The Role of Surgical Closure Position in Total Knee Arthroplasty: Flexion versus Extension—A Randomized Prospective Study

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Abstract

We aimed to investigate the effect of the knee position during the surgical closure on isokinetic muscle strength, clinical score, and range of motion in total knee arthroplasty. Seventy-five eligible patients were enrolled in the study and randomly divided into two groups; wound closure was performed with the knee flexed at 90° in group 1 and knee extended in group 2. All the surgeries were performed by the same surgeon and by the same prosthesis type. All the patients received the same rehabilitation program postoperatively. The primary outcomes were the knee flexion degrees and the American Knee Society Score values at preoperative and postoperative 6 weeks, 3, and 6 months. The secondary outcome was the isokinetic muscle strength measurements of both knees before the surgery and after 6 months. There were no significant differences in the American Knee Society Scores and knee flexion degrees between the flexion and extension groups. However, a significant decrease was found in the extensor muscle strength in the extension group after 6 months of the surgery. The findings of our study are that the closing of the knee in flexion or extension does not affect the postoperative knee flexion degrees and scores in total knee arthroplasty. However, quadriceps strength recovers early if the knee closure is performed in flexion position.

Keywords
- wound closure
- total knee arthroplasty
- flexion
- extension
- isokinetic muscle strength

Total knee arthroplasty (TKA) is the most commonly used arthroplasty procedure in orthopedic practice[1] and provides pain relief, restores anatomic alignment and functional range of motion (ROM), and allows returning to daily activity of the patient who suffers from severe knee osteoarthritis. Functional outcome following TKA is influenced by several factors,[2–4] including age, obesity, smoking, diabetes, etiology of knee osteoarthritis (posttraumatic, metabolic, and endocrine diseases), patient selection, preoperative ROM, implant design, soft tissue balance, surgical technique and skill, postoperative rehabilitation, and pain management, among others.[5–9] Studies evaluating the effect of soft tissue closing at different angles of the knee on the clinical outcomes after TKA are limited.[10–16] Early studies showed the benefits of closing the TKA in flexion position.[10–12] They mentioned that closing in flexion position reduces soft tissue tension and improves patient comfort and postoperative ROM. But recent studies have shown that closing the knee at 90° flexion position does

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not significantly influence postoperative ROM and clinical outcome.[13,15,16] There is only one study comparing the knee closure at 90° flexion and extension position regarding isokinetic muscle strengths.[13] They concluded that closing the knee at 90° flexion position improved flexor muscle strength but had no influence on postoperative ROM and clinical scores. Therefore, our study aimed to evaluate if closing the knee in flexion or extension has any impact on postoperative ROM, clinical scores, and isokinetic muscle strength following TKA. The hypothesis was that closing the knee in flexed or extended position does not make a significant difference in these three parameters.

Materials and Methods

This study was a double-blinded, prospective, and randomized clinical trial performed after our hospital ethical committee approval. Patients with grade 3 and 4 unilateral knee osteoarthritis based on the Kellgren and Lawrence classification system were included in the study.[17] All patients underwent primary TKA by a blinded expert surgeon. Exclusion criteria were bilateral osteoarthritis, prior knee trauma or surgery, knees with preoperative flexion contracture greater than 30°, preoperative flexion less than 90°, varus or valgus deformity exceeding 15°, inflammatory arthritis, and neuromuscular diseases.

Surgical closing and rehabilitation

All surgical procedures were performed under spinal or general anesthesia using a pneumatic tourniquet. With the knee flexed to 90°, anterior midline skin incision was utilized, and after passing the subcutaneous fat, a medial parapatellar approach was used for arthrotomy. Soft tissue release was performed from proximal tibia and patella is everted and dislocated laterally with the full knee extension. İntramedullary guides were utilized both on the femoral and tibial side. After ensuring ligamentous balance following proper soft tissue release, and gap-balance technique with the femoral and tibial cuts, definitive implants were cemented. We used a posterior cruciate ligament substituting cemented total knee prosthesis (Vanguard ROCC, Biomet Inc., Warsaw, IN) without patellar resurfacing. After cement hardening, the tourniquet was deflated and bleeding foci were cauterized. A suction drain was placed, and wound closure was performed with the knee flexed at 90° in group 1 and knee extended in group 2. In both groups, layers were repaired using 1 Vicryl for the joint capsule, 2–0 Vicryl for subcutaneous tissue, and a stapler for skin closure.

