Original Article
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Predictors of Recurrent Flexion Contracture after Total Knee Arthroplasty in Osteoarthritic Knees with Greater Than 15° Flexion Contracture

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Background: This study aimed to analyze the risk factors that predict recurrent flexion contracture (FC) after total knee arthroplasty (TKA) in osteoarthritic knees with FC ≥ 15°.

Methods: Data from a consecutive cohort comprising 237 TKAs in 187 patients with degenerative osteoarthritis, preoperative FC ≥ 15°, and a minimum follow-up period of 2 years were retrospectively reviewed. Preoperative FC was corrected intraoperatively from 0° to 5°. The incidence of recurrent FC (FC ≥ 10°) at 2 years postoperatively was investigated. Potential risk factors predicting recurrent FC including age, sex, body mass index, unilateral TKA, severity of preoperative FC, 3-month postoperative residual FC, γ angle, change in posterior femoral offset ratio, and lumbar degenerative kyphosis (LDK) were analyzed using logistic regression analysis. The post-hoc powers for the identified factors were then determined.

Results: Forty-one knees (17.3%) with recurrent FC were identified. Risk factors with sufficient power for recurrent FC were unilateral TKA, severity of preoperative FC, residual FC at 3 months postoperatively, and LDK (odds ratios of 3.579, 1.115, 1.274, and 3.096, respectively; $p < 0.05$; power ≥ 86.1).

Conclusions: Recurrent FC can occur in TKAs with the risk factors including unilateral TKA, severe preoperative FC, residual FC at 3 months postoperative, and LDK despite appropriate intraoperative correction. Surgical strategies and rehabilitation protocols used in managing FC should be applied in TKA cases with risk factors for recurrent FC.

Keywords: *Knee, Arthroplasty, Flexion contracture, Risk factor*

Mechanical alignment in total knee arthroplasty (TKA) aims to restore the mechanical axis of the lower extremity in both the coronal and sagittal planes.[1-3] Recurrent knee flexion contracture (FC) after TKA can lead to unsatisfactory results, owing to abnormal stresses on the femorotibial and patellofemoral joints, greater energy expenditure, quadriceps muscle fatigue, and alteration of gait mechanics.[4] Previous studies have reported that the incidence of postoperative recurrent FC after TKA varies from 1.4% to 48%.[5-7] Although this wide range is possibly caused by preoperative FC severity and different follow-up periods, the most important cause is heterogeneity due to varying preoperative knee status for TKA.[1,5-8]

Intraoperative surgical strategies and intensive rehabilitation methods are used to correct FC after TKA.[4,9-11] To apply appropriate intraoperative and postoperative procedures, it is necessary to investigate variables that can predict recurrent FC. Although the literature reported predictors for postoperative recurrent FC,[8,12-15] few studies have systematically analyzed risk factors predicting recurrent FC.[12]

This study aimed to investigate the incidence and natural history of recurrent FC after TKA in osteoarthritic knees with FC ≥ 15° and analyze risk factors for predict-

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ing recurrent FC. We hypothesized that a proportion of patients would have recurrent FC with either gradual improvement or deterioration and that several factors (including preoperative FC severity, postoperative residual FC, and extra-knee conditions such as lumbar degenerative kyphosis [LDK]) would significantly affect recurrent FC.

METHODS

This study was approved by the Institutional Review Board of Kyung Hee University Hospital (No. KHMC 17-11-046). Informed consent was obtained from all patients before commencing the review.

Study Participants

In total, 2,074 consecutive primary TKAs performed by a single surgeon (SJS) from 2010 to 2018 at Kyung Hee University Hospital were retrospectively reviewed using a database that included medical records and radiographs. The inclusion criteria were as follows: (1) primary TKAs due to Kellgren-Lawrence grade 4 degenerative osteoarthritis; (2) preoperative FC ≥ 15°; (3) a minimum of 2 years of follow-up; and (4) appropriate medical records and radiographs. Severe FC is defined as preoperative FC ≥ 15° because soft tissue balancing is more difficult intraoperatively and FC can likely recur in TKAs with preoperative FC ≥ 15°.[16-18] The exclusion criteria were as follows: (1) inflammatory arthritis; (2) history of knee trauma, infection, and previous knee surgery; and (3) extra-articular deformity. According to the criteria, 237 TKAs in 187 patients were included in the study (Fig. 1). Detailed patient demographics are presented in Table 1.

