CLINICAL ARTICLE

Stretching Force of Incision Affects Early Clinical Results After Primary Total Knee Arthroplasty: A Retrospective Study

Tang Xiang-sheng, MD1†, Zhang Hu, MD2†, Chen Lei, MD3, Qian Huan-juan, MD3, Yi Ping, MD1

1Department of Orthopaedics, China-Japan Friendship Hospital, Peking Union Medical College, Chinese Academy of Medical College, Beijing, 2Department of Orthopaedics, The 980th Hospital of Joint Logistic Support Force of PLA, Shijiazhuang and 382nd Group Military Hospital of Chinese PLA, Baoding, China

Objective: To investigate the impact of different skin incisions on recovery from total knee arthroplasty (TKA).

Methods: This is a retrospective study conducted in a tertiary hospital. A total of 1210 patients accepted primary and unilateral total knee arthroplasty (TKA) at the authors’ affiliated institutions between January 2015 and January 2019. Patients who accepted primary and unilateral TKA due to OA under epidural anesthesia were included. Excluded cases included patients who had no completed follow-up; preoperative flexion contracture greater than 15° and preoperative flexion less than 90°; paresthesia in lower limb; scar within the knee area; patella alta or baja. We recorded and analyzed the following data, including each patient’s characteristics, incision stretching index (IS index), perioperative information, and follow-up assessments. Patients were grouped by trisecting the range of IS index we observed in the present study. The primary outcome measure was the visual analog scale (VAS) pain score rated on a scale of 0–10 from no pain to severe pain. Secondary outcome measures include knee girth reflecting postoperative swelling, knee range of motion (ROM), sensory testing, and the strength of quadriceps. These measures were completed 2 weeks postoperatively.

Results: A total of 1089 patients undergoing primary and unilateral TKA in our two institutions were screened for final analysis, and 121 ones were excluded. The patients were followed up for an average of 13.3 months postoperatively. The mean length of FL was 28.3 cm (range: 21.0–38.8 cm). The mean IS index was 2.7 cm (range: 0.4–5.1 cm). We found no significant difference in those data among groups (P > 0.05). VAS pain scores among group IS A, IS B, and IS C were significantly different (2.3 ± 0.6 vs 3.4 ± 1.6 vs 3.9 ± 1.5, P = 0.0001). Similar situations were seen in knee circumference, ROM, area of abnormal sensation, and quadriceps strength among groups (all P < 0.05). With the increase in the IS index, VAS pain score, knee circumference, area of abnormal sensation, and incision problems were significantly increased (P < 0.05). At the same time, ROM and the strength of quadriceps decreased (P < 0.05). With the increase in the IS index, the number of patients with incision problems was increased significantly (P < 0.05). Besides, no significant difference in PJI and DVT among groups was observed (P > 0.05).

Conclusions: Proper incision stretching can improve postoperative pain relief, surgical swelling, ROM, sensory disturbance of the knee, and the strength of quadriceps with reduced risk of incision complications.

Key words: Incision stretching index (IS index); Range of motion; Total knee arthroplasty; Visual analogue scale

Address for correspondence Yi Ping, MD, Department of Orthopaedic, China-Japan Friendship Hospital, No. 2 Yinhuayuan East Street, Chaoyang, Beijing, China 100029 Tel: 0086-10-84205566; Fax: +861084205011; Email: zyyp@sina.com

These two authors equally contribute to this work. They are the co-first authors.

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Introduction

Total knee arthroplasty (TKA) is regarded as a successful surgical method to treat the severe degenerative tibiofemoral joint. In the United States, more than 500,000 TKAs are performed each year, and according to current trends, more than 3.5 mn knee arthroplasties will be done annually within the next 25 years. In general, rates of surgical “success” exceed 80% in terms of complete pain relief, although success is rarely so defined. Generally, we can evaluate, qualitatively and quantitatively, how much patients benefit from TKA by using Short-Form 36 and Western Ontario and McMaster Universities (WOMAC) questionnaire, which cover pain relief, functional recovery, and improvement in the quality of life. A successful TKA depends on multiple factors, such as patient and prosthesis selection, surgical technique, pain management, and functional exercise. While total knee arthroplasty has long been considered the gold standard, there is still room for improvement in the perioperative period. Minimally invasive procedures for TKA (MIS TKAs) have become popular and are associated with whether the exposure is clear or unclear. No reported MIS TKAs can provide optimal incision length, that is, appropriate incision stretching; (ii) understand the impact of different skin approaches on recovery from TKA; and (iii) determine the relationship between the length of skin incision and incision stretching. Therefore, in the present study, we intend to: (i) investigate the tension of the incision for the TKA determines the surgical trauma has never been investigated. Therefore, in the present study, we intend to: (i) investigate the relationship between the length of skin incision and incision stretching; (ii) understand the impact of different skin incisions on recovery from TKA; and (iii) determine the optimal incision length, that is, appropriate incision stretching in patients undergoing primary TKA. To our knowledge, this is the first study to quantitatively compare the tension of the incision of TKA. We hypothesized that patients with a large tension of the incision would have worse clinical outcomes and higher complication rates.

