Knee Surgery, Sports Traumatology, Arthroscopy (2020) 28:1419–1424
https://doi.org/10.1007/s00167-019-05511-5

KNEE

Posteromedial vertical capsulotomy selectively increases the extension gap in posterior stabilized total knee arthroplasty

Shin Masuda[1] · Shinichi Miyazawa[1] · Kodama Yuya[1] · Yusuke Kamatski[1] · Hino Tomohito[1] · Okazaki Yoshiki[1] · Okazaki Yuki[1] · Takayuki Furumatsu[1] · Toshifumi Ozaki[1]

Received: 4 December 2018 / Accepted: 18 April 2019 / Published online: 25 April 2019

Abstract

Purpose In total knee arthroplasty (TKA), it is important to obtain an appropriate flexion–extension gap. The extension gap is expanded by posteromedial vertical capsulotomy (PMVC). This study aimed to evaluate the increase in the extension gap by PMVC using a navigation system.

Methods In posterior stabilized (PS)-type TKA, PMVC was performed in 37 knees. The medial extension gap at 0° and flexion gap at 90° flexion of the knee joint using the navigation system before and after PMVC were measured.

Results The extension gap before the PMVC was 5.3 ± 2.9 mm. After PMVC, the extension gap had significantly increased to 8.0 ± 2.8 mm ($p < 0.001$). In addition, the flexion gap was 8.1 ± 2.7 mm before the PMVC, but it was 8.7 ± 2.8 mm after the PMVC, and the flexion gap was not enlarged (n.s.).

Conclusion In PS-type TKA, it is possible to obtain selective expansion of about 2.7 mm of the extension gap by PMVC. Therefore, gap balance can be acquired by soft-tissue treatment while preserving the bone. The PMVC was a useful method for acquiring gap balance and preserving the bone stock.

Level of evidence IV.

Keywords Extension gap · Flexion gap · Navigation system · Posteromedial vertical capsulotomy · PS · Total knee arthroplasty

Introduction

Appropriate bone cutting and soft-tissue balance are very important while performing total knee arthroplasty (TKA) by any surgical technique [3, 5]. If excessive bone-cutting volume or soft-tissue balance is inappropriate, the joint line is increased, which causes joint laxity during intermediate flexion and restriction of range of motion [8]. Especially, in posterior stabilized (PS)-type TKA, the posterior cruciate ligament (PCL) is removed. In a previous study, PCL resection increased the flexion gap and created a space that accommodated approximately 3-mm polyethylene [6, 13]. With this procedure, obtaining balance between the extension gap and flexion gap is impossible. Therefore, joint instability and restricted range of motion occur. In PS-type TKA, the extension gap can be selectively increased in several cases. Until now, expansion methods for selective extension gap have been femoral posterior condylar bony spur resection and soft-tissue treatment, for example, release of the medial collateral ligament, and additional distal osteotomy of the femur was finally performed. However, when additional distal osteotomy of the femur is performed, the joint line rises, causing laxity of the intermediate flexion position [4, 11, 14]. Considering the possibility of revision TKA, we would like to preserve bone as much as possible [15]. To that end, soft-tissue treatment as a selective extension gap-expansion method is important. Kaneyama et al. reported that posteromedial vertical capsulotomy (PMVC) selectively expands the extension gap [7]. PMVC is the method of cutting the joint capsule behind the medial collateral ligament (MCL). This method has two effects. First, the extension limitation can be canceled by vertically cutting the contracted posteromedial joint capsule. Second, cutting the

✉ Shin Masuda
me18066@s.okayama-u.ac.jp

[1] Department of Orthopedic Surgery, Okayama University Graduate School of Medicine, Dentistry, and Pharmaceutical Sciences, 2-5-1 Shikatacho, Kitaku, Okayama 700-8558, Japan

contracted posteromedial joint capsule vertically can possibly restore the excessive tension of the MCL to its normal state, which is an indirect effect that can resolve restricted extension. With these two effects, selective expansion of the extension gap can be obtained by PMVC. PMVC was the method for balancing flexion and extension, not balancing varus and valgus. Although there have been reports that PMVC was performed in cruciate-retaining TKA, only a few studies have reported PMVC in PS-type TKA.

Moreover, few studies have used navigation systems before and after soft-tissue balance [9, 16]; thus, the actual soft-tissue processing is unclear. As hypothesis, PMVC is a useful selective extension gap-expansion method in PS-type TKA, where PCL is excised, and the flexion gap was expanded. The purpose of this study was to evaluate the increase in extension gap due to PMVC using a navigation system.