Surgical Technique

All TKA procedures were performed using modified measured resection and patellar resurfacing; the instruments used for implanting the contemporary prostheses are listed in Table 1. The following surgical strategies were used based on FC severity and intraoperative assessment: complete posterior femoral osteophyte removal, posterior capsule release, posterior tibial slope (PTS) reduction, avoidance of surgical procedures to widen the flexion gap, and 2-mm additional distal femoral bone resection.[4,8] Then, after assessing the flexion and extension gaps of the patient, either the PTS was re-adjusted or an additional 2-mm resection of the distal femoral bone up to a total of 4 mm was performed. The degree of knee extension was corrected to approximately 0°–5° intraoperatively because such an extension consistently provides an appropriate degree of knee extension and favorable postoperative clinical outcomes.[19]

The drain was removed on the second postoperative day, followed by active and assisted range of motion (ROM) exercises. A bolster under the ankle was placed to suspend the knee and put an extension moment, and a knee immobilizer was occasionally used at night for patients who tended to sleep with their knees flexed. Full weight-

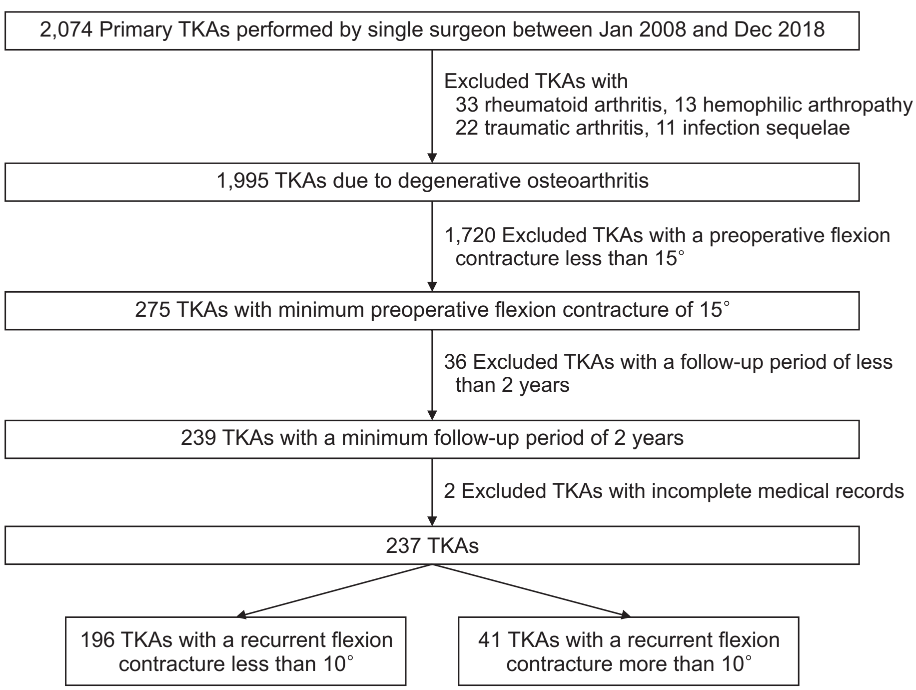

Fig. 1. Flowchart of patient selection. TKA: total knee arthroplasty.

Table 1. Patient Demographics

Variable	Total	Last FC* of < 10°	Last FC* of ≥ 10°	*p*-value
Number of knees (patients)	237 (187)	196 (152)	41 (35)	-
Age (yr)	71.8 ± 7.4	70.9 ± 7.4	76.1 ± 5.7	< 0.001
Female : male	158 : 29	135 : 17	23 : 12	< 0.001
Height (cm)	152.1 ± 7.1	152.1 ± 7.0	152.5 ± 7.9	0.752
Body mass index (kg/m^2)	26.9 ± 4.0	27.0 ± 3.9	26.1 ± 4.6	0.161
Right : left	121 : 116	101 : 95	20 : 21	0.864
Unilateral TKA : bilateral TKA	137 : 100	108 : 88	29 : 12	0.046
CR : PS†	57 : 180	53 : 143	4 : 37	0.025
PFC : Attune : NexGen : Persona‡	75 : 66 : 38 : 58	59 : 50 : 32 : 55	16 : 16: 6 : 3	0.128
Follow-up period (yr)	3.5 ± 1.9	3.6 ± 2.0	3.2 ± 1.4	0.221

Values are presented as mean ± standard deviation unless otherwise indicated.
FC: flexion contracture, TKA: total knee arthroplasty.
*Last FC: recurrent flexion contracture at 2 years postoperatively. †CR : PS: the types of prostheses implanted including those retaining and substituting the posterior cruciate ligament. ‡PFC (Press Fit Condylar, Depuy, Raynham, MA, USA), Attune (Depuy), NexGen (Zimmer, Warsaw, IN, USA), Persona (Zimmer).

