Importance of knee flexion range of motion during the acute phase after total knee arthroplasty

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ABSTRACT. Background: We investigate the association with knee flexion range of motion (ROM) during the acute phases and that at 12 months after total knee arthroplasty (TKA). We also clarified the cut-off ROM during the acute phases in predicting the goal of knee flexion ROM at 12 months. **Methods:** In this retrospective study, 193 patients with knee osteoarthritis (female:144 patients, age:73.2 ± 7.7 years) who underwent unilateral TKA at an orthopedic clinic were recruited. They underwent assessments of knee flexion ROM at 5 days, 1 month, and 12 months after TKA. The goal of knee flexion ROM at 12 months after TKA was set at 120°. Single and logistic-regression analyses were performed with the dependent variables including the outcome of the goal of knee flexion ROM at 12 months, and the independent variables included knee flexion ROM at 5 days and 1 month, separately. We calculated the cut-off ROM at 5 days and 1 month for predicting the goal of knee flexion ROM at 12 months with receiver operating curve analysis. **Results:** Knee flexion ROM at 5 days and 1 month were significantly associated with the goal of that at 12 months ($p < 0.01$). The cut-off ROM were 85° at 5 days and 105° at 1 month separately. **Conclusions:** Our results suggest the importance of early improvement in knee flexion ROM after TKA, and that at 1 month postoperatively indicates the likelihood of achievement of the goal of knee flexion ROM at 12 months after TKA.

Key words: knee flexion range of motion, acute phase, total knee arthroplasty

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Total knee arthroplasty (TKA) is a standard surgical treatment for end-stage knee osteoarthritis (OA). One of the clinical goals of TKA is to provide pain relief and to restore the range of motion (ROM) of the knee joint, which contributes significantly to the clinical outcome following TKA¹⁾. Several studies have demonstrated that knee flexion ROM is positively associated with knee function, and greater knee flexion ROM results in better clinical outcomes following TKA²⁻⁶⁾. In line with this, restricted knee flexion ROM after TKA has been reported to be associated with restriction of activities of daily living, lower quality of

life, and patient dissatisfaction with the treatment^{1,5-7)}. Therefore, the improvement of postoperative knee flexion ROM is clinically relevant since it aids in the achievement of successful TKA.

Knee flexion ROM after TKA has been shown to have significant correlations with age, body mass index (BMI), implant design, surgical technique, pain, and preoperative ROM⁸⁻¹³⁾. Additionally, knee flexion ROM after TKA is associated with acute postoperative ROM¹⁴⁾. A previous study reported that knee flexion ROM at 6 days after TKA was a predictive factor for knee flexion ROM at 2 months after TKA¹⁴⁾. Acute postoperative knee flexion ROM may also be predictive of knee flexion ROM at 12 months after TKA. However, the relationship between knee flexion ROM during acute postsurgical phases, and at 12 months after TKA, remains unknown. Furthermore, Ebert et al. identified a 7-week postoperative cut-off point for achieving maximal knee flexion ROM after TKA¹⁵⁾. However, the follow-up

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period in this study was insufficient because postoperative knee flexion ROM continued to improve for up to 12 months after TKA¹⁶⁾. Prediction of long-term knee flexion ROM based on values during the acute postoperative phases allows for better identification of patients progressing poorly who may require early intervention. Therefore, it is necessary to assess whether knee flexion ROM during the acute phases is predictive of knee flexion ROM at 12 months after TKA, in order to assist in the planning of post-acute rehabilitation. The degree of knee flexion during the acute phases may be a useful clinical indicator of postoperative rehabilitation for surgeons and therapists.

The aim of the present study was to investigate whether knee flexion ROM during the acute phases, such as within 5 days and 1 month, were useful for predicting achievement of knee flexion ROM at 12 months. In addition, we identified the degree of knee flexion ROM during the acute phases that represents the cut-off point for achieving the goal of knee flexion ROM at 12 months after TKA. We hypothesized that the knee flexion ROM during the acute phases predicts the achievement of the goal of knee flexion ROM at 12 months after TKA.