Materials and methods

Thirty-seven knees (9 male knees and 28 female knees) that underwent first operation using PS-type TKA, which required expansion of the extension gap during surgery, and PMVC between February 2017 and February 2019 at our hospital were included. All patients were diagnosed with primary osteoarthritis. All surgeries were performed by two senior authors (S.M. and Y.K.). PMVC was performed on patients with ≥ 2 mm difference between the extension gap and the flexion gap after the precut trial.

The Attune PS-type mobile bearing (DePuy-Johnson and Johnson, Warsaw, IN, USA) was used for all patients. The computer navigation program Vector Vision (CT-free, opto-electronic, passive marker navigation system, Brain-Lab, Munich, Germany) was used for all patients. The precut trial was inserted, and the extension gap was measured at 0° and flexion gap at 90° flexion of the knee joint using the navigation system. In addition, the differences between the extension gap and flexion gap before and after PMVC were retrospectively evaluated and compared (Fig. 1).

The exclusion criteria were rheumatoid arthritis, revision TKA, valgus knee, no navigation system evaluation data, and patients who did not undergo PMVC because of unnecessary expansion of the extension gap.

Surgical procedure

All cases in which the medial parapatellar approach was used, and the precut trial method was performed were investigated. First, the femoral distal cut was performed, followed by proximal tibial resection, which created the extension gap. Thereafter, the femoral posterior condyle was cut in two steps. During cutting of the posterior condyles of the femur in parallel with the surgical epicondylar axis, a precut trial with a thickness of the portion of the posterior condyle and 4 mm thinner than the ordinary implant was prepared, and the posterior femoral condyle was cut 4 mm thinner than the usual femoral posterior condyle. Subsequently, a temporary flexion gap was made. In the precut trial, the extension and flexion gaps were measured using the navigation system. At that time, PMVC was performed when the flexion gap was 2 mm or larger than the extension gap. For PMVC, first, a hole of approximately 1 cm was made in the posteromedial capsule at the distal lateral part of the MCL using an electric scalpel (Fig. 2a). Second, the hole was expanded vertically from the medial femoral condyle to the medial tibial plateau using surgical scissors (Fig. 2b). Finally, the vertical hole was expanded using a spacer block, and the vertical hole was only checked in the posteromedial capsule, not in the MCL (Fig. 2c, d). In this technique, the MCL was not released. This confirmed that the MCL was not loose. Then, the mid-flexion (30° and 60°) instability was evaluated. At each knee positions, stress force was applied on the varus and valgus, and the knee did not show instability. Extension and flexion gaps were checked using a spacer block, and additional cutting of the posterior femoral condyle was performed. The Hospital Ethics Committee and Internal Review Board of the Okayama University, Okayama, Japan (1811-031) approved this study, and informed consent was obtained from all patients.

Statistical analysis

Data were presented as means ± standard deviation. Differences between groups were compared using Wilcoxon's signed rank test. Power and statistical analyses were performed using EZR-WIN software (Saitama Medical Center, Saitama, Japan). Statistical significance was set to $p < 0.05$. The sample size was estimated for a minimal statistical power of 80% ($\alpha = 0.05$). All sample size and power calculations were performed using the EZR-WIN software. Assuming a two-tailed testing, an alpha of 0.05, and an independent samples t test, 21 patients per group was sufficient to detect an effect size of $d = 0.79$ with 80% statistical power.

Results

The median patient age was 72 (63–88) years, average femorotibial angle was 183° ± 10.6°, and average flexion contracture was 16.2° ± 12° (Table 1). All patients had a minimum of 5° flexion contracture. The extension gap before the PMVC was 5.3 ± 2.9 mm. After PMVC, the extension gap had significantly increased to 8.0 ± 2.8 mm (Table 2; $p < 0.001$). In addition, the flexion gap was 8.1 ± 2.7 mm before the PMVC, but it was 8.7 ± 2.7 mm