Methods

Study Design and Study Population

This is a retrospective study conducted in a tertiary hospital. A total of 1210 patients accepted primary and unilateral TKA at the authors’ affiliated institutions between January 2015 and January 2019. This study had been approved by the ethics committee of the authors’ affiliated institutions and is in accordance with the Declaration of Helsinki.

Inclusion criteria for the case group included: (i) the diagnosis of osteoarthritis (OA) following the International Classification of Diseases 9th Revision (ICD-9); (ii) undergoing primary and unilateral TKA; (iii) had a completed data including clinical evaluation and examination used for comparison; (iv) a retrospective study.

Exclusion criteria included: (i) preoperative flexion contracture greater than 15° and preoperative flexion less than 90°; (ii) paresthesia in lower limb; (iii) scar within the
knee area; (iv) patella alta or baja. The patients were followed up for an average of 13.3 months postoperatively.

We recorded and analyzed the following data, including each patient's characteristics, perioperative information, and follow-up assessments. These data were completed and evaluated by respective experienced therapists who were blinded to this research based on uniform standards.

**Clinical Assessment**

**Incision Stretching Index (IS Index)**
We calculated the incision stretching index (IS index), which is defined as FL-EL in the present study (Fig. 1). FL represented the length of surgical incision when the knee was flexed at 120°. EL represented the length of surgical incision when the knee was extended at 0°. The length of surgical incision was measured intraoperatively using a sterile tape with care taken to avoid crinkling. Patients were grouped by trisecting the range of IS index we observed in the present study.

**Visual Analog Scale (VAS)**
The primary outcome measure was the visual analog scale (VAS) pain score rated on a scale of 0–10 from no pain to severe pain. This measure was completed 2 weeks postoperatively.

**Knee Girth**
Knee girth was measured on the proximal pole of the patella using a tape. Patients were required to lie on their back on the bed. This measure was completed 2 weeks postoperatively.

**Range of Motion (ROM)**
ROM was measured using a standard hand-held goniometer with a patient in a supine position. The goniometer was placed over joint space with one arm aligned with fibular head and lateral malleolus and the other in line with the greater trochanter. The knee was flexed maximally at the patient's best, and then the angle was measured in degrees.

**Sensory Testing**
In the sensory testing, all patients were examined for the area of altered sensations to “light touch” using a pin-prick over the front of the knee based on Appendix Table A1. After mapping the margins of the area of abnormal sensation, the surgeon’s assistant measures that using a plastic tape. Patients were required to indicate abnormal sensation from anesthesia to hypersensitivity (see Appendix Table A1), and we measures its area using a purpose-designed grid 6 months postoperatively. Each sensory test was performed twice, and the mean value was finally analyzed.

**Quadriceps Strength (QS)**
The isokinetic strength of quadriceps (QS) was assessed using a ConTrex System Dynamometer (ConTrex MJ; CMV AG, Dübendorf, Switzerland) preoperatively and 2 weeks postoperatively at 60°/s. When evaluated, the patient exerted maximum effort for two attempts, and then the peak torque values of quadriceps were obtained. All the assessments mentioned above were completed 2 weeks postoperatively.

**Complications**
Significant complaints and complications over the study period would be reported to respectively experienced orthopaedists, which were then determined whether to be analyzed. Incision problems include delayed union, non-union, and skin necrosis. Doppler ultrasonography was arranged to confirm the presence or absence of deep vein thrombosis (DVT) after surgery and before discharge. All patients who performed the assignments mentioned above were blinded to the final analysis.

