n = 31)	SR Group[b] (n = 28)	*P* Value
Female:male (knees)	28:3	26:2	.639
Age (y)	70.6 ± 5.3 (61-86)	70.0 ± 5.6 (60-81)	.571
BMI (kg/m^2)	27.1 ± 3.1 (21.8-32.9)	27.4 ± 3.4 (22.3-35.3)	.135
Range of motion (°)	125.8 ± 12.5 (90-135)	124.6 ± 10.7 (100-135)	.293
Femorotibial angle (°)	Varus 3.8 ± 4.1 (0.1-13.1)	Varus 6.1 ± 5.2 (0.1-17.8)	<.001
Hip-knee-ankle axis (°)	171.5 ± 5.4 (161-179)	167.2 ± 6.2 (152-175)	<.001

Data are means ± standard deviations (range).
SNR, semimembranosus nonrelease; SR, semimembranosus release; BMI, body mass index.
[a] Semimembranosus nonrelease group.
[b] Semimembranosus release group.

Statistical Analysis

Our primary outcome measurement was maximum isometric flexion torque 6 months postoperatively. We performed an “a priori” power analysis based on the results of a previous study [30] to determine whether our sample size had sufficient statistical power. We estimated that 25 knees would be required for each group to provide power of 80% to detect a muscle strength change of 20% with a two-sided α of 0.05. All measurements are expressed as means ± standard deviations. The Shapiro-Wilk test was used to determine normality of the data. Student *t* test or the paired *t* test was used to analyze continuous variables. Fisher exact test was used to detect differences in categorical variables. A $P < .05$ was considered significant. Statistical analyses were performed using SPSS, version 21.0, for Windows (SPSS Inc, Chicago, IL).

Results

The preoperative demographics are summarized in Table 1. No differences were observed in the preoperative demographics between the SNR and SR groups, except severity of varus deformity. The SR group showed more severe varus deformity than that of the SNR group ($P < .001$).

The preoperative and postoperative mean peak isometric contraction torque values are summarized in Table 2. Preoperative mean flexor peak torque, extensor peak torque, and the F/E ratio of

Table 2
Comparison of Peak Isometric Contraction Torque Values Preoperatively and 6 Months Postoperatively.

	Preoperative	Postoperative 6 mo	*P* Value
Flexor peak torque (Nm/kg)			
SNR group[a] (n = 31)	1.5 ± 0.5 (0.9-2.7)	2.0 ± 0.4 (1.3-3.1)	.015
SR group[b] (n = 28)	1.6 ± 0.5 (0.9-2.8)	1.9 ± 0.5 (1.2-3.0)	.033
P value	.213	.322	
Extensor peak torque (Nm/kg)			
SNR group (n = 31)	3.0 ± 1.1 (1.1-6.3)	3.8 ± 1.0 (1.9-6.6)	<.001
SR group (n = 28)	3.0 ± 1.0 (1.6-6.2)	3.8 ± 1.1 (2.3-6.6)	<.001
P value	.662	.383	
F/E ratio[c]			
SNR group (n = 31)	0.64 ± 0.2 (0.42-0.94)	0.62 ± 0.2 (0.38-0.92)	.137
SR group (n = 28)	0.59 ± 0.1 (0.41-0.94)	0.54 ± 0.2 (0.31-0.77)	.148
P value	.691	.741	

Data are means ± standard deviations (range).
SNR, semimembranosus nonrelease; SR, semimembranosus release; F/E, flexion power to extension power.
[a] Semimembranosus nonrelease group.
[b] Semimembranosus release group.
[c] Flexion peak torque/extension peak torque ratio.

Table 3
Comparison of Medial and Lateral Joint Opening Angles on Stress Radiographs Between the Groups.