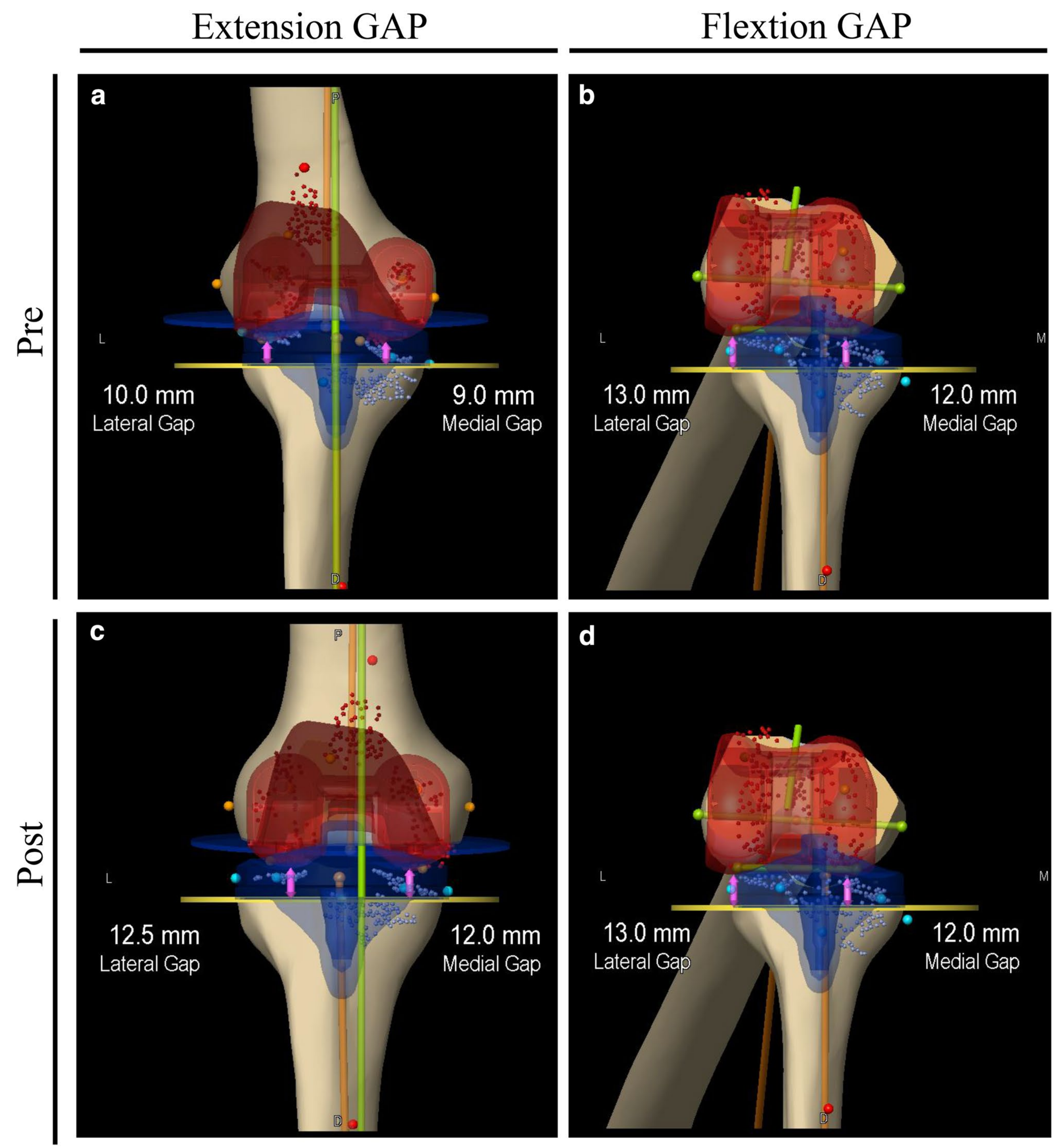

Fig. 1 Navigation-based measurement. The extension gap with the knee at 0° position and flexion gap with the knee at 90° position were measured. **a** Extension gap at pre-posterior medial vertical capsulotomy. **b** Flexion gap at pre-posterior medial vertical capsulotomy. **c** Extension gap at post-posterior medial vertical capsulotomy. **d** Flexion gap at post-posterior medial vertical capsulotomy

after the PMVC, and the flexion gap had not expanded (Table 2; n.s.). Although the difference between the extension gap and flexion gap was 2.8 ± 2.1 mm before the PMVC, it became 0.7 ± 1.1 mm after the PMVC (Table 2; $p < 0.001$), and the difference between the extension gap and flexion gap was found to decrease. In all cases, the extension gap expanded, and the difference in the extension gap and flexion gap decreased. For this reason, no case required additional distal femoral osteotomy. In addition, with PMVC, there were no cases, wherein the medial