**Surgical Procedure**
All operations were performed by one surgical team in respective institutions using epidural anesthesia.

An anterior midline skin incision and a medial parapatellar approach were used, and the patella was everted. A measured resection technique was used to balance the extension and flexion gap. A distal femoral cut was performed with an intramedullary instrumentation setting of 6° of the anatomic valgus. Referring to the surgical transepicondylar axis, the femoral external rotation cut was performed. Extramedullary instrumentation was used to achieve a target tibial cut of 90° relative to the mechanical axis in the coronal plane and of 3° to 5° relative to the posterior slope in the sagittal plane.

Cruciate-retaining (CR) prosthesis (Gemini MK-II, Link, Germany) or DePuy (Warsaw, Ind) Sigma posterior-stabilized (PS) with patellar resurfacing was used for all patients in this study. All components were cemented.
During the operation, no intravenous dexmethasone, tranexamic acid, or “cocktail” therapy was used. Wounds were closed in the same manner for each knee with two 1/8-inch suction drains in each knee. The recollected blood was filtered and washed in the recovery room and then transfused into the patient within 6 hours following surgery. The drainage tube was promptly extracted within 24 hours postoperatively. The pneumatic tourniquet was generally applied at 300 mm Hg. It was used from the beginning of femur osteotomy to the end of tibia osteotomy and then released following the joint capsule’s closure.

All patients were routinely administered with prophylactic cefotaxime (1 g, iv, tid) before the skin incision. Patients were connected to a patient-controlled analgesia (PCA) pump during the postoperative 48 hours. For relieving postoperative pain, all patients would receive diclofenac sodium (50 mg, po, tid) routinely orally during the hospital stay and tramadol (100 mg, po, tid) after discharge if they needed that. Preventive anticoagulant therapy (10 mg rivaroxaban every day or 2850 international units [IU] low-molecular-weight heparin [LMWH] [body weight < 90 kg] or 5700 IU [bodyweight >90 kg]) began within 12 hours after the operation and continued for 14 days.

### Statistical Analysis

By trisecting the IS index, patients were grouped and compared. Continuous data in this study were normally distributed and were listed as mean ± standard deviation (SD), respectively. They were analyzed via the Analysis of Variance (ANOVA) and Tukey’s post hoc. Countable variables were listed as percentages and compared via the chi-square test and Fisher exact test. The statistical significance and the power analysis were required with \( P \)-value ≤0.05 and 1-\( \beta \) = 0.8. Using G Power 3.1.9.2, the study power was calculated for the effect size of 0.3, error of the first type 0.05, and the total number of respondents with the number of 358 patients undergoing TKA. The calculated study power equals 95.45%, which indicates good study power. We performed statistics analysis by SAS 9.2 (SAS Institute Inc., Cary, NC, USA) and Excel 2003, version 11 (Microsoft, Redmond, Washington).

### Results

#### General Results

A total of 1089 patients undergoing primary and unilateral TKA in our two institutions were screened for final analysis. Specifically, patients who had no completed follow-ups (\( n = 32 \)), preoperative flexion contracture greater than 15° and preoperative flexion less than 90° (\( n = 34 \)), paresthesia in the lower limb (\( n = 34 \)), scar within the knee area (\( n = 10 \)), patella alta or baja (\( n = 8 \)), and death after surgery (\( n = 3 \)) were excluded.

#### Demographic Profiles

A total of 78.1% of included patients were female (\( n = 851 \)), and their mean ages were 66.0 (SD: 4.8) years. Perioperative information was detailed in Table 1. We found no significant difference in mean age, gender, and BMI (all \( P > 0.05 \)) among groups (Table 1).