	SNR Group[a] (n = 31)	SR Group[b] (n = 28)	*P* Value
Medial joint opening angle (°)	2.6 ± 1.1 (0.5-4.8)	2.9 ± 1.2 (0.8-4.5)	.327
Lateral joint opening angle (°)	3.7 ± 1.5 (0.1-7.1)	3.2 ± 1.9 (0.1-6.8)	.352
Difference (°)	6.3 ± 1.5 (3.1-9.2)	6.1 ± 2.7 (2.2-11.3)	.815

Data are means ± standard deviations (range).
SNR, semimembranosus nonrelease; SR, semimembranosus release.
[a] Semimembranosus nonrelease group.
[b] Semimembranosus release group.

the knee did not differ between the groups ($P = .213$, $P = .662$, and $P = .691$, respectively). Mean flexor peak torque and extensor peak torque were increased significantly in both groups 6 months postoperatively, compared to their preoperative values (SNR group; $P = .015$ and $P < .001$, respectively, and SR group; $P = .033$ and $P < .001$, respectively). However, mean flexor peak torque, extensor peak torque, and the F/E ratio of the knee did not differ between the 2 groups ($P = .322$, $P = .383$, and $P = .741$, respectively) 6 months postoperatively.

The mean postoperative knee range of motion was 129.9 ± 9.2° (range, 105°-138°) in the SNR group and 130.1 ± 8.1° (range, 110°-138°) in the SR group ($P = .432$). Knee stability on the coronal plane was compared between the groups on stress radiographs 6 months after surgery (Table 3). No differences in the medial joint opening angle on the valgus stress radiograph or the lateral joint opening angle on the varus stress radiograph were detected between the SNR and SR groups ($P = .327$ and $P = .352$, respectively). No differences in preoperative and postoperative functional outcomes or Knee Society score and Western Ontario and McMaster Universities Osteoarthritis Index score were observed between 2 groups ($P > .1$ in all comparisons; Table 4).

Discussion

This study compared flexor peak torque, extensor peak torque, and the F/E ratio between the SNR and SR groups after TKA. The major finding was that SR as a sequential step for medial soft tissue balancing did not weaken flexion strength of the knee 6 months after TKA.

The term "balanced knee" describes a knee with normal motion that is not hindered by soft tissue constraint [31]. A stepwise release technique is the ideal way to correct medial contracture in varus knees and avoid unnecessary overrelease [3,11,20,32,33]. Although variations in releasing structures and sequences exist, many authors include SR as a sequential medial release step for varus TKA [1,2,16-19,21,34].

Controversy persists on the safety of SR. Chen et al [34] reported that great care should be taken when the semiM is released during PS TKA. Theoretically, SR is effective mainly for extension because the fibers run perpendicular to the femorotibial joint in the extended position but parallel to the femorotibial joint during flexion. However, after excising the PCL, the effect of releasing the semiM becomes larger, which can alter the laxity pattern of the knee toward instability [7,34]. In contrast, Koh and In [1] reported that SR is safe, efficient, and reliable. They measured the gap increase after SR during TKA. Medial gaps increased significantly at 0°, 45°, and 90° of knee flexion by 1.45 ± 1.60, 2.00 ± 1.57, and 2.25 ± 1.29 mm, respectively. Lateral gaps also increased significantly after SR, except in full extension, in which the gaps increased by 0.51 ± 1.82, 1.06 ± 2.06, and 1.41 ± 1.58 mm, respectively. In our study, SR was efficacious and safe for balancing the medial soft tissue. Twenty-four of 28 knees (85.7%) that remained tight medially after dMCL release were balanced after SR. This finding shows that our three-step release technique was conservative as possible for releasing the sMCL. Only the last 4 knees were balanced after additional sMCL needle puncturing. No knee was unstable after SR or sMCL needle puncturing.

The collective term "hamstrings" refers to the 4 muscles located in the posterior compartment of the thigh, such as the semiM, semitendinosus (semiT), biceps femoris long head, and biceps femoris short head [35]. The SemiM and semiT flex the knee and internally rotate the lower leg when the knee is bent. The short and long heads of the biceps femoris flex the knee and externally rotate the lower leg when the knee is bent [35,36]. In our study, complete SR did not weaken knee flexion strength 6 months postoperatively. Possible explanations for this lack of a difference in flexor peak torque between the groups could be the complex nature of the hamstring muscles. Both the biceps femoris and semiT compensate for the knee flexion function of the semiM.

The posteromedial one-third of the knee extends from the posterior edge of the MCL to the medial edge of the PCL. The major components are the POL, expansion of the semiM, the oblique popliteal ligament, and the posteromedial horn of the medial meniscus [37]. Five expansions of the semiM have been described: (1) the pars reflexa; (2) direct posteromedial tibial insertion; (3) oblique popliteal ligament insertion; (4) expansion to the POL; and (5) the popliteus aponeurosis expansion [37]. The semiM contributes to the dynamic stabilization of the posteromedial corner and allows for retraction of the posterior meniscus during knee flexion [37]. Unlike the kinematic pattern of a normal knee, the stability of an implanted knee is mainly maintained by the conformity and constraints of the implant. In this study, we used a PS knee prosthesis, and femoral rollback was maintained by the cam-post mechanism of the knee system.