Methods

1. Participants

In this retrospective study, 193 patients who underwent unilateral TKA at an orthopedic clinic between November 2012 and December 2015 were recruited. The participants were categorized as grade 3 or 4 based on the Kellgren and Lawrence radiographic grading system (K/L grade). All the procedures in this investigation were performed by one orthopedic surgeon (HM) using a low-contact-stress mobile-bearing Universal rotational platform (Depuy Orthopaedics Inc., Kobe city, Japan) and a medial parapatellar approach. The inclusion criteria consisted of (i) medial OA and (ii) more than 120° in preoperative knee flexion ROM, because the preoperative ROM and soft-tissue condition affect postoperative ROM⁸⁻¹⁰⁾. The exclusion criteria consisted of (i) neurological conditions such as Parkinson disease or stroke, (ii) severe symptoms in other lower extremity joints, and (iii) an inability to participate in a follow-up period of up to 12 months after TKA. The ethics committee of Anshin hospital approved all the procedures performed in the present study (Assignment number. 60), and all patients provided written informed consent in accordance with the declaration of Helsinki before participating.

2. Rehabilitation protocol

The rehabilitation protocol consisted of 6 days of inpatient rehabilitation and once-a-week outpatient rehabilitation for 12 weeks. During the postoperative stay in the hospital, all patients were treated twice daily for 40 minutes by

physical therapists. Inpatient rehabilitation consisted of passive knee ROM exercises; patellofemoral joint mobilization as needed; incision mobility; lower extremity flexibility exercises for the quadriceps, calves, and hamstrings; icing; gait training; and functional training for going up and down on stairs. After being discharged from the hospital, patients received outpatient physical therapy once a week for 12 weeks. Outpatient rehabilitation consisted of passive and active knee ROM exercises, quadriceps strengthening, gait training, and activities of daily living training (i.e., climbing and descending stairs). Additionally, all the patients were prescribed a standard home exercise program to be performed twice daily. The home exercise program included active knee ROM exercises and strengthening exercises for the quadriceps, hip abductors, and hip extensors in both weight-bearing and non-weight-bearing conditions. After 12 weeks, patients completed the outpatient rehabilitation and home exercise program.

3. Assessment

3-1. Knee flexion ROM

Knee flexion ROM was measured preoperatively and at 5 days, 1 month, and 12 months postoperatively, because our patients were discharged 5 days postoperatively, and the average length of hospital stay in Japan is 1 month postoperatively^{17,18)}. Measurement of knee flexion ROM was followed the methods recommended by the Japanese Orthopedic Association and the Japanese Association of Rehabilitation Medicine. Passive ROM of the involved limb was measured every 5 degrees in the supine position. Seven trained physical therapists carried out all measurements. The reliability of knee flexion goniometric measurement after TKA is appropriate in the acute (intraclass correlation coefficient [ICC], 0.89) and outpatient settings (ICC, 0.81-0.87)^{19,20)}. Therefore, we measured knee flexion ROM using a goniometer.

3-2. Walking Pain

Walking pain is the quantification of knee pain just after walking at a normal speed at 5 days and 1 month postoperatively. The numeric rating scale (NRS) is a valid and reliable instrument used in clinical practice due to its high degree of sensitivity²¹⁾. In the present study, NRS was used to quantify knee pain in the surgical side during walking. Patients were asked to verbally rate the walking pain on a scale from 0 to 10 immediately after walking, with 0 representing no pain and 10 representing the worst pain imaginable.