#### Other Preoperative Data of the Patients

The mean length of EL was 23.2 cm (range: 16.5–33.5 cm). The mean length of FL was 28.3 cm (range: 21.0–38.8 cm). The mean IS index was 2.7 cm (range: 0.4–3.8 cm). The range of IS index of groups A, B, and C was 0–1.7 cm, 0–1.7 cm, and 0–3.4 cm (including 1.7 cm), and 0–3.4 cm (including 3.4 cm), respectively. Clinical parameters in each group were detailed in Table 1. We found no significant difference in prosthesis type, surgery time, tourniquet time, intraoperative bleeding, and transfusion among groups (all \( P > 0.05 \)) (Table 1).

| Clinical parameters in each group | IS A (\( n = 355 \)) | IS B (\( n = 416 \)) | IS C (\( n = 318 \)) | \( P \) value |
|----------------------------------|-----------------|-----------------|-----------------|------------|
| Age (years)                     | 66.3 ± 4.8      | 65.8 ± 5        | 66.0 ± 5        | 0.3774     |
| Gender (female) (\( n \), percentage) | 287/80(84) | 325/78(78) | 239/75(72) | 0.2042     |
| BMI > 25 kg/m² (\( n \), percentage) | 278/78.3   | 337/81.0       | 249/77(70)    | 0.3974     |
| Prosthesis type (CR/PS) (\( n \), percentage) | 220/135 (62.0%/38.0%) | 248/168 (60.0%/40.0%) | 207/111 (65.1%/34.9%) | 0.3173   |
| Surgery time (min)              | 58.9 ± 5.8      | 38.8 ± 6.8      | 38.7 ± 7.1     | 0.3791     |
| Tourniquet time (min)           | 39.2 ± 7.2      | 36 ± 7.6        | 36 ± 7.6       | 0.6095     |
| Intraoperative Bleeding (mL)    | 183.5 ± 43.8    | 190.6 ± 52.6    | 186.6 ± 50.2   | 0.1330     |
| Transfusion (\( n \), percentage) | 108/30 (34)    | 138/33 (32)     | 93/29 (29)     | 0.4917     |
| VAS pain score                  | 3.0 ± 3.6       | 3.1 ± 1.8       | 2.9 ± 1.8      | 0.3012     |
| Knee girth (cm)                 | 32.4 ± 3.0      | 32.7 ± 3.3      | 32.2 ± 3.5     | 0.1125     |
| ROM (°)                         | 103.2 ± 12.5    | 101.5 ± 14.7    | 103.8 ± 13.6   | 0.0578     |
| Strength of quadriceps (Nm)     | 30.9 ± 13.6     | 32.4 ± 12.4     | 31.2 ± 14.0    | 0.2500     |

BMI, body weight index; CR, Cruciate-retaining; PS, Posterior cruciate ligament-substitute; ROM, range of motion; VAS, visual analogue scale.; * Significant difference among groups.
TABLE 2 Clinical comparisons among different IS index groups

| Clinical characteristics (Number = 1089) | 1:IS A (n = 355) | 2:IS B (n = 416) | 3:IS C (n = 318) | P value |
|-----------------------------------------|-------------------|-------------------|-------------------|---------|
| VAS pain score                          | 2.3 ± 0.6         | 3.4 ± 1.6         | 3.9 ± 1.5         | 1–2:0.001*  |
| Knee girth(cm)                          | 33.9 ± 3.5        | 35.8 ± 3.1        | 37.4 ± 3.5        | 1–3:0.001*  |
| ROM(°)                                  | 115.2 ± 10.8      | 105.5 ± 9.6       | 100.7 ± 14.6      | 2–3:0.001*  |
| Sensory testing(cm²)                    | 36.2 ± 5.4        | 40.4 ± 6.5        | 44.6 ± 6.8        | 1–2:0.001*  |
| QS(Nm)                                  | 28.4 ± 12.2       | 23.0 ± 12.5       | 20.5 ± 9.8        | 1–3:0.001*  |
| Incision problems (n, percentage)       | 9 (2.5)           | 15(3.6)           | 31(9.7)           | 2–3:0.001*  |
| PJI (n, percentage)                     | 3(0.8)            | 5(1.2)            | 3(0.9)            | 1–2:0.001*  |
| DVT (n, percentage)                     | 1(0.3)            | 2(0.5)            | 1(0.3)            | 1–3:0.2348  |

DVT, deep venous thrombosis; PJI, periprosthetic joint infection; QS, strength of quadriceps; ROM, range of motion; VAS, visual analogue scale.; * Significant difference among groups.

Visual Analog Scale Pain Score
There was no significant difference in VAS pain score among group IS A, IS B, and IS C before surgery (P = 0.3012). However, with the increase in the IS index, the VAS pain score was significantly increased postoperatively (2.3 ± 0.6 vs 3.4 ± 1.6 vs 3.9 ± 1.5, P < 0.001) (Table 2).