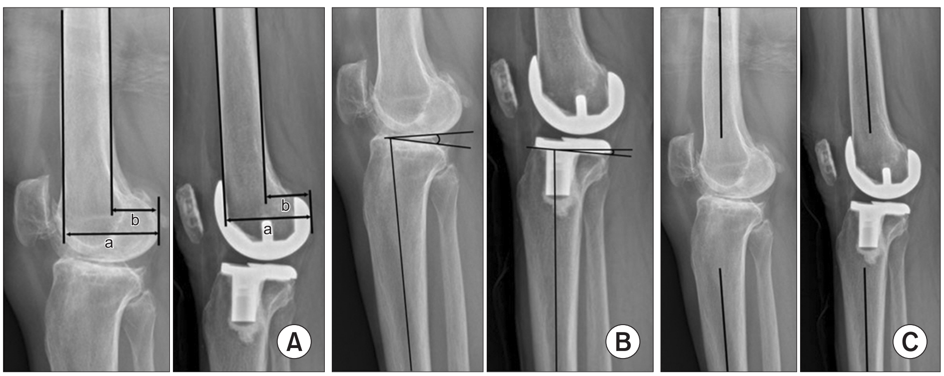

Fig. 2. Radiographic parameters. Preoperative posterior femoral offset ratio = b + 2 / a + 2; a cartilage thickness of 2 mm was considered. Postoperative posterior femoral offset ratio = b / a. (B) Preoperative posterior tibial slope (PTS) indicates the angle between the perpendicular line of the tibial intramedullary canal axis and a line connecting the anterior and posterior borders of the medial tibial plateau. To measure the postoperative PTS, the cutting surface margin of the proximal tibia was used instead of a line on the medial tibial plateau. (C) The knee sagittal angle indicates the acute angle between the distal femoral and the proximal tibial diaphyseal axes, which were defined as the line connecting the midpoints of the inner cortical diameter at 5 cm and 15 cm proximal or distal to the joint line, respectively. Positive and negative values indicate flexion contracture and hyperextension, respectively.

bearing ambulation with crutches was started on the third postoperative day. Free ambulation without crutches was started 4 weeks after surgery based on the patient's condition. When residual FC was observed, the patients continued passive knee extension exercises to extend the knee.

Clinical Evaluation

Knee Society knee and function scores, Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC), maximum knee flexion angle, and ROM were evaluated preoperatively and 2 years postoperatively.[20) The degree of FC was measured by asking the patient to extend the knees as fully as possible while in a supine position with the ankle on a foam roller preoperatively and at 1 week, 6 weeks, 3 months, 6 months, 1 year, and up to 2 years postoperatively since the gradual change in knee extension was reported to stop at this time point in previous studies.[21) Serial FC was consistently measured by the operator (SJS); a goniometer was used to measure the degree of FC with its fulcrum placed over the lateral femoral epicondyle, its upper arm directed toward the greater trochanter, and its lower arm directed toward the lateral malleolus.[22] The FC state was given a "+" value and hyperextension state was given a "–" value. An FC ≥ 10° at postoperative 2 years was defined as recurrent FC because postoperative clinical outcomes are worse in knees with such a degree of FC.[5,23]

Radiographic Evaluation

Pre- and postoperative true anteroposterior (AP) and lateral knee radiographs, orthoroentgenograms (full-length, standing AP radiographs), and preoperative whole spine and pelvic lateral radiographs were taken with the patient in a standing position and the knee fully and actively ex-