4. Statistical analysis

Continuous variables are expressed as mean $\pm$ standard deviation of the mean (SD), and ordinal and categorical variables are expressed as number (%). The goal of knee flexion ROM at 12 months after TKA was set at 120° because this is sufficient for most activities of daily living,

Table 1. Demographic data of patients in the achievement and no-achievement groups

Variables	all (n=193)	achievement group (n=152)	no-achievement group (n=41)	<i>p</i> -value
Gender: female/male, n (%)	144/49 (76/24)	115/37 (77/23)	30/11 (75/25)	0.68
Age, yrs	73.2±7.7	73.1±7.8	73.7±7.4	0.66
Height, cm	153.5±7.7	154.0±7.4	151.9±8.6	0.13
Weight, kg	60.5±10.2	60.2±10.0	61.8±10.8	0.38
BMI ^a , kg/m ²	25.8±4.1	25.5±4.3	26.6±3.1	0.12
surgical time, time	99.3±10.9	99.6±11.0	98.2±10.0	0.47
Preoperative FTA ^b , degree	181.3±4.7	181.6±4.7	180.2±4.3	0.12
KL ^c grade in the involved limb, n (%)				0.55
Grade3	19 (9.8)	16 (10.5)	3 (7.3)	
Grade4	174 (90.2)	136 (89.5)	38 (92.7)	
walking pain at postoperative 5 days, score	2.5±1.8	2.4±1.7	2.9±1.9	0.16
walking pain at postoperative 1 month, score	2.4±1.8	2.3±1.7	4.0±1.6	<0.01
knee flexion ROM, degree				
Preoperatively	124.7±4.9	125.4±5.1	122.1±3.1	0.42
5 days postoperatively	92.7±6.7	94.0±6.8	90.4±6.0	<0.01
1 month postoperatively	111.2±10.4	113.4±9.2	103.0±10.6	<0.01
12 months postoperatively	121.1±8.9	124.5±5.0	108.5±9.2	<0.01

^aBMI; body mass index, ^bFTA; femorotibial angle,

^cKL grade; Kellgren-Lawrence grade of knee osteoarthritis

Continuous variables were expressed as mean±SD, and ordinal and categorical variables were expressed as number (%)

including kneeling, and is performed with less risk to the patellofemoral joint^{22,23}.

Initially, the characteristics were compared between participants who met the goal (achievement group) versus those who did not (no-achievement group). The parametric values were compared using the unpaired *t*-test, while the non-parametric values were compared using the Mann-Whitney U test.

Thereafter, single and multiple logistic-regression analyses were performed to investigate the relationship between knee flexion ROM at 5 days or 1 month postoperatively, and at 12 months. In addition, we performed the logistic-regression analysis investigating the relationship between that at preoperatively with that at 12 months and compared it with the results at 5 days and 1 month postoperatively. The dependent variable was the goal of 120° in knee flexion ROM at 12 months (0: no-achievement group, 1: achievement group). The independent variables were knee flexion ROM at 5 days or that at 1 month postoperatively, separately. Age, gender (0: male, 1: female), BMI, and walking pain at 5 days or 1 month were considered potential confounders.

Finally, we identified the cut-off point for the degree of knee flexion ROM at 5 days and 1 month postoperatively for achieving 120° of knee flexion ROM at 12 months using receiver operating curve analysis with the Youden index. We also calculated the cut-off point for the degree of knee flexion ROM at preoperatively and compared it with that at 5 days and 1 month postoperatively.

Statistical significance was accepted at *p* < 0.05. All analyses were carried out using SPSS for Windows 21.0.0 version (IBM Corp., Tokyo, Japan).

Results

Table 1 summarizes the gender, age, height, weight, BMI, surgical time, preoperative femorotibial angle, knee OA grade of K/L grade, and walking pain at 5 days and 1 month postoperatively for each patient. Patients with more than 120° of knee flexion ROM at 12 months after TKA included 152 of 193 patients (78.7%), while 41 of 193 patients (21.3%) had less than 120° of ROM. There were no significant differences in the characteristics such as age, BMI, duration of surgery, and grade of OA in the involved limb between the two groups at baseline. Walking pain score at 1 month was higher in the no-achievement group than in the achievement group (4.0 ± 1.6 vs. 2.3 ± 1.7, *p* < 0.01).