All patients underwent the same postoperative physiotherapy protocol. On the day following surgery, drainage tube was removed, bedside exercises (quadriceps sets, straight leg raises, ankle pumps, posterior knee stretch, seated self-assisted knee flexion/extension) were started, and a continuous passive motion (CPM) device was applied at 0° to 90° flexion. Patients were encouraged to stand and do protected weight-bearing walk with a walker device. On the postoperative day 2 to 5, CPM range was increased to 0° to 120° flexion. Patients continued to regain at least 90° of active and passive ROM in the knee and were allowed to walk, stair climb, and descend using an assistive device. On the postoperative day 5 to 7, patients were discharged to home with continued therapy. Outpatient therapy program was implemented based on each individual patient's needs. Therapeutic exercises included lower extremity strengthening and stretching exercises. The goal of knee ROM was 0° to 110° within 6 weeks.

Clinical Outcomes

All patients were evaluated by a blinded clinical investigator preoperatively and postoperative at 6 weeks, and 3 and 6 months with the American Knee Society Score (AKSS), and knee flexion degrees using a goniometer.[18] AKSS was recorded in two parts as knee score and functional score.

Isokinetic Muscle Strength Test

The isokinetic muscle strength testing was performed on a Biodex Multi Joint System 3 Pro computerized dynamometer device (Biodex Medical Systems, Shirley, NY).[19] Muscle testing was performed at preoperatively and postoperative month 6. The patients were tested in a seated position. The trunk and thighs were stabilized with straps. Before the performance, all subjects completed 10 times of knee flexion/extension practice to warm up. All patients were provided same vocal encouragement for maximal effort. The flexor and extensor muscle strength of both knees at angular velocities of 60°/sec (5 repetitions) and 180°/sec (20 repetitions) were measured by the same blinded physiatrist. There were 30-second resting intervals between the tests. The peak torque (PT) and total work (TW) values were measured and recorded in the flexor and extensor muscle groups for each velocity. PT difference (PTD) and TW difference (TWD) were used to compare operated and nonoperated knees (►**Figs. 1** and **2**).[13]

Randomization

Study randomization plan is generated using an online software program (http://www.graphpad.com/quickcalcs/index.cfm) which has been used for other clinical trials in the literature.[20]

Statistical Analysis

The G power 3.1 statistical analysis program (Erdfelder, Faul, & Buchner, Düsseldorf, Germany) was used to compute the study power. The allocation ratio, α error probability, effect

$$\text{Peak Torque Difference (PTD)} = \frac{\text{Peak Torque}_{\text{operated knee}} - \text{Peak Torque}_{\text{non-operated knee}}}{\text{Peak Torque}_{\text{non-operated knee}}} \times 100$$

Fig. 1 Calculation of peak torque difference.

$$\text{Total Work Difference (TWD)} = \frac{\text{Total Work}_{\text{operated knee}} - \text{Total Work}_{\text{non-operated knee}}}{\text{Total Work}_{\text{non-operated knee}}} \text{ X } 100$$

Fig. 2 Calculation of total work difference.

size *d* value, and power of the study were 1, 0.05, 0.6, and 0.8, respectively. The required sample size for each group was 36; thus, 37 patients in group 1 and 38 patients in group 2 were included in our study.

The statistical analysis was performed using the SPSS (version 20.0 for Mac, Armonk, NY) software. Qualitative data were compared using the chi-square test. The distribution between the groups was assessed by the Kolmogorov–Smirnov test. Quantitative variables did not follow a normal distribution. Hence, Mann–Whitney *U*-test was used to compare the independent variables, and Wilcoxon test was used to compare the related variables. The significance level adopted was $p < 0.05$.