Table 2. Clinical Results

Variable	Last FC* of < 10°	Last FC* of ≥ 10°	*p*-value
Number of knees (%)	196 (82.7)	41 (17.3)	
Knee score			
Preoperative	40.7 ± 8.1	40.7 ± 11.6	0.970
Postoperative 2 yr	84.9 ± 6.6	83.4 ± 6.5	0.186
Functional score			
Preoperative	40.1 ± 9.9	40.2 ± 12.8	0.976
Postoperative 2 yr	84.8 ± 7.3	84.7 ± 8.0	0.957
WOMAC score			
Preoperative	70.4 ± 8.5	71.2 ± 8.7	0.590
Postoperative 2 yr	17.7 ± 2.4	17.8 ± 2.6	0.856
Flexion contracture (°)			
Preoperative	18.1 ± 5.4	21.7 ± 6.6	< 0.001
Postoperative 1 wk	1.6 ± 3.8	2.7 ± 3.7	0.088
Postoperative 6 wk	4.0 ± 3.8	8.9 ± 5.1	< 0.001
Postoperative 3 mo	3.6 ± 3.8	8.4 ± 3.8	< 0.001
Postoperative 6 mo	3.0 ± 3.2	9.3 ± 3.1	< 0.001
Postoperative 1 yr	2.0 ± 2.6	10.3 ± 4.1	< 0.001
Postoperative 2 yr	1.3 ± 2.4	12.0 ± 3.5	< 0.001
Maximum flexion (°)			
Preoperative	114.6 ± 17.4	117.4 ± 21.1	0.370
Postoperative 1 wk	122.9 ± 10.0	117.7 ± 14.1	0.006
Postoperative 2 yr	128.9 ± 17.8	126.7 ± 15.7	0.306
Range of motion (°)			
Preoperative	97.7 ± 20.1	95.9 ± 22.8	0.611
Postoperative 1 wk	121.3 ± 11.7	115.0 ± 14.1	0.003
Postoperative 2 yr	127.6 ± 12.3	114.8 ± 16.5	< 0.001

Values are presented as mean ± standard deviation unless otherwise indicated.
FC: flexion contracture, WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index.
*Last FC: recurrent flexion contracture at 2 years postoperatively.

tended. The mechanical hip-knee-ankle axis (MA), femorotibial angle (FTA), and positions of the components, including the α, β, and γ angles, were measured according to the Knee Society radiological evaluation method.[24] The PTS, posterior femoral offset (PFO) ratio, and knee sagittal angle (positive and negative values indicated FC and hyperextension, respectively) were measured, as previously described (Fig. 2).[22,25-28]

The spinopelvic parameters were measured. These included the pelvic tilt, sacral slope, pelvic incidence, lumbar lordosis, and C7 sagittal vertical axis in general methods.[29-31] According to the Scoliosis Research Society-Schwab classification, LDK was diagnosed using the following criteria: (1) C7 sagittal vertical axis ≥ 5 cm; (2) pelvic incidence–lumbar lordosis ≥ 10°; and (3) pelvic tilt ≥ 20°.[32]

The quality of the radiographs was improved by the radiographic protocol of standardization in the position of the knee and spine, and an identical distance between the X-ray beam and cassette.[19] The images were digitally transferred to a picture archiving and communication system (PACS). Assessment was performed using the PACS software, which could detect an angle and length of 0.1° and 0.1 mm, respectively. To minimize observation bias, two independent investigators (HWL and CHP) performed all radiographic measurements. The interobserver reliabilities were assessed using intraclass correlation coefficients with regard to MA (≥ 0.893), FTA (≥ 0.892), component position (≥ 0.821), PTS (≥ 0.847), PFO ratio (≥ 0.813), and knee sagittal angle (≥ 0.854), all of which showed excellent reliability.[33] Thus, the average values of the two investigators were used.

Statistical Analysis

The incidence of recurrent FC at 2 years postoperatively was evaluated. Clinical and radiographic results were compared between the groups with or without recurrent FC using the independent *t*-test or Mann-Whitney *U*-test. Logistic regression analysis with forward stepwise selection was used to identify potential risk factors in terms of demographics (age, sex, and body mass index), unilateral TKA, severity of preoperative FC, residual FC at postoperative 3months, γ angle, change in PFO ratio, and LDK, which were selected based on previous studies.[7,14,34-36] The cutoff value of preoperative FC and residual FC at postoperative 3 months to predict the risk of recurrent FC was analyzed using receiver operating characteristic (ROC) analysis, which was determined as the point where sensitivity and specificity were balanced in the ROC curve.

Statistical analyses were performed using IBM SPSS ver. 22.0 (IBM Corp., Armonk, NY, USA), and statistical significance was set at $p < 0.05$. Post-hoc power analyses with significance set at an alpha of 0.05 were performed to determine whether the identified factors in the logistic regression had sufficient power. A statistical power of > 80% was considered sufficient.