Knee Circumference
There was no significant difference in knee circumference among group IS A, IS B, and IS C before surgery (P = 0.1125). However, with the increase in the IS index, knee circumference was significantly increased postoperatively (33.9 ± 3.5 vs 35.8 ± 3.1 vs 37.4 ± 3.5, P ≤ 0.001) (Table 2).

Range of Motion (ROM)
There was no significant difference in ROM among group IS A, IS B, and IS C before surgery (P = 0.0578). However, with the increase in the IS index, ROM was significantly decreased postoperatively (115.2 ± 10.8 vs 105.5 ± 9.6 vs 100.7 ± 14.6, P ≤ 0.001) (Table 2).

Abnormal Sensation Area
With the increase in the IS index, the area of abnormal sensation was significantly increased postoperatively (36.2 ± 5.4 vs 40.4 ± 6.5 vs 44.6 ± 6.8, P < 0.001) (Table 2).

Quadriceps Strength
There was no significant difference in the strength of quadriceps among group IS A, IS B, and IS C before surgery (P = 0.2500). However, with the increase in the IS index, the strength of quadriceps was significantly decreased postoperatively (28.4 ± 12.2 vs 23.0 ± 12.5 vs 20.5 ± 9.8, P < 0.001) (Table 2).

Complications
With the increase in the IS index, the number of patients with incision problems was increased significantly (2.5% vs 3.6% vs 9.7%, P < 0.001) (Table 2). Besides, no significant difference in PJI and DVT among groups was observed (P > 0.05) (Table 2).

Discussion
In this study, we investigated the outcome related to the amount of stretch placed on the skin incision as measured by the gap between the incision length in flexion and that in extension in patients undergoing primary TKA. Furthermore, we included the IS index as an assessment criterion to determine how the difference between EL and FL affected TKA outcomes. We compared VAS pain score, ROM, QS, knee circumference, and incision problems among groups. The present study revealed that pain feeling, ROM, QS, swelling, and incision problems improved two weeks after TKA with a decrease in the IS index. These results showed that the closer the gap between EL and FL was, the less the
incision stretching was, which benefit outcomes after TKA. Our present results suggested IS A was the optimal range between flexion and extension length in patients undergoing primary TKA. Given the above, during the study we observed that in such an incision (IS A) TKA results could be improved if the quadriceps tendon was incised 4 cm proximally above the upper border of the patella and distally along the medial side of the patellar tendon to the tubercle of the tibia.

There are primarily three reasons that explain the above findings. Firstly, the strength of the quadriceps is decreased by up to 60% after TKA due to the cutting of quadriceps muscle, elevation of the patella, and extreme knee flexion during TKA. In addition to that, Charancholvanich et al reported a significant effect of the length of surgical incision on the postoperative strength of quadriceps. Furthermore, incision size directly affects pain feeling and swelling as a larger incision produces more inflammatory factors. Less pain decreased swelling, and better strength of quadriceps made patients relatively comfortable while performing the functional exercise. Finally, IS C represents the highest stretch level in comparison to IS A and B, which make surrounding tissue tolerate the largest tensile force, especially as the knee is in an extreme flexion intraoperatively. Made up of a complex network of collagen and elastin fibers, the skin has elastic characteristics and mechanical strength within its physiological limits. However, previous studies indicated that the acute, purely reversible elastic response of stretched skin tissue, which is similar to the stretching process of the incision during TKA, would be impaired to a certain extent if we extended it beyond its physiological limits. This impairment by releasing inflammatory elements and strain injury of nerves showed pain feelings, paresthesia, and tissue edema. Therefore, the information above can explain why IS A is the optimal gap between the incision length in flexion and in extension in patients undergoing primary TKA.