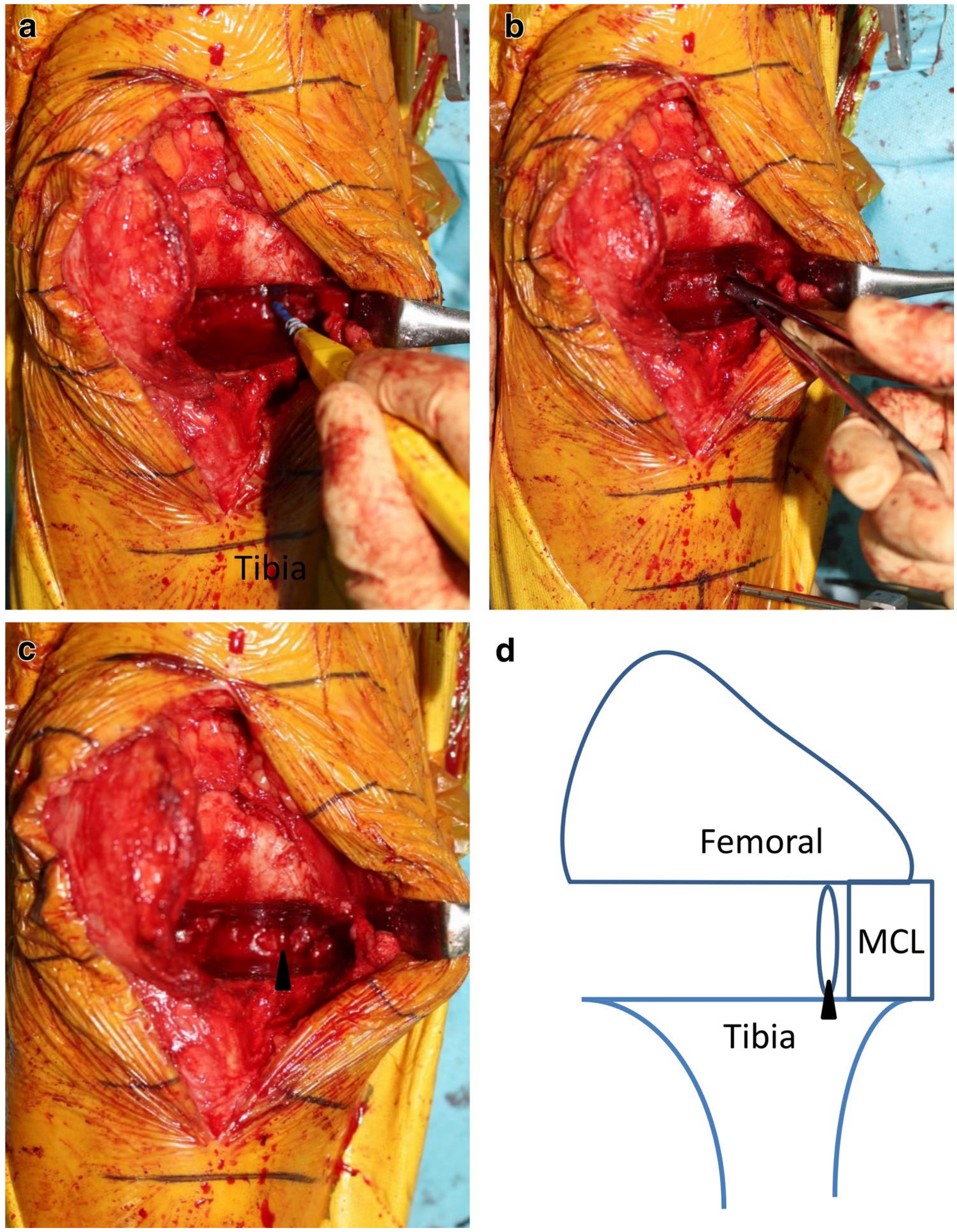

Fig. 2 Surgical procedure. **a** Make a hole at the posteromedial capsule using an electric scalpel. **b** Expand the hole vertically using surgical scissors. **c** Expand the vertical hole using a spacer block and check the vertical hole (arrowhead) in the medial collateral ligament and posteromedial capsule. **d** PMVC schema