Table 2 summarizes the results of the logistic regression analysis to investigate the effect of knee flexion ROM at 5 days or 1 month on the ROM at 12 months. Knee flexion ROM at 5 days and 1 month were significantly associated with achievement of knee flexion ROM at 12 months (knee flexion ROM at 5 days; odds ratio (OR) = 1.10 [95% confidence interval (CI), 1.03-1.20], *p* = 0.01, Hosmer-Lemeshow test *p* = 0.27, knee flexion ROM at 1 month; OR = 1.13 [95% CI, 1.08-1.18], *p* < 0.01, Hosmer-Lemeshow test, *p* = 0.81) adjusting for age, gender, body

Table 2. Results of logistic regression analysis to investigate the effect of knee flexion ROM at 5 days or 1 month on the achievement of knee flexion ROM at 12 months.

Independent variables	Crude model		Adjusted model	
	OR (95% CI)	<i>p</i> value	OR (95% CI)	<i>p</i> value
Knee flexion ROM at 5 days after TKA	1.09 (1.02-1.16)	0.02	1.10 (1.03-1.20)	0.01
Age			0.97 (0.92-1.02)	0.20
Gender			0.58 (0.25-1.32)	0.19
Body mass index			0.94 (0.86-1.03)	0.17
Walking pain at 5 days			0.99 (0.80-1.22)	0.89
Knee flexion ROM at 1 month after TKA	1.12 (1.07-1.16)	<0.01	1.13 (1.08-1.18)	<0.01
Age			0.94 (0.88-0.99)	0.03
Gender			0.40 (0.15-1.10)	0.08
Body mass index			0.98 (0.89-1.08)	0.63
Walking pain at 1 month			0.86 (0.67-1.09)	0.22
Knee flexion ROM at preoperatively	1.22 (1.09-1.35)	<0.01	1.23 (1.10-1.37)	<0.01
Age			0.99 (0.94-1.04)	0.61
Gender			0.59 (0.25-1.37)	0.22
Body mass index			0.92 (0.84-1.02)	0.07
Walking pain at preoperatively			1.16 (0.99-1.36)	0.06

Dependent variable: the outcome of the achievement of knee flexion ROM at 12 months.

Independent variable: knee flexion ROM at 5 days and 1 month after TKA separately

Age, gender, body mass index and walking pain at 5 days or 1 month were considered potential confounders.

OR; odds ratio, CI; confidence interval

Figure 1. Receiver operating characteristic curve analysis at 5 days after TKA. **Figure 2.** Receiver operating characteristic curve analysis at 1 month after TKA.

mass index, and walking pain. (preoperatively; OR = 1.23 [95% CI, 1.10-1.37], $p < 0.01$, Hosmer-Lemeshow test $p = 0.21$)

The cut-off points of knee flexion ROM for achieving 120° of knee flexion at 12 month were 85° for knee flexion ROM at 5 days postoperatively [sensitivity: 0.27, specificity: 0.94, AUC: 0.63] (Figure 1), and 105° for 1 month

postoperatively [sensitivity: 0.63, specificity: 0.82, AUC: 0.80] (Figure 2). (The cut-off point was 122° for knee flexion ROM preoperatively [sensitivity: 0.68, specificity: 0.61, area under curve (AUC): 0.68]).

Discussion

Our study aimed to investigate whether knee flexion ROM during the acute phases of postoperative rehabilitation were useful for predicting achievement of knee flexion ROM at 12 months postoperatively, and to clarify the degree of knee flexion ROM during the acute phases that represents the cut-off point for achieving the goal of knee flexion ROM (120°) at 12 months after TKA. The primary results of the present study were that knee flexion ROM at 1 month was a more useful parameter than that at preoperatively and 5 days postoperatively for predicting the achievement of knee flexion ROM at 12 months. Moreover, the cut-off value at 1 month after TKA for indicating the achievement of 120° ROM by 12 months was 105° . To the best of our knowledge, our study is the first to identify the cut-off point and predictive precision for achieving 120° of knee flexion ROM at 12 months after TKA.