RESULTS

There were 41 knees (17.3%) with recurrent FC ≥ 10° at 2 years postoperatively, even after full intraoperative correction of the FC in osteoarthritic knees with preoperative FC ≥ 15°. The clinical results are presented in Table 2. Regarding FC, the severity of preoperative FC was greater in the group with postoperative recurrent FC (Table 2). Although the degree of FC at 1 week postoperatively did not differ between the two groups, it was greater in the group with recurrent FC thereafter. The FC worsened after postoperative 3 months in the recurrent FC group, whereas it gradually improved in the group without recurrent FC (Fig. 3).

The radiographic results are shown in Table 3. The γ angle and postoperative PTS were slightly different between the groups with and without recurrent FC. The knee sagittal angle on the standing lateral radiographs showed more severe FC preoperatively, 1 week postoperatively, and 2 years postoperatively in the group with recurrent FC (Table 3). There were significant differences between the groups in the pelvic tilt, pelvic incidence-lumbar lordosis, and C7 sagittal vertical axis, which were the diagnostic criteria for LDK (Table 4). The incidence of LDK was significantly higher in the recurrent FC group than in the no recurrent FC group.

In the final (fifth) step of forward selection in logis-

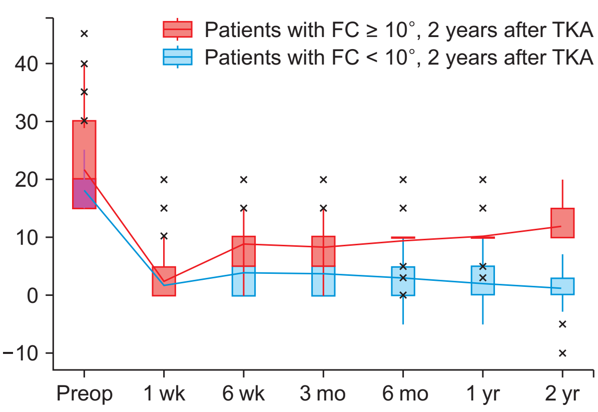

Fig. 3. Periodic change in flexion contracture preoperatively, postoperatively, and during regular follow-up visits after total knee arthroplasty. FC: flexion contracture, TKA: total knee arthroplasty.

Table 3. Radiographic Results

Variable	Last FC* of < 10°	Last FC* of ≥ 10°	*p*-value
Number of knees (%)	196 (82.7)	41 (17.3)	
Mechanical hip-knee-ankle axis (°)			
Preoperative	Varus 11.3 ± 8.2	Varus 10.7 ± 8.7	0.681
Postoperative	Varus 2.1 ± 2.8	Varus 2.2 ± 2.8	0.858
Femorotibial axis (°)			
Preoperative	Varus 5.2 ± 7.6	Varus 5.1 ± 9.5	0.982
Postoperative	Valgus 5.4 ± 2.6	Valgus 4.8 ± 2.5	0.183
Position of components (°)			
α Angle	95.3 ± 1.8	95.4 ± 2.0	0.814
β Angle	90.9 ± 1.9	91.2 ± 2.0	0.258
γ Angle	2.8 ± 2.1	3.2 ± 2.0	0.037
Posterior tibial slope (°)			
Preoperative	13.4 ± 5.3	14.3 ± 5.2	0.334
Postoperative	5.5 ± 2.5	4.6 ± 2.8	0.044
Posterior femoral offset ratio			
Preoperative	0.56 ± 0.04	0.55 ± 0.04	
Postoperative	0.55 ± 0.04	0.54 ± 0.05	
Change	–0.01 ± 0.04	–0.01 ± 0.04	0.578
Knee sagittal angle in standing lateral radiograph (°)			
Preoperative	19.7 ± 7.5	27.4 ± 5.6	< 0.001
Postoperative 1 wk	5.2 ± 4.6	7.2 ± 5.3	0.013
Postoperative 2 yr	4.6 ± 4.8	17.5 ± 6.2	< 0.001

Values are presented as mean ± standard deviation unless otherwise indicated.
FC: flexion contracture.
*Last FC: recurrent flexion contracture at 2 years postoperatively.