Table 1 Demographics and clinical characteristics

	Posteromedial vertical capsulotomy
Number of patients (men/women)	37 (9/28)
Age	72.5 ± 8.7
Body weight (kg)	66.3 ± 12
Height (m)	1.55 ± 8.23
Femoral tibial angle (°)	183 ± 10.6
Kellgren–Lawrence grade 0/1/2/3/4	0/0/0/6/31
Flexion contracture (°)	16.2 ± 12

Data of age, height, and body weight are displayed as mean ± standard deviation

Table 2 Measurement of gap

	Pre	Post	*p* value
Extension gap (EG) (mm)	5.3 ± 2.9	8.0 ± 2.8	< 0.001
Flexion gap (FG) (mm)	8.2 ± 2.7	8.7 ± 2.7	n.s.
EG–FG (mm)	2.8 ± 2.1	0.7 ± 1.1	< 0.001

Data are displayed as mean ± standard deviation

EG extension gap, *FG* flexion gap

flexion gap expanded in comparison with the extension gap.

Discussion

The most important finding in this study was that with the PS-type TKA, selective expansion of the extension gap was obtained by PMVC. A previous study reported that the flexion gap was expanded by approximately 3 mm due to PCL resection [6, 12]. According to this study, the difference between the flexion gap and the extension gap was reduced by about 2.7 mm after PMVC. For that reason, equivalent extension gap opening could be acquired for the flexion gap opening by PCL ablation, and appropriate soft balance could be obtained. In addition, the MCL was not released, and mid-flexion (30° and 60°) instability was evaluated. At each knee position, when knee was applied stress on the varus and valgus, the knee did not show instability. This study did not use cadaver knees, as it is considered difficult to evaluate soft-tissue balance in cadaver knees. Moreover, accurate soft-tissue balance using intraoperative navigation data was evaluated.

PMVC is a useful method that led to selective expansion of the extension gap. In addition, PMVC made it possible to balance the extension gap and flexion gap [2]. In other words, PMVC expanded the extension gap moderately and not excessively. Moreover, there was no case requiring flexion gap expansion after PMVC, which subsequently obtains appropriate balance. In addition, in this study, the extension gap expanded with a significant difference, but the flexion gap did not expand. This showed that PMVC is useful, as it selectively expands the extension gap. In PS-type TKA with PCL removal, it is often necessary to expand only the extension gap. Therefore, this study suggests that PMVC in PS-type TKA is a very useful soft-tissue treatment method. In addition, no case required additional femoral distal osteotomy by PMVC. In a previous study, increasing the joint line for additional distal osteotomy caused mid-flexion laxity [10], and the intraoperative medial joint laxity decreased patient satisfaction [1]. PCL resection (PS-type TKA) will increase the flexion gap and cause a mismatch between the extension and flexion gaps for tibial cut. For this reason, the balance between the extension gap and flexion gap was obtained without performing additional distal femoral osteotomy, which increases the joint line and laxity of the intermediate flexion position. Therefore, the PMVC is effective for obtaining an appropriate gap. For TKA that requires appropriate soft-tissue balance, PMVC that preserves bone and adjusts the balance is very useful. In each case, the extension gap that can be acquired by PMVC is different. However, in every case, it was balanced with the flexion gap. That is, the PMVC after appropriate bone cutting may improve and restore the flexion gap to that in a normal knee.

This study had several limitations. First, a tensor device was not used in this study. For extension–flexion gap measurements, whether the spacer block lifts off and appropriate balance is obtained were confirmed, as detected by the operator. In addition, the navigation system could not evaluate the force. Therefore, when actually inserting a spacer block, the tightness at the tibiofemoral joints was not known. Second, the PMVC facilitates extension gap opening by tearing the posterior medial joint capsule and inserting a tight spacer block and extending it. Thus, it is unknown by how much the posterior medial joint capsule actually dissociates. Third, the varus, valgus, and rotation of the knee joint were not assessed. Excessive tension of the MCL may be normalized using the posterior medial capsule vertical incision method. Therefore, it is thought that changes will also occur in internal and external rotations. Despite the possibility that the medial gap was expanded, in this study, the internal and external rotations of the knee were not considered. Fourth, this study had a short observation period. Therefore, long-term data and clinical outcome could not be evaluated. Thus, long-term changes in clinical outcome for PMVC should be assessed.

However, in this study, the extension gap could be expanded selectively without bone cutting. Therefore, because this method could preserve the bone stock, it may be considered useful for revision TKA and infection cases.

