The impact of the stretching force of incision on early clinical results after primary total knee arthroplasty (TKA)

Long Gong (Gonglong301@163.com)
252 hospital of Chinese PLA https://orcid.org/0000-0002-6040-7537
Wang Yanlei
China-Japan Friendship Hospital
Yi Ping
China-Japan Friendship Hospital
Sun Yan
China-Japan Friendship Hospital
Song Jipeng
China-Japan Friendship Hospital
Tan Mingsheng
China-Japan Friendship Hospital

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Abstract

Background：A variety of surgical approaches are used in primary total knee arthroplasty (TKA), including medial parapatellar, sub-vastus, mid-vastus, lateral, and less invasive techniques. Previous studies demonstrated that there existed widely varied degrees of anterior knee soft-tissue stretching in patients undergoing primary TKA. However, the impact of incision stretching on TKA's results failed to be investigated.Methods：1210 patients accepted primary and unilateral TKA at the authors' affiliated institutions between Jan. 2011 and Dec. 2015. We recorded and analyzed the following data, including each patient's characteristics, incision stretching index (IS index), perioperative information, and follow-up assessments. By trisecting the IS index, patients were grouped and compared about visual analogue scale (VAS) pain scores as the primary outcome, knee circumference, knee range of motion (ROM), sensory testing, and the strength of quadriceps. Results：1089 patients undergoing primary and unilateral TKA in our two institutions were screened for final analysis, and 121 ones were excluded. The mean IS index was 22.6 (range: 19.7-24.8). VAS pain score, knee circumference, ROM, area of abnormal sensation, and the strength of quadriceps among group IS A, IS B, and IS C were significantly different (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), while ROM and the strength of quadriceps decreased (P<0.05). Also, no significant difference in PJI and deep vein thrombosis (DVT) among groups was observed (P>0.05). Conclusions： There was a significant impact of incision stretching on clinical outcomes after TKA. Decreased incision stretching, which mainly depended on the length in full extension of the knee, can improve postoperative pain relief, surgical swelling, ROM, sensory disturbance of the knee, and the strength of quadriceps with reduced risk of incision complications.

Introduction

Total knee arthroplasty (TKA) is regarded as a successful surgical method to treat the severe degenerate tibiofemoral joint. While total knee arthroplasty has long been judged primarily by implant survivorship, the focus is increasingly on patient-reported outcomes [1]. Reconstructive surgeons use several methods to improve patient outcomes following total knee arthroplasty, which include surgical closure [2, 3], cocktail therapy [4], use of tranexamic acid [5, 6], and cryotherapy [7]. Those are effective treatments to achieve improved outcomes according to previous studies.

A variety of surgical approaches are used in TKA, including medial parapatellar, sub-vastus, mid-vastus, and lateral techniques [8–11]. These approaches are typically applied through incisions up to 20–30 cm in length and offer optimal exposure of the entire knee joint [12]. Minimally invasive approaches for TKA have become popular and often require specialized training, modified retractors, and modular implants. In all approaches, a certain amount of skin stretching occurs to expose the knee adequately [13, 14]. Nikolaos demonstrated varying degrees of anterior soft-tissue stretching during primary TKA [14], but the impact of this variation in tension has yet to be investigated and is not fully understood.

We assumed that the length of skin incision determines incision stretching, which would affect recovery from TKA. To our best knowledge, no study has examined that point. Therefore, the present study was conducted to investigate the optimal incision length, that is, appropriate incision stretching in patients undergoing primary TKA.

Materials And Methods

Patients and Data

1210 patients accepted primary and unilateral TKA at the authors' affiliated institutions between Jan. 2011 and Dec. 2015. This study had been approved by the ethics committee of the authors' affiliated institutions and accorded with the declaration of Helsinki. Patients who accepted primary and unilateral TKA due to OA were included. Excluded cases including the patients who were unable to complete necessary follow-up; have a knee with preoperative flexion contracture greater than 15° and preoperative flexion less than 90°; have paresthesia in lower limb; have any scar within the knee area; have patella alta or baja; dead after surgery. 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.

We calculated the incision stretching index (IS index), which is defined as FL-EL/EL in the present study. 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. The primary outcome measure was visual analogue 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. Knee circumference was measured on the proximal pole of the patella using a tape. 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 degree. In the sensory testing, all patients were examined for the area of altered sensations to 'light touch' using pin-prick over the front of the knee based on Appendix Table 1.

Table 1
Clinical parameters in each group.