tic regression, the significant factors affecting the recurrent FC were age, unilateral TKA, severity of preoperative FC, residual FC at postoperative 3 months, and LDK (Nagelkerke $R^2 = 0.452$, $p < 0.001$) (Table 5). The powers for the identified factors, except age (power = 5.1), were sufficient; those for unilateral TKA, severity of preoperative FC, 3-month postoperative residual FC, and LDK were 99.4, 86.1, 99.9, and 96.9, respectively. The preoperative FC and residual FC at 3 months postoperatively were predictors with a relatively lower odds ratio. The odds ratios of unilateral TKA and LDK were relatively greater than those of pre- and postoperative FC (Table 5). For predicting recurrent FC, the cutoff value of preoperative FC and residual FC at 3 months postoperatively were 17.4° and 7.5°, respectively (Fig. 4).

DISCUSSION

The most important finding of the present study is that 17.3% of the knees had recurrent FC ≥ 10° at 2 years postoperatively, despite appropriate intraoperative FC correction during TKA in osteoarthritic knees with preoperative FC ≥ 15°. The risk factors for postoperative recurrent FC with sufficient power were unilateral TKA, severity of preoperative FC, residual FC at 3 months postoperatively, and LDK.

Postoperative recurrent FC has a wide range of incidence.[5-7] The range of incidence for recurrent FC is also wide (from 8.5% to 43%), even focusing only on results at 1 year or more after TKA performed for preoperative FC ≥ 15°.[7,15] The important reason would be heterogeneity of study participants, such as various preoperative knee diseases. In this regard, our incidence of recurrent FC after TKA performed only on osteoarthritic knees with severe FC will be valuable with less confounding.

Several previous studies have reported that residual FC after TKA may improve over time,[8,37,38] but contradictory results have also been reported.[35,39] These conflicting results may be because they did not distinguish cases with and without postoperative recurrent FC. Considering our results, it is necessary to separately predict the natural course of FC in patients with and without recurrent FC. Additionally, the improvement of FC from 3 to 6 months postoperatively can be an indicator to help predict recurrent FC.

Unilateral TKA was a significant risk factor for predicting recurrent FC in our study (Table 5). Bhave et al.[40] reported that the limb length difference with the side of the TKA was longer, resulting in a flexed knee posture, which may cause FC on the operated side. Considering this, correction of leg length discrepancy via shoe lifts in the contralateral leg can effectively prevent postoperative recurrent FC.[41] In addition, the possibility of recurrent FC after unilateral TKA should be considered in determining the timing of TKA in the contralateral osteoarthritic knee.

It is well known that the preoperative FC is the most important predictor of postoperative recurrent FC.[34,35] Additionally, residual FC at 3 months postoperatively could be a factor in predicting recurrent FC, as Mitsuyasu et al.[35] reported that FC would eventually develop by the last follow-up if the FC was ≥ 15° at 3 months after TKA. Consistent with the previous studies, preoperative FC severity and residual FC at 3 months postoperatively were significant risk factors for recurrent FC in our study; recurrent FC was likely when the degrees of preoperative and 3-month postoperative FC were greater than 17.4° and 7.5°, respectively (Fig. 4).

Sheppard et al.[42] reported that lumbar spine sagittal deformity negatively affected clinical outcomes after TKA; 23% of knees with sagittal deformity developed an average FC of 6.3° postoperatively. When sagittal imbalance progresses, after the hips reach their maximum extension, the knees start to flex as the last compensatory mechanism.[30] In the present study, LDK was a significant risk factor with an odds ratio of 3.096 for postoperative recurrent FC.

Table 4. Comparison of Spinopelvic Parameters

Variable	Last FC* of < 10°	Last FC* of ≥ 10°	*p*-value
Number of knees (%)	196 (82.7)	41 (17.3)	-
Pelvic tilt (°)	22.4 ± 9.1	26.1 ± 9.7	0.024
Sacral slope (°)	32.9 ± 9.4	30.9 ± 9.6	0.226
Pelvic incidence (°)	55.3 ± 10.5	56.9 ± 11.7	0.394
Lumbar lordosis (°)	42.3 ± 15.4	38.3 ± 12.5	0.139
Pelvic incidence-lumbar lordosis (°)	13.1 ± 14.8	18.6 ± 14.1	0.034
C7 sagittal vertical axis (mm)	57.2 ± 28.6	72.6 ± 38.3	0.005
Number of lumbar degenerative kyphosis (%)	38 (19.4)	19 (46.3)	0.001

Values are presented as mean ± standard deviation unless otherwise indicated.
FC: flexion contracture.
*Last FC: recurrent flexion contracture at 2 years postoperatively.