Conclusions

In PS-type TKA, it is possible to obtain selective expansion of the extension gap by PMVC. Therefore, balance can be acquired by soft-tissue treatment while preserving bone. These results conclude that the posterior medial capsule vertical segmentation method in PS-type TKA may be a very useful method.

Funding No external funding was used.

Compliance with ethical standards

Conflict of interest Shinichi Miyazawa received contribution from Teizin Nakashima Medical.

Ethical approval This article does not contain any studies with human participants performed by any of the authors.

References

1. Azukizawa M, Kuriyama S, Nakamura S et al (2018) Intraoperative medial joint laxity in flexion decreases patient

satisfaction after total knee arthroplasty. Arch Orthop Trauma Surg 138:1143–1150
2. Bottros J, Gad B, Krebs V, Barsoum WK (2006) Gap balancing in total knee arthroplasty. J Arthroplasty 21:11–15
3. Dennis DA, Komistek RD, Kim RH, Sharma A (2010) Gap balancing versus measured resection technique for total knee arthroplasty. Clin Orthop Relat Res 468:102–107
4. Iamthanaporn K, Yuenyongviwat V, Laohawiriyakamol T, Tanutit P (2019) Accuracy of medial-side cutting guide compared to anterior cutting guide in distal femoral osteotomy of total knee arthroplasty. J Clin Orthop Trauma 10:87–90
5. McAuliffe MJ, O'Connor PB, Major LJ, Garg G, Whitehouse SL, Crawford RW (2019) Highly satisfied total knee arthroplasty patients display a wide range of soft tissue balance. J Knee Surg. https://doi.org/10.1055/s-0039-1677873
6. Kadoya Y, Kobayashi A, Komatsu T, Nakagawa S, Yamano Y (2001) Effects of posterior cruciate ligament resection on the tibiofemoral joint gap. Clin Orthop Relat Res 391:210–217
7. Kaneyama R, Shiratsuchi H, Oinuma K, Higashi H, Miura Y, Tamaki T (2018) Posteromedial vertical capsulotomy increases the medial extension gap in total knee arthroplasty. Orthop Proc
8. Jawhar A, Shah V, Sohoni S, Scharf HP (2013) Joint line changes after primary total knee arthroplasty: navigated versus non-navigated. Knee Surg Sports Traumatol Arthrosc 21:2355–2362
9. Lee DH, Park JH, Song DI, Padhy D, Jeong WK, Han SB (2010) Accuracy of soft tissue balancing in TKA: comparison between navigation-assisted gap balancing and conventional measured resection. Knee Surg Sports Traumatol Arthrosc 18:381–387
10. Luyckx T, Vandenneucker H, Ing LS, Vereecke E, Ing AV, Victor J (2018) Raising the joint line in TKA is associated with mid-flexion laxity: a study in cadaver knees. Clin Orthop Relat Res 476:601–611
11. Ji HM, Han J, Jin DS, Seo H, Won YY (2016) Kinematically aligned TKA can align knee joint line to horizontal. Knee Surg Sports Traumatol Arthrosc 24:2436–2441
12. Matthews J, Chong A, McQueen D, O'Guinn J, Wooley P (2014) Flexion-extension gap in cruciate-retaining versus posterior-stabilized total knee arthroplasty: a cadaveric study. J Orthop Res 32:627–632
13. Nielsen ES, Hsu A, Patil S, Colwell CW Jr, D'Lima DD (2018) Second-generation electronic ligament balancing for knee arthroplasty: a cadaver study. J Arthroplasty 33:2293–3300
14. van Lieshout WAM, Valkering KP, Koenraadt KLM, van Etten-Jamaludin FS, Kerkhoffs GMMJ, van Geenen RCI (2018) The negative effect of joint line elevation after total knee arthroplasty on outcome. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-018-5099-8
15. Shi M, Chen L, Wu H, Wang Y, Wang W, Zhang Y, Yan S (2018) Effect of bisphosphonates on periprosthetic bone loss after total knee arthroplasty: a meta-analysis of randomized controlled trials. BMC Musculoskelet Disord 19:177
16. Van der List JP, Chawla H, Joskowicz L, Pearle AD (2016) Current state of computer navigation and robotics in unicompartmental and total knee arthroplasty: a systematic review with meta-analysis. Knee Surg Sports Traumatol Arthrosc 24:3482–3495