Clinically, more incision problems, even including skin necrosis, occurred as the incision was at higher stretch levels. Therefore, to avoid these problems, a decrease in incision stretching force by increasing its length in extension, which improves microcirculation of surrounding tissue, leads to better incision healing. Hence, it is clinically meaningful. Our results may provide clinical evidence and basic data of the obvious effects of incision stretching on key outcomes after TKA, such as pain, ROM, QS, and swelling. Furthermore, our results reveal a greater surface area of sensory change in the front of the knee following TKA occurs in patients with an incision at higher stretch level, since nerves around the knee which were stretched beyond physiological limits were shown to be impaired more widely due to the characteristic of the extensibility of the axon. This greater alteration in skin sensation discounted the ability to kneel due to the fear of harming the prosthesis. It combined a negative effect on subjective feelings such as titillation, resulting in patient dissatisfaction following TKA. This study suggests that the length of incision, in extension, is possibly an effective treatment method, especially when patients perform the painful exercise, as appropriate incision stretching makes them comfortable with less pain and improved strength of quadriceps. It is conceivable and desirable that there were medical costs saved due to earlier recovery. Therefore, the present study’s findings suggest selecting the optimal gap between the incision length in flexion and that in extension, which determines incision stretching and would be significant in the clinical practice.

To our best knowledge, there are merely two studies involving the incision length in primary TKA, and their results have limitations. Charancholvanich’s report only investigated the effect of the range of knee incision in full extension on quadriceps strength. Despite elaborate data regarding quadriceps strength following TKA in his report, only different incision length in extension was discussed. However, incision length in flexion, namely the problem of incision stretching, was not studied. By contrast, Roidis’s study paid close attention to the incision stretching in patients undergoing primary TKA. He reported that the incision length was 5.7 cm longer in flexion than extension. The surgical incision site stretched an average of 23.6% in flexion compared to in extension. However, the impact incision stretching could have on clinical outcomes after TKA, such as pain, ROM, and swelling, have not yet been investigated. Based on these two studies, our study further deepens the significance of incision stretching, and this is the first study to investigate that topic. A comprehensive understanding of the impact of incision stretching on TKA results may help surgeons to optimize clinical practice. This study’s findings can guide surgeons to attach importance to the length of incision in extension, which determines the stretching force of your incision. Despite being a seemingly minor problem, it is a real concern that requires attention. Less incision stretching becomes a good treatment for fast recovery from TKA. We hope the present results could be helpful in optimizing this technique and perfecting clinical outcomes.

Limitation
Several limitations in this study warrant discussion. First, our data of incision stretching was obtained by calculating the self-designed formula FL-EL, and thus the examination of its real size was indirectly and relatively inaccurate. Second, no pathological examination was applied. However, that serves as the golden criterion, which demonstrates that incision stretching can be observed as changes in the microscopic structure, such as the disruption of skin collagen bundles. Third, our study employs many different combinations, and this made pain score evaluations accurate to a certain extent. Finally, a relatively small sample results in less persuasive conclusions. Therefore, in future studies, we intend to quantitatively evaluate changes in the tissue under different stretching forces via microscopic examination and objective measurements such as a mechanical sensor.
Conclusions

In the present study, there was a significant impact of incision stretching on clinical results after TKA. Appropriate incision stretching mainly depended on the length of full extension of the knee, which can benefit postoperative pain, surgical swelling, ROM, abnormal sensation, strength of quadriceps, and patient’s perception of recovery from TKA with the decreased risks of incision complications.