Based on the results of the logistic-regression analyses, we found that knee flexion ROM during the acute postoperative phases was predictive of the achievement of the clinical goal (120° ROM) at 12 months after TKA. This finding was consistent with the results of a previous study, which demonstrated that knee flexion ROM during the acute phase could predict knee flexion ROM at 2 months postoperatively¹⁴. Our findings suggest that if knee flexion ROM is improved within the acute phase in an inpatient or outpatient setting, this may translate to improved long-term outcomes.

We also identified the degree and predictive precision of knee flexion ROM during the acute phase. The predictive precision at 5 days postoperatively showed high specificity, which indicated a high probability that patients will not reach 120° at 12 months if they fail to reach 85° of knee flexion ROM at 5 days after TKA. However, the sensitivity and AUC suggest low accuracy. Knee flexion ROM during hospitalization depends on pain, pain tolerance, type of anesthesia used in TKA, and postoperative dosing of pain medications^{24,25}, which may cause a decrease in the predictive precision of knee flexion ROM at this time point. Due to these reasons, the sensitivity and AUC decreased, indicating a reduced accuracy. Therefore, we considered that the cut-off ROM at 5 days postoperatively might not be useful in predicting the achievement of knee flexion ROM at 12 months after TKA.

Conversely, all the constituents of predictive accuracy at 1 month were higher than that at 5 days. We found that walking pain at 1 month after TKA in the no-achievement group was higher than that in the achievement group, suggesting that pain during walking could affect knee flexion ROM at 1 month after TKA. Muscle spasm of the knee joint, owing to postoperative pain, led to a stiff knee during walking²⁶. As the patients with stiff knee gait showed decreased knee flexion ROM during walking, these gait pat-

terns might have affected knee flexion ROM. Furthermore, our results showed the predictive accuracy at 1 month postoperatively was higher than that preoperatively. Bade MJ et al. reported that preoperative knee flexion ROM can predict long-term knee flexion ROM than postoperative knee flexion ROM at 2 days²⁷. Our results indicate that it is inadequate to predict long-term ROM based on preoperative ROM, and it is essential to check ROM carefully until 1 month postoperatively.

These results suggest that it is essential to restore knee flexion ROM within 1 month to reach the critical flexion ROM at 12 months. The results from the present investigation may be useful for establishing a rehabilitation plan and procedure to identify patients at high risk of poor knee flexion ROM at 12 months. In addition, our results indicate that establishing clear goals of knee flexion ROM during the acute phases following surgery may provide reassurance to the patients with regards to the increased chance of good ROM at 12 months after TKA.

This study has several methodological limitations. First, to remove the influence of preoperative knee ROM, patients with less than 120° of preoperative knee flexion ROM were excluded as 120° was set as the clinical goal of knee flexion ROM at 12 months. Second, we did not examine potential confounders such as knee extensor strength, surgical variables, comorbidities, and psychological factors that might have affected knee flexion ROM after TKA²⁸⁻³¹. Finally, we did not confirm whether home exercise was performed after 3 months postoperatively. This might have affected the results of this study. Given these limitations, care should be taken when extrapolating the results of this investigation to all individuals who undergo TKA.

Conclusions

Knee flexion ROM during the acute postoperative phases is useful in predicting the achievement of knee flexion ROM at 12 months in patients who undergo TKA. Furthermore, we identified the cut-off ROM and predictive precision of ROM values measured during the acute postoperative phase. Our findings highlight the importance of early improvement in knee flexion ROM after TKA, and demonstrate that ROM at 1 month postoperatively indicates the likelihood of achieving the clinical goal of knee flexion ROM at 12 months after TKA.

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Conflict of Interest: None.

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