Results

Group 1 (flexion group) consisted of 37 patients (15 males, 22 females) with a mean age of 62.8 years (range: 51–77) and group 2 (extension group) consisted of 38 patients (13 males, 25 females) with a mean age of 63.4 years (range: 54–79). The flow diagram of the patients is shown in ►**Fig. 3**.

There were no significant differences found between the flexion and extension group at preoperative and postoperative week 6 and 3 and 6 months in the knee score and function score (►**Table 1**).

Closing the knee in 90° flexion or extension did not significantly change the knee flexion ROM in the postoperative period. The summary of ROM results between the groups is given in ►**Table 1**.

For the 180°/sec, the mean extensor muscle strength values significantly decreased at postoperative 6 months in the extension group, whereas it strokes to preoperative level at postoperative 6 months in the flexion group (►**Table 2**).

Discussion

There are several parameters that affect clinical outcomes after TKA. These can be classified as preoperative,

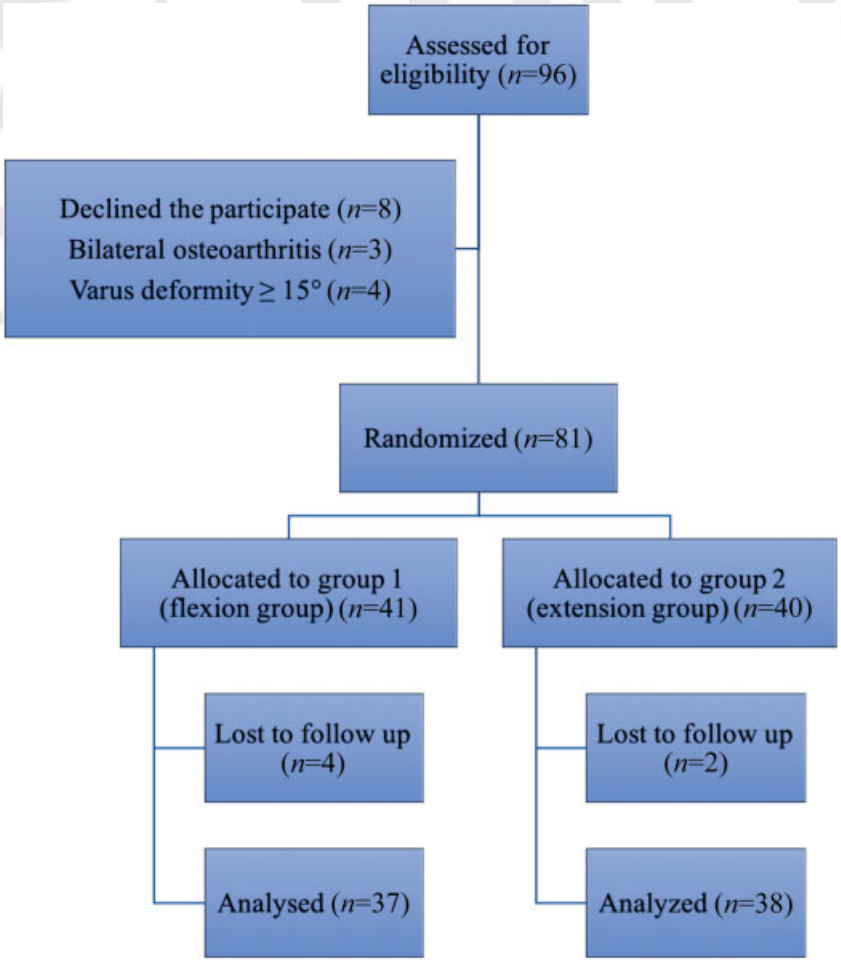

Fig. 3 Flow diagram of the participants.