Clinical characteristics (Number = 1089)	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 ± 5.1	0.3774
Gender(female)	287(80.8%)	325(78.1%)	239(75.2%)	0.2042
BMI > 25 kg/m2	278(78.3%)	337(81.0%)	245(77.0%)	0.3974
Prosthesis type (CR/PS)	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	108(30.4%)	138(33.2%)	93(29.2%)	0.4917
VAS pain score	3.0 ± 1.6	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 VAS visual analogue scale ROM range of motion				
* Significant difference among groups				

After mapping the margins of the area of abnormal sensation, surgeon assistant measures that using the grid made of a thin sheet of plastic. The isokinetic strength of quadriceps (QS) was assessed using a ConTrex System Dynamometer (ConTrex MJ; CMV AG, Dübendorf, Switzerland) pre-operatively and two weeks postoperatively at 60°/s. When being 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 two weeks postoperatively. Participants were required to indicate abnormal sensation from anesthesia to hypersensitive (see appendix Table 1), and we measure its area using a purpose-designed grid six months postoperatively [1]. Each sensory test was performed twice, and the mean value was finally analyzed. Significant complaints and complications over the study period would be reported to respectively experienced orthopedists and then determined whether to be analyzed finally. Incision problems include delayed union, nonunion, and skin necrosis. Doppler ultrasonography was arranged to confirm the presence or absence of deep vein thrombosis (DVT) after surgery and before discharge. All participants who performed the above-mentioned assignments were blinded to the final analysis.

Surgical Procedure

All operations were performed by one surgical team in respective institutions using epidural anesthesia alone, general anesthesia alone, regional anesthesia alone, or combined general and regional anesthesia. A standard medial parapatellar arthrotomy was used. 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. Wounds were closed in the same manner for each knee with two1/8-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 h 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 closure of the joint capsule. All patients were routinely administered with prophylactic cefotaxime (1 g, iv, tid) before the skin incision. Patients were applicated with a patient-controlled analgesic (PCA) pump during 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). Countable variables were listed as percentages and compared via the Chi-square test. The statistical significance and the power analysis were required with p-value ≤ 0.05 and $1-\beta = 0.8$. We performed statistics analysis by SAS 9.2 by SAS Institute Inc., Cary, NC, USA, and Excel 2003, version 11 by Microsoft, Redmond, Washington.

Results

1089 patients undergoing primary and unilateral TKA in our two institutions were screened for final analysis. Specifically, patients who were unable to complete necessary follow-ups (N = 32), had a knee with preoperative flexion contracture greater than 15° and preoperative flexion less than 90°(N = 34), had paresthesia in lower limb(N = 34), had any scar within the knee area(N = 10), had patella alta or baja (N = 8) and dead after surgery(N = 3), were excluded. 78.1% of included patients were female (N = 851), and their mean ages were 66.0 years old. Perioperative information was detailed in Table 1.

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 22.6 (range: 19.7–24.8). The knee incision stretched, on average, 22.6% (range: 19.7%-24.8%). The range of IS index of group A, B, and C was 19.7–21.4 (including 21.4), 21.4–

23.1(including 23.1), and 23.1–24.8 (including 24.8), respectively. Clinical parameters in each group were detailed in Table 1. We found no significant difference in those data among groups.

The effect of IS index on clinical outcomes after primary TKA

VAS pain score, knee circumference, ROM, area of abnormal sensation, and the strength of quadriceps among group IS A, IS B, and IS C were significantly different ($P < 0.05$). With the increase in the IS index, VAS pain score, knee girth and the area of abnormal sensation were significantly increased ($P < 0.05$), while ROM and the strength of quadriceps decreased ($P < 0.05$) (Table 2).

Table 2
Clinical comparisons among different IS index groups.

Clinical characteristics (Number = 1089)	IS A (N = 355)	IS B (N = 416)	IS C (N = 318)	P value
VAS pain score	3.2 ± 1.8	3.4 ± 2.0	3.7 ± 1.9	0.0031*
Knee girth(cm)	35.4 ± 2.9	35.8 ± 3.1	36.4 ± 3.5	0.0002*
ROM(°)	107.2 ± 10.8	105.5 ± 9.6	103.7 ± 14.6	0.0005*
Sensory testing(cm2)	39.2 ± 5.4	40.4 ± 6.5	41.6 ± 6.8	< 0.0001*
QS(Nm)	24.4 ± 12.2	23.0 ± 12.5	20.5 ± 9.8	< 0.0001*
Incision problems	8	12	19	0.0216*
PJI	3	5	3	0.8746
DVT	1	2	1	0.8862

Definition	Terminology
Absent sensation to pin-prick/light touch	Anaesthesia
Diminished sensation to light touch blunt sensation to pin-prick	Hypoesthesia
Normal sensation	Normal
Abnormal but tolerable sensation to pin prick/light touch	Sensitive
Marked/unbearable sensation to pin prick/light touch	Hypersensitive

VAS visual analogue scale ROM range of motion QS Strength of quadriceps PJI periprosthetic joint infection DVT deep venous thrombosis

* Significant difference among groups

Appendix Table 1 Grading of sensation to pin-prick and light touch testing

Complications

With the increase in the IS index, the number of patients with incision problems was increased significantly ($P < 0.05$) (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 ratio of the incision length in flexion to 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's 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 were improved better two weeks after TKA with a decrease in 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 ratio between flexion and extension length in patients undergoing primary TKA. Given the above, during the study, we observed that such an incision (IS A) that 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 could improve the results after TKA.