Table 5. Risk Factors to Predict Recurrent Flexion Contracture Greater Than 10° after TKA

Risk factor	Odds ratio	95% CI	*p*-value	VIF
Age	1.125	1.047–1.208	0.001	1.072
Unilateral TKA	3.579	1.392–9.207	0.008	1.008
Preoperative flexion contracture	1.115	1.046–1.189	0.001	1.056
Flexion contracture at postoperative 3 months	1.274	1.144–1.420	< 0.001	1.103
Lumbar degenerative kyphosis	3.096	1.239–7.7.8	0.016	1.087

TKA: total knee arthroplasty, CI: confidential interval, VIF: variance inflation factor.
The table shows the results at the final (fifth) step of forward selection in logistic regression (Nagelkerke R^2 = 0.452, *p*-value for regression model < 0.001). The powers of the identified factors, except age (power = 5.1), were sufficient; the powers of unilateral TKA, preoperative flexion contracture, residual flexion contracture at 3 months postoperatively, and lumbar degenerative kyphosis were 99.4, 86.1, 99.9, and 96.9, respectively.

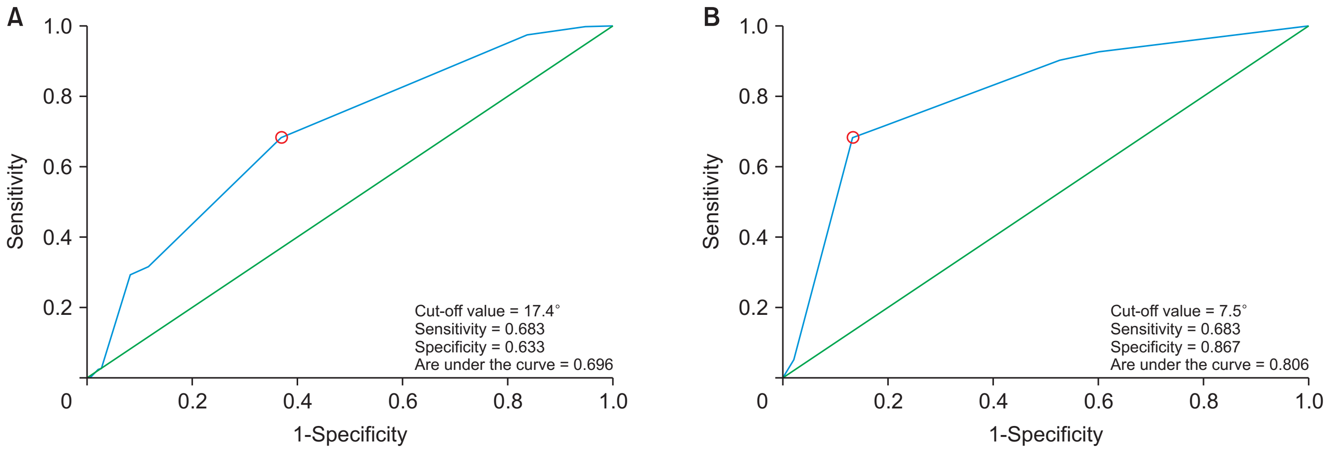

Fig. 4. Receiver operating characteristic curve to determine the cutoff value of preoperative flexion contracture (A) and residual flexion contracture at 3 months postoperatively (B) for predicting the risk of recurrent flexion contracture ≥ 10° at 2 years after total knee arthroplasty. The red circles indicate the cutoff points.