Table 1 Summary of the American Knee Society Score (AKSS) and knee flexion degree results in the flexion and extension groups

Follow-up	AKSS				ROM (degree, °)	
	Knee score	*p*-Value	Function score	*p*-Value		*p*-Value
	FG / EG		FG / EG		FG / EG	
Preoperative	42.3 ± 6.2 / 43.6 ± 6.6	0.588	47.1 ± 5.7 / 47.2 ± 4.3	0.950	108.2 ± 6.8 / 106.6 ± 6.9	0.286
Postoperative 6 wk	53 ± 6.8 / 54.9 ± 6.3	0.147	52.7 ± 4 / 52.6 ± 4.1	0.856	113.2 ± 6.6 / 111.4 ± 6.8	0.239
Postoperative 3 mo	63.9 ± 5.7 / 62.6 ± 5.3	0.216	61.9 ± 5.3 / 61 ± 5.1	0.460	113 ± 4.1 / 112.3 ± 4.8	0.581
Postoperative 6 mo	72.7 ± 7.5 / 73.0 ± 5.9	0.949	78.5 ± 7.1 / 75.8 ± 8	0.149	114.8 ± 4.5 / 115.5 ± 5.2	0.514

Abbreviations: EG, extension group; FG, flexion group; ROM, range of motion.

intraoperative, and postoperative factors. Preoperative factors include age, obesity, smoking, diabetes, etiology, patient selection, and preoperative ROM.[6,7,9] Intraoperative parameters include implant design, soft tissue balance, surgical technique, and skill. Postoperative factors include postoperative rehabilitation, pain management, and arthrofibrosis.[2,3,7,8] The role of knee position during surgical closing, one of the intraoperative factors, is still controversial.[1,16] King et al mentioned that closing the knee in 120° flexion prevents extensor mechanism overtension and leads to increased postoperative ROM.[12] In a prospective study, Emerson et al found significantly quicker ROM recovery and less physical therapy requirements in the flexion group with a 1-year follow-up.[10,11] Wang et al conducted a similar study, but they marked the articular capsule incision using a suture to avoid wound misalignment while closing the knee. They found that the knee ROM was significantly higher and the visual analogue scale pain score of the anterior knee was significantly lower in the 90° flexion repaired group at 6 weeks and 3 months postoperatively. However, no significant differences were found at 6 months postoperatively.[16] Masri et al found that the knee position during surgical closing does not affect postoperative ROM, Knee Society Score, and rate of complications.[14] Short-term follow-up, low flexion angle (60°), the use of two different types of prosthesis, and the performance of three different surgeons was the weakness of their study.

Recent randomized clinical trials have shown that postoperative ROM and clinical scores are not affected by the knee position during the surgical closure.[13,15] Motififard et al reported no differences between the flexion and extension groups after a 12-month follow-up of 85 patients and suggested that the surgical closure angle should be chosen according to the surgeon's preference.[15] Similar to recent studies, our study showed that postoperative ROM and Knee Society Scores were not affected by closing the knee in flexion or extension.

Kömürcü et al conducted the first study to investigate the effect of knee closure in flexion or extension on isokinetic muscle strength on 29 patients.[13] They found a significant difference in the PTD and TWD values of the flexor muscles for 180°/sec between the flexion and extension groups and concluded that closing the knee in 90° flexion improves flexor muscle strength. However, no significant differences were found in the postoperative ROM and AKSS values between the groups. This study also had some limitations; small sample size, short-term follow-up, and the lack of preoperative isokinetic muscle strength measurements. In our study, preoperative and postoperative isokinetic muscle strength scores were evaluated and no significant differences found in the PTD and TWD values. In the PTD and TWD calculations, patient-related factors are neutralized using the normal contralateral knee. However, Farquhar et al mentioned that after unilateral TKA, uninvolved knee worsened, so the use of nonoperated knee as a healthy group may underestimate study standardization.[21]

Quadriceps strength decreases maximally at 3 months following TKA, and reaches the preoperative level at 6 months, and maintains the preoperative status at postoperative year 1.[22] In this study, we found a significant decrease in extensor muscle strength at postoperative 6 months compared with preoperative status in the extension group. No such difference was found in the flexion group.