Matsumoto et al [23] reported that minimal medial release and avoiding SR maintains internal tibial rotation during CR TKA,

Table 4
Comparison of Clinical Outcomes Preoperatively and 6 Months Postoperatively.

	SNR Group[a] (n = 31)		SR Group[b] (n = 28)		*P* Value	
	Preoperative	Postoperative	Preoperative	Postoperative	Preoperative	Postoperative
KSS score	116.9 ± 24.2 (62-155)	157.5 ± 23.5 (102-175)	113.6 ± 24.3 (60-155)	161.1 ± 25.7 (140-175)	.617	.840
Pain	28.8 ± 9.7 (0-40)	46.2 ± 7.8 (20-50)	29.3 ± 8.2 (0-40)	49.5 ± 7.5 (20-50)	.587	.813
Function	88.1 ± 23.5 (35-125)	111.3 ± 19.3 (50-142)	84.3 ± 19.2 (32-115)	111.6 ± 18.6 (50-142)	.718	.532
WOMAC	135.8 ± 42.6 (67-230)	22.6 ± 17.1 (1-57)	134.3 ± 40.1 (53-226)	27.1 ± 23.5 (3-78)	.611	.682
Pain	28.9 ± 11.3 (9-47)	1.4 ± 2.1 (0-6)	27.9 ± 13.2 (8-47)	1.2 ± 2.1 (0-6)	.514	.824
Stiffness	10.9 ± 5.6 (3-20)	2.4 ± 1.6 (0-10)	10.5 ± 5.3 (2-20)	3.0 ± 2.1 (0-10)	.627	.463
Function	96.0 ± 36.2 (46-163)	18.8 ± 16.8 (0-53)	95.9 ± 43.5 (37-159)	22.9 ± 15.3 (1-68)	.635	.619

Data are means ± standard deviations (range).
SNR, semimembranosus nonrelease; SR, semimembranosus release; KSS, Knee Society score; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index score.
[a] Semimembranosus nonrelease group.
[b] Semimembranosus release group.

resulting in a high postoperative flexion angle. However, they measured the tibial internal rotation angle intraoperatively using navigation kinematic data obtained during the motion cycle only in a SR group. The kinematic patterns of axial femorotibial rotation after TKA can be paradoxical and are different from those of a normal knee. Although normal axial rotation patterns are essential to maximize knee flexion, Dennis et al [38] reported that all TKA groups including CR and PS had at least 19% of patients with a reverse axial rotation pattern during deep knee bend. Of course, if a varus deformed knee can be balanced with only minimal dMCL release, additional SR would be unnecessary. In contrast, we used a PS prosthesis, and no difference in postoperative range of motion was detected between the SNR and SR groups.

Lorentzen et al [39] reported that peak isometric extension torque decreased temporarily 3 months after TKA but returned to the preoperative level 6 months postoperatively. In the present study, we compared flexion strength between the SNR and SR groups 6 months postoperatively. Although mean flexor and extensor peak torques increased significantly in both groups compared with their preoperative values, no differences in postoperative peak flexor or extensor torques or the F/E ratio were detected between the groups.

This study had several limitations. First, all patients were Asian, so the demographic characteristics, such as a pronounced female predominance or more frequent varus knee alignment of our study population, should be noted before extrapolating the findings to other ethnic populations [40-43]. Second, because our study was performed using a fixed bearing PS prosthesis, dynamometer data or clinical outcomes may be different from those of a mobile or CR prosthesis. Third, we compared only flexion and extension strength of the knee using an isokinetic dynamometer and did not evaluate tibial internal rotation strength. Fourth, this study lacked long-term follow-up results. Although no differences in muscle strength, extension knee stability, or clinical outcomes were observed 6 months postoperatively, longer term follow-up data would support these results. Despite these limitations, this is the first study to evaluate flexion strength after SR to balance the medial soft tissue in patients with varus knees treated by TKA.