References

1. M H, Artz N, Weale A, Porteous A. Alteration in skin sensation following knee arthroplasty and its impact on kneeing ability: a comparison of three common surgical incisions. Knee Surg Sports Traumatol Arthrosc, 2012, 20: 1983–1987.
2. Gilliland JM, Anderson LA. Perioperative closure-related complication rates and cost analysis of barbed suture for closure in TKA. Clin Orthop Relat Res, 2012, 470: 125–129.
3. Gilliland JM, Lucas A. Is there an advantage to knotless barbed suture in TKA wound closure? A randomized trial in simultaneous bilateral TKAs. Clin Orthop Relat Res, 2015, 473: 2019–2027.
4. Nakai T, Tamaki M, Nakamura T, Nakai T, Onishi A, Hashimoto K. Controlling pain after total knee arthroplasty using a multimodal protocol with local percutaneous injections. J Orthop, 2013, 10: 92–94.
5. Chen Y, Chen Z, Cui S, Li Z, Yuan Z. Topical versus systemic tranexamic acid after total knee and hip arthroplasty: a meta-analysis of randomized controlled trials. Medicine (Baltimore), 2016, 95: e4656.
6. Charoencholvanich K, Siriwattanasakul P. Tranexamic acid reduces blood loss and blood transfusion after TKA: a prospective randomized controlled trial. Clin Orthop Relat Res, 2011, 469: 2874–2880.
7. Pan L, Hou D, Liang W, Fei J, Hong Z. Comparison of the effects of pressurized salt ice packs with water ice packs on patients following total knee arthroplasty. Int J Clin Exp Med, 2015, 8: 18179–18184.
8. Engh GA, Holt BT, Parks NL. A midvastus muscle-splitting approach for total knee arthroplasty. J Arthroplasty, 1997, 12: 322–331.
9. Hofmann AA, Plaster RL, Murdock LE. Subvastus (southern) approach for primary total knee arthroplasty. Clin Orthop Relat Res, 1991, 269: 70–77.
10. Insall J. A midline approach to the knee. J Bone Joint Surg Am, 1971, 53: 1584–1586.
11. Keblish PA. The lateral approach for total knee arthroplasty. J Knee Surg, 2003, 16: 62–68.
12. Flören M, Reichel H, Davis J, Laskin RS. The mini-incision midvastus approach for total knee arthroplasty. Oper Orthop Traumatol, 2008, 2: 534–543.
13. Stulberg SD. Minimally invasive navigated knee surgery: an American perspective. Orthopedics, 2005, 28: S1241–S1246.
14. Tanavalee A, Thiengwittayaporn S, Itiravivong P. Results of the 136 consecutive minimally invasive total knee arthroplasties. J Med Assoc Thai, 2005, 88: S74–S78.
15. Tria AJ Jr, Coon TM. Minimal incision total knee arthroplasty: early experience. Clin Orthop Relat Res, 2003, 416: 185–190.
16. Dabboussi N, Safir M, Girard J, Fakh R. Minimally Invasive total knee arthroplasty: a comparative study to the standard approach. N Am J Med Sci, 2012, 4: 81–85.
17. Roidis NT, Karachalios TS, Malizos KN, McPherson EJ. Incision stretching in primary TKA: what is the real length of our approach? Orthopedics, 2007, 3: 397–398.
18. León-Muñoz VJ, Martínez-Martínez F, López-López M, Santonja-Medina F. Patient-specific instrumentation in total knee arthroplasty. Expert Rev Med Devices, 2019, 16: 555–567.
19. Hopton BP, Tommichian MC, Howell FR. Reducing lateral skin flap numbness after total knee arthroplasty. Knee, 2004, 11: 289–291.
20. Johnson DF, Love DT, Love BR, Lester DK. Dermal hypoesthesia after total knee arthroplasty. Am J Orthop, 2000, 29: 863–866.
21. Sundaram RO, Ramakrishnan M, Harvey RA, Parkinson RW. Comparison of scars and resulting hypoesthesia between the medial parapatellar and midline skin incisions in total knee arthroplasty. Knee, 2007, 14: 375–378.
22. Tennent TD, Birch NC, Holmes MJ, Birch R, Goddard NJ. Knee pain and the infrapatellar branch of the saphenous nerve. J R Soc Med, 1998, 91: 573–575.
23. Berth A, Urbach D, Neumann W, Awiszus F. Strength and voluntary activation of quadriceps femoris muscle in total knee arthroplasty with midvastus and subvastus approaches. J Arthroplasty, 2007, 22: 63–88.
24. Chareancholvanich K, Pornrattanamaneepong C. Does the length of incision in the quadriceps affect the recovery of strength after total knee replacement? Bone Joint J, 2014, 96: 902–906.
25. Tepole AB, Gosain AK, Kuhl E. Stretching skin: the physiological limit and beyond. Int J Non Linear Mech, 2012, 47: 938–949.
26. Jiang HH, Jian XF, Shangguan YF, Qing J, Chen LB. Effects of enhanced recovery after surgery in total knee arthroplasty for patients older than 65 years. Orthop Surg, 2019, 11: 229–235.

APPENDIX

| TABLE A1 Grading of sensation to pin-prick and light touch testing |
|---------------------------------------------------------------|
| Definition | Terminology |
| Absent sensation to pin-prick/light touch | Anesthesia |
| Diminished sensation to light touch blunted sensation to pin-prick | Hypoesthesia |
| Abnormal but tolerable sensation to pin-prick/light touch | Normal Sensitive |
| Marked/unbearable sensation to pin-prick/light touch | Hypersensitive |