A limitation of our study is the relatively short follow-up. Second, we evaluated only 90° of flexion. Intermediate angles (30°, 45°, 60°) were not used. Another possible weakness of our study may be the limited inclusion criteria such as lack of some patient factors (smoking, diabetes) that affect the outcome of TKA.

In this study, we used CPM to encourage patients' early knee motions. There are conflicting results in the literature regarding the use of CPM following TKA.[23] While the early studies advocated the CPM,[24–26] the recent studies found a little or no value in the rehabilitation of the knee following TKA.[27,28] Despite these controversies, CPM is still used for rehabilitation in some clinics.[29]

Another controversial situation is the use of suction drainage following TKA. There are many studies comparing the drainage and nondrainage methods.[30,31] In our study, we used a suction drain because of the advantage[31,32] of

Table 2 Summary of the isokinetic muscle strength results

	Flexion group		Extension group		*p*-Value
	Preoperative	Postoperative 6 mo	Preoperative	Postoperative 6 mo	
Flexor muscle strength at 60°/s angular velocity					
Peak torque (N/m)	40.2 ± 18.1	37.1 ± 20.1	32.1 ± 7.9	29.9 ± 8.2	0.101[a] 0.108[b] 0.697[c]
Total work (joule)	37.4 ± 19.3	35.0 ± 20.8	29.5 ± 9.3	27.9 ± 9.2	0.100[a] 0.053[b] 0.990[c]
Peak torque difference (PTD)		−16.9 ± 37.8		−30.7 ± 23.6	0.436
Total work difference (TWD)		−25.3 ± 32.7		−37.8 ± 32.9	0.284
Extensor muscle strength at 60°/s angular velocity					
Peak torque (N/m)	51.1 ± 18.9	51.6 ± 17.2	52.6 ± 4.3	52.2 ± 3.2	0.677[a] 0.717[b] 0.912[c]
Total work (joule)	55.3 ± 19.1	54.7 ± 17.2	62.3 ± 11.3	62.8 ± 9.7	0.686[a] 0.716[b] 0.370[c]
Peak torque difference (PTD)		−25.7 ± 23.3		−22.5 ± 16.4	0.697
Total work difference (TWD)		−30.1 ± 20.2		−24 ± 20.2	0.770
Flexor muscle strength at 180°/s angular velocity					
Peak torque (N/m)	25.4 ± 15.3	24.4 ± 15.5	17.9 ± 6.9	15.3 ± 7.42	0.156[a] 0.114[b] 0.205[c]
Total work (joule)	22.4 ± 14.9	21.4 ± 15.3	14.6 ± 9.5	15.6 ± 11.0	0.170[a] 0.450[b] 0.697[c]
Peak torque difference (PTD)		−21.6 ± 52.5		−46.5 ± 34.8	0.559
Total work difference (TWD)		−9.8 ± 70.4		−52.5 ± 30.1	0.242
Extensor muscle strength at 180°/s angular velocity					
Peak torque (N/m)	34.5 ± 8.2	35.1 ± 10.5	40.9 ± 3.5	38.5 ± 4.14	0.697[a] **0.048**[b] 0.770[c]
Total work (joule)	35.8 ± 13	36.0 ± 14.6	49.8 ± 13	46.8 ± 12.2	0.841[a] **0.011**[b] 0.119[c]
Peak torque difference (PTD)		−25.7 ± 20.3		−19.2 ± 12.2	0.561
Total work difference (TWD)		−31.9 ± 28.7		−19.5 ± 23.1	0.381

Note: The boldfaced *p*-Values indicate statistical significance.
[a]Wilcoxon test between preoperative and postoperative at 6 months in the flexion group.
[b]Wilcoxon test between preoperative and postoperative at 6 months in the extension group.
[c]Mann–Whitney *U*-test between the flexion and extension group at postoperative 6 months.

reducing postoperative fluid collection. However, higher blood transfusion rates, increased postoperative blood loss, higher infection risk, and longer hospital stays were reported by using suction drainage.[33–35] Recently published studies showed using suction drain have no additional benefit in terms of patient outcome following TKA.[31,36]

Conclusion

Based on the results of our study, the position of the knee during surgical closure in TKA does not affect the postoperative ROM and AKSS values. However, the quadriceps strength recovered in the flexed closure earlier than in extended position.