In conclusion, our results demonstrate that SR as a sequential step to balance medial soft tissue was efficacious and safe without any apparent increased risk for knee flexion weakness or instability.

Acknowledgments

The authors thank Jong In Lee, MD, PhD (Department of Rehabilitation Medicine, Seoul St. Mary's Hospital, Seoul, Korea), for assistance with the measurements and interpretation of the isometric muscle strength test results.

References

1. Koh HS, In Y. Semimembranosus release as the second step of soft tissue balancing in varus total knee arthroplasty. J Arthroplasty 2013;28(2):273.
2. Engh GA. The difficult knee: severe varus and valgus. Clin Orthop Relat Res 2003;416:58.
3. Bellemans J, Vandenneucker H, Vanlauwe J, et al. The influence of coronal plane deformity on mediolateral ligament status: an observational study in varus knees. Knee Surg Sports Traumatol Arthrosc 2010;18(2):152.
4. Insall JN, Binazzi R, Soudry M, et al. Total knee arthroplasty. Clin Orthop Relat Res 1985;192:13.
5. D'Lima DD, Patil S, Steklov N, et al. Best paper: dynamic intraoperative ligament balancing for total knee arthroplasty. Clin Orthop Relat Res 2007;463:208.
6. Verdonk PC, Pernin J, Pinaroli A, et al. Soft tissue balancing in varus total knee arthroplasty: an algorithmic approach. Knee Surg Sports Traumatol Arthrosc 2009;17(6):660.
7. Hunt NC, Ghosh KM, Athwal KK, et al. Lack of evidence to support present medial release methods in total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2014;22(12):1300.
8. Laskin RS. The Insall Award. Total knee replacement with posterior cruciate ligament retention in patients with a fixed varus deformity. Clin Orthop Relat Res 1996;331:29.
9. Lombardi Jr AV, Nett MP, Scott WN, et al. Primary total knee arthroplasty. J Bone Joint Surg Am 2009;91(Suppl 5):52.
10. Luring C, Bathis H, Hufner T, et al. Gap configuration and anteroposterior leg axis after sequential medial ligament release in rotating-platform total knee arthroplasty. Acta Orthop 2006;77:149.
11. Luring C, Hufner T, Perlick L, et al. The effectiveness of sequential medial soft tissue release on coronal alignment in total knee arthroplasty: using a computer navigation model. J Arthroplasty 2006;21:428.
12. Matsueda M, Gengerke TR, Murphy M, et al. Soft tissue release in total knee arthroplasty. Cadaver study using knees without deformities. Clin Orthop Relat Res 1999;366:264.
13. Tanaka K, Muratsu H, Mizuno K, et al. Soft tissue balance measurement in anterior cruciate ligament-resected knee joint: cadaveric study as a model for cruciate-retaining total knee arthroplasty. J Orthop Sci 2007;12:149.
14. Teeny SM, Krackow KA, Hungerford DS, et al. Primary total knee arthroplasty in patients with severe varus deformity. A comparative study. Clin Orthop Relat Res 1991;273:19.
15. Whiteside LA, Saeki K, Mihalko WM. Functional medical ligament balancing in total knee arthroplasty. Clin Orthop Relat Res 2000;380:45.
16. Mullaji A, Sharma A, Marawar S, et al. Quantification of effect of sequential posteromedial release on flexion and extension gaps: a computer-assisted study in cadaveric knees. J Arthroplasty 2009;24(5):795.
17. Matsumoto T, Kubo S, Muratsu H, et al. Different pattern in gap balancing between the cruciate-retaining and posterior-stabilized total knee arthroplasty. Knee Surg Sports Traumatol Arthrosc 2013;21(10):2338.
18. Matsumoto T, Muratsu H, Kubo S, et al. The influence of preoperative deformity on intraoperative soft tissue balance in posterior-stabilized total knee arthroplasty. J Arthroplasty 2011;26(8):1291.
19. Matsumoto T, Muratsu H, Tsumura N, et al. Soft tissue balance measurement in posterior-stabilized total knee arthroplasty with a navigation system. J Arthroplasty 2009;24(3):358.