There are primarily three reasons that explain the above findings. Firstly, the strength of quadriceps is decreased by up to 60% after TKA, as the cutting of quadriceps muscle, eversion of the patella, and extreme knee flexion during TKA [18]. In addition to that, K. Chareancholvanich et al. reported that there is a significant effect of the length of surgical incision on the postoperative strength of quadriceps [18]. What's more, the size of incision directly affects pain feeling and swelling as larger incision produces more inflammatory factors [16]. Less pain decreased swelling, and better strength of quadriceps makes patients relatively comfortable while they perform the functional exercise. Finally, IS C represents the ratio at 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 [17]. 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 stretched it beyond its physiological limits [17]. This impairment by releasing inflammatory elements and strain injury of nerves showed pain feelings, paresthesia, and tissue edema. Therefore, the contents above can help explain why IS A is the optimal ratio of the incision length in flexion to 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 a better incision healing, and hence it is clinically important. 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 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 [1]. This greater alteration in skin sensation discounted the ability to kneel due to the fear of harming the prosthesis [1], combined a negative effect on subjective feelings such as titillation, results in patient dissatisfaction following TKA. That is, 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 by less pain and improved strength of quadriceps. It is conceivable and desirable that there were medical costs saved due to earlier recovery. Therefore, the findings in the present study suggest that selecting the optimal ratio of the incision length in flexion to extension in extension, which determines incision stretching would be significant in the clinical practice.

To our best knowledge, although there merely two studies involving the incision length in primary TKA. However, their results have a certain limitation. K. Chareancholvanich's report only investigated the effect of the length of knee incision in full extension on quadriceps strength [16]. 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, did not be studied. By contrast, Roidis NT's study paid close attention to the incision stretching in patients undergoing primary TKA [14]. 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 [14]. However, what impact could incision stretching have on clinical outcomes after TKA, such as pain, ROM, and swelling, has not been investigated yet. Based on these two studies, our study further deepens the significance of incision stretching, and this is the first study to investigate that. A comprehensive understanding of the impact of incision stretching on TKA's results may help surgeons to optimize clinical practice. This helps us know the effect of incision stretching on TKA's results we interested in. Findings from this study can guide surgeons to attach importance to the length of incision in extension, which determines the stretching force of your incision. Despite being the seemingly minor problem, it is a real concern we should deliberate on. It becomes a well treatment of fast recovery from TKA with the circumstance of less incision stretching. We hope the present results could be helpful in optimizing TKA's detail and perfect clinical outcomes.

Several limitations in this study warrant discussion. First, our data of incision stretching was obtained by calculating the self-designed formula: FL-EL/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 the incision stretching exists by the observation of 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 evaluation accurate to a certain extent. Finally, relatively small sample results in less persuasive conclusions. Therefore, in the future study, we intend to quantitatively evaluate changes in the tissue under different stretching forces via microscopic examination and objective measurements such as a mechanical sensor.

Conclusion

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 in full extension of the knee, which can benefit on postoperative pain, surgical swelling, ROM, abnormal sensation, the strength of quadriceps and patient's perception of recovery from TKA with the decreased risks of incision complications.

Abbreviations

TKA	total knee arthroplasty
IS	incision stretching
VAS	visual analogue scale
ROM	range of motion
FL	the length of surgical incision when the knee was flexed in 120°
EL	the length of surgical incision when the knee was extended in 0°
QS	strength of quadriceps
PS	posterior-stabilized
CR	Cruciate-retaining
PCA	patient-controlled analgesic
IU	international units
LMWH	low-molecular-weight heparin
SD	standard deviation
ANOVA	Analysis of Variance

Declarations

Ethics approval and consent to participate

Ethical approval for this study was obtained from the Medical Ethics Committee of China-Japan Friendship Hospital.

Consent for publication

The patient had made consent to publish identifiable information and data.

Availability of data and materials

Data can be made available upon request to the corresponding author.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

TM and GL participated in concept development, data generation, quality control of the data, data analysis and interpretation, and writing of the manuscript. TM, SY, and YP were responsible for the data analysis and participated in the interpretation and presentation of the data. SJ and GL provided input into the data interpretation. TM, GL, and YP were involved in the concept development, quality control of the data, and data analysis and interpretation of the manuscript. All authors have read and approved the final version of the submitted manuscript.

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Appendix Table

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