Conflict of Interest
None.

References

1 Smith TO, Davies L, Hing CB. Wound closure in flexion versus extension following total knee arthroplasty: a systematic review. Acta Orthop Belg 2010;76(03):298–306
2 Faldini C, Traina F, De Fine M, Pedrini M, Sambri A. Post-operative limb position can influence blood loss and range of motion after total knee arthroplasty: a systematic review. Knee Surg Sports Traumatol Arthrosc 2015;23(03):852–859
3 Bade MJ, Kittelson JM, Kohrt WM, Stevens-Lapsley JE. Predicting functional performance and range of motion outcomes after total knee arthroplasty. Am J Phys Med Rehabil 2014;93(07):579–585
4 Harvey IA, Barry K, Kirby SP, Johnson R, Elloy MA. Factors affecting the range of movement of total knee arthroplasty. J Bone Joint Surg Br 1993;75(06):950–955
5 Parsley BS, Engh GA, Dwyer KA. Preoperative flexion. Does it influence postoperative flexion after posterior-cruciate-retaining total knee arthroplasty? Clin Orthop Relat Res 1992;(275):204–210
6 Dennis DA, Komistek RD, Scuderi GR, Zingde S. Factors affecting flexion after total knee arthroplasty. Clin Orthop Relat Res 2007; 464(464):53–60
7 Cerciello S, Morris BJ, Lustig S, et al. The role of wound closure in total knee arthroplasty: a systematic review on knee position. Knee Surg Sports Traumatol Arthrosc 2016;24(10):3306–3312
8 Hoogeboom TJ, van Meeteren NL, Schank K, Kim RH, Miner T, Stevens-Lapsley JE. Risk factors for delayed inpatient functional recovery after total knee arthroplasty. BioMed Res Int 2015; 2015:167643
9 Shoji H, Solomonow M, Yoshino S, D'Ambrosia R, Dabezies E. Factors affecting postoperative flexion in total knee arthroplasty. Orthopedics 1990;13(06):643–649
10 Emerson RH Jr, Ayers C, Head WC, Higgins LL. Surgical closing in primary total knee arthroplasties: flexion versus extension. Clin Orthop Relat Res 1996;(331):74–80
11 Emerson RH Jr, Ayers C, Higgins LL. Surgical closing in total knee arthroplasty. A series follow-up. Clin Orthop Relat Res 1999; (368):176–181
12 King TV, Kish G, Eberhart RE, Holzaepfel JL. The "genuflex" skin closure for total knee arthroplasty. Orthopedics 1992;15(09):1057–1058
13 Kömürcü E, Yüksel HY, Ersöz M, et al. Effect of surgical closing in total knee arthroplasty at flexion or extension: a prospective, randomized study. Knee Surg Sports Traumatol Arthrosc 2014;22(12):3067–3073
14 Masri BA, Laskin RS, Windsor RE, Haas SB. Knee closure in total knee replacement: a randomized prospective trial. Clin Orthop Relat Res 1996;(331):81–86
15 Motififard M, Heidari M, Nemati A. No difference between wound closure in extension or flexion for range of motion following total knee arthroplasty: a randomized clinical trial. Knee Surg Sports Traumatol Arthrosc 2016;24(01):74–78
16 Wang S, Xia J, Wei Y, Wu J, Huang G. Effect of the knee position during wound closure after total knee arthroplasty on early knee function recovery. J Orthop Surg 2014;9(01):79
17 Kellgren JH, Lawrence JS. Radiological assessment of rheumatoid arthritis. Ann Rheum Dis 1957;16(04):485–493
18 Insall JN, Dorr LD, Scott RD, Scott WN. Rationale of the Knee Society clinical rating system. Clin Orthop Relat Res 1989;248(248):13–14
19 Nordez A, Casari P, Cornu C. Accuracy of Biodex system 3 pro computerized dynamometer in passive mode. Med Eng Phys 2008;30(07):880–887