20. Yagishita K, Muneta T, Ikeda H. Step-by-step measurements of soft tissue balancing during total knee arthroplasty for patients with varus knees. J Arthroplasty 2003;18(3):313.
21. Kim MW, Koh IJ, Kim JH, et al. Efficacy and safety of a novel three-step medial release technique in varus total knee arthroplasty. J Arthroplasty 2015;30(9):1542.
22. Benninger B, Delamarter T. Distal semimembranosus muscle-tendon-unit review: morphology, accurate terminology, and clinical relevance. Folia Morphol (Warsz) 2013;72(1):1.
23. Matsumoto T, Takayama K, Muratsu H, et al. Semimembranosus release reduces tibial internal rotation and flexion angle in cruciate-retaining total knee arthroplasty. J Arthroplasty 2015;30(9):1537.
24. Kellgren JH, Lawrence JS. Radiological assessment of osteo-arthrosis. Ann Rheum Dis 1957;16(4):494.
25. Bellamy N, Buchanan WW, Goldsmith CH, et al. Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to antirheumatic drug therapy in patients with osteoarthritis of the hip or knee. J Rheumatol 1988;15(12):1833.
26. Insall JN, Dorr LD, Scott RD, et al. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;248:13.
27. Berman AT, Bosacco SJ, Israelite C. Evaluation of total knee arthroplasty using isokinetic testing. Clin Orthop Relat Res 1991;271:106.
28. Rossi MD, Brown LE, Whitehurst M. Knee extensor and flexor torque characteristics before and after unilateral total knee arthroplasty. Am J Phys Med Rehabil 2006;85(9):737.
29. Schroer WC, Diesfeld PJ, Reedy ME, et al. Isokinetic strength testing of minimally invasive total knee arthroplasty recovery. J Arthroplasty 2010;25(2):274.
30. Kim JG, Lee SW, Ha JK, et al. The effectiveness of minimally invasive total knee arthroplasty to preserve quadriceps strength: a randomized controlled trial. Knee 2011;18(6):443.
31. Incavo SJ, Schmid S, Sreenivas K, et al. Total knee arthroplasty using anatomic alignment can produce mid-flexion laxity. Clin Biomech 2013;28(4):429.
32. Fishkin Z, Miller D, Ritter C, et al. Changes in human knee ligament stiffness secondary to osteoarthritis. J Orthop Res 2002;20(2):204.
33. Mihalko WM, Saleh KJ, Krackow KA, et al. Soft-tissue balancing during total knee arthroplasty in the varus knee. J Am Acad Orthop Surg 2009;17(12):766.
34. Chen W, Nagamine R, Kondo K, et al. Effect of medial soft-tissue releases during posterior-stabilised total knee arthroplasty. J Orthop Surg (Hong Kong) 2011;19(2):230.
35. Woodley SJ, Mercer SR. Hamstring muscles: architecture and innervation. Cells Tissues Organs 2005;179(3):125.
36. van der Made AD, Wieldraaijer T, Kerkhoffs GM, et al. The hamstring muscle complex. Knee Surg Sports Traumatol Arthrosc 2015;23(7):2115.
37. Sims WF, Jacobson KE. The posteromedial corner of the knee: medial-sided injury patterns revisited. Am J Sports Med 2004;32(2):337.
38. Dennis DA, Komistek RD, Mahfouz MR, et al. A multicenter analysis of axial femorotibial rotation after total knee arthroplasty. Clin Orthop Relat Res 2004;428:180.
39. Lorentzen JS, Petersen MM, Brot C, et al. Early changes in muscle strength after total knee arthroplasty. A 6-month follow-up of 30 knees. Acta Orthop Scand 1999;70(2):176.

40. Chang CB, Choi JY, Koh IJ, et al. What should be considered in using standard knee radiographs to estimate mechanical alignment of the knee? Osteoarthritis Cartilage 2010;18(4):530.
41. Cho HJ, Chang CB, Kim KW, et al. Gender and prevalence of knee osteoarthritis types in elderly Koreans. J Arthroplasty 2011;26(7):994.
42. Koh IJ, Kim TK, Chang CB, et al. Trends in use of total knee arthroplasty in Korea from 2001 to 2010. Clin Orthop Relat Res 2013;471(5):1441.
43. Lasam MP, Lee KJ, Chang CB, et al. Femoral lateral bowing and varus condylar orientation are prevalent and affect axial alignment of TKA in Koreans. Clin Orthop Relat Res 2013;471(5):1472.