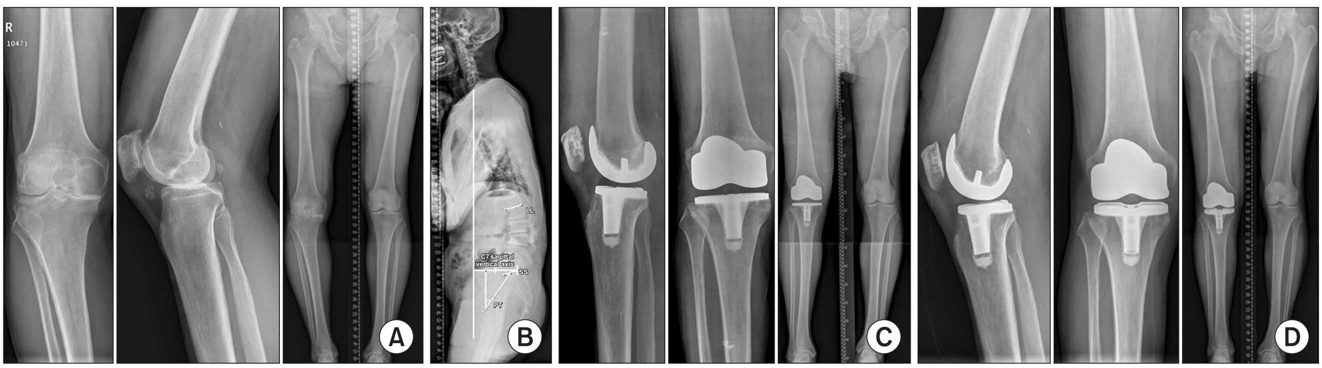

Fig. 5. A patient with recurrent flexion contracture after full correction of preoperative flexion contracture during total knee arthroplasty (TKA). (A) Preoperative radiograph. Unilateral TKA was performed in a 75-year-old man with lumbar degenerative kyphosis and preoperative flexion contracture of 20°. (B) Spinopelvic parameters on the standing lateral radiographs: pelvic tilt, 34.8°; pelvic incidence–lumbar lordosis, 50.9°; C7 sagittal vertical axis, 11.4 cm. (C) One-week postoperative radiographs showing no residual flexion contracture after TKA. (D) Two-year postoperative radiographs showing recurrent flexion contracture after TKA.

The group with recurrent FC had significantly different spinopelvic parameters compared with the group without recurrent FC, which pertains to the loss of lumbar lordosis and the compensatory mechanism of the hip and pelvis. The risk of FC due to a compensatory mechanism of LDK seems to be persistent after TKA (Fig. 5).

The odds ratios of unilateral TKA and LDK were greater than those of perioperative FCs in our study (Table 5). Unilateral TKA and LDK are considered as equally or more important risk factors than perioperative FC state, although our ranking of odds ratio, which is different from those in the previous studies, could be affected by differences in the demographics, degree of intraoperative correction of FC, and definition for recurrent FC.

The role of age in the development of FC after TKA remained unclear.[12] Several authors have contradicted the role of age as a risk factor for predicting postoperative FC.[14,36] Age was identified as a risk factor in our study, but power for age was insufficient. Sufficient theoretical evidence regarding its role is needed through a randomized controlled prospective trial with a sufficient sample size.

The clinically relevant issues from the present study suggest that TKA patients with unilateral TKA, severe preoperative FC, residual FC at postoperative 3 months, and LDK should not rely on gradual improvement of FC. For patients with risk factors, various surgical strategies and rehabilitation protocols should be intensively applied to correct FC. Surgical methods include an additional 2- to 4-mm resection of the distal femur, posterior capsular release, avoidance of femoral component flexion positioning, and avoidance of surgical procedures to widen the flexion gap, including femoral downsizing and increasing of PTS.[4] Rehabilitation methods include splinting, custom-molded knee devices, and low-load prolonged stretching techniques with TheraBands and/or ankle weights.[9-11]

The present study has several limitations. First, this is a retrospective study of a single surgeon's case series with the possibility of selection bias. A prospective randomized study is required to achieve more robust conclusions. Second, the sample size was relatively small. However, it was confirmed that the powers of the identified risk factors, except age, were sufficient. Third, patients who underwent bilateral TKA were included. This could be a factor that could confound the independent comparisons. Fourth, the variables included in the logistic regression were not standardized. The magnitudes of the odds ratios might not be directly comparable to each other, as these values are not on the same scale. Fifth, there could be performance bias due to improvements in surgical techniques and FC correction methods over time (soft tissue release only, more bone resection only, or both). In addition, patient compliance for postoperative rehabilitation might affect the outcomes. Finally, radiographic evaluation of the spinopelvic parameters was conducted using simple radiographs instead of the EOS imaging system. However, the radiation hazard from the EOS system and the extra cost for research were not justified for conventional TKA patients.

Recurrent FC can occur in TKAs with the risk factors including unilateral TKA, severe preoperative FC, residual FC at 3 months postoperative, and LDK despite appropriate intraoperative correction. Surgical strategies and rehabilitation protocols used in managing FC should be applied in TKA cases with risk factors for recurrent FC.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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