20 Suresh K. An overview of randomization techniques: an unbiased assessment of outcome in clinical research. J Hum Reprod Sci 2011;4(01):8–11
21 Farquhar S, Snyder-Mackler L. The Chitranjan Ranawat Award: the nonoperated knee predicts function 3 years after unilateral total knee arthroplasty. Clin Orthop Relat Res 2010;468(01): 37–44
22 Moon Y-W, Kim H-J, Ahn H-S, Lee D-H. Serial changes of quadriceps and hamstring muscle strength following total knee arthroplasty: a meta-analysis. PLoS One 2016;11(02):e0148193
23 Mau-Moeller A, Behrens M, Finze S, Bruhn S, Bader R, Mittelmeier W. The effect of continuous passive motion and sling exercise training on clinical and functional outcomes following total knee arthroplasty: a randomized active-controlled clinical study. Health Qual Life Outcomes 2014;12(01):68
24 Romness DW, Rand JA. The role of continuous passive motion following total knee arthroplasty. Clin Orthop Relat Res 1988; (226):34–37
25 Coutts RD. A conversation with Richard D. Coutts, MD. Continuous passive motion in the rehabilitation of the total knee patient, its role and effect. Orthop Rev 1986;15(03):126–134
26 Bennett LA, Brearley SC, Hart JA, Bailey MJ. A comparison of 2 continuous passive motion protocols after total knee arthroplasty: a controlled and randomized study. J Arthroplasty 2005;20(02):225–233
27 Harvey LA, Brosseau L, Herbert RD. Continuous passive motion following total knee arthroplasty in people with arthritis. Cochrane Database Syst Rev 2014;6(02):CD004260
28 Denis M, Moffet H, Caron F, Ouellet D, Paquet J, Nolet L. Effectiveness of continuous passive motion and conventional physical therapy after total knee arthroplasty: a randomized clinical trial. Phys Ther 2006;86(02):174–185
29 Alaca N, Atalay A, Güven Z. Comparison of the long-term effectiveness of progressive neuromuscular facilitation and continuous passive motion therapies after total knee arthroplasty. J Phys Ther Sci 2015;27(11):3377–3380
30 Zhang XN, Wu G, Xu RZ, Bai XZ. Closed suction drainage or non-drainage for total knee arthroplasty: a meta-analysis [in Chinese]. Zhonghua Wai Ke Za Zhi 2012;50(12):1119–1125
31 Watanabe T, Muneta T, Yagishita K, Hara K, Koga H, Sekiya I. Closed suction drainage is not necessary for total knee arthroplasty: a prospective study on simultaneous bilateral surgeries of a mean follow-up of 5.5 years. J Arthroplasty 2016;31(03):641–645
32 Omonbude D, El Masry MA, O'Connor PJ, Grainger AJ, Allgar VL, Calder SJ. Measurement of joint effusion and haematoma formation by ultrasound in assessing the effectiveness of drains after total knee replacement: a prospective randomised study. J Bone Joint Surg Br 2010;92(01):51–55
33 Markar SR, Jones GG, Karthikesalingam A, Segaren N, Patel RV. Transfusion drains versus suction drains in total knee replacement: meta-analysis. Knee Surg Sports Traumatol Arthrosc 2012; 20(09):1766–1772
34 Erne F, Wetzel S, Wülker N, Gesicki M, Hofmann UK. Closed suction drainage after primary total knee arthroplasty: a prospective randomized trial. J Knee Surg 2018. Doi: 10.1055/s-0037-1615297
35 Willemen D, Paul J, White SH, Crook DW. Closed suction drainage following knee arthroplasty. Effectiveness and risks. Clin Orthop Relat Res 1991;(264):232–234
36 Quinn M, Bowe A, Galvin R, Dawson P, O'Byrne J. The use of postoperative suction drainage in total knee arthroplasty: a systematic review. Int Orthop 2015;39(04):653–658