The effect of anteroposterior laxity on the range of movement and knee function following a cruciate-retaining total knee replacement

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The amount of anteroposterior laxity required for a good range of movement and knee function in a cruciate-retaining total knee replacement (TKR) continues to be debated. We undertook a retrospective study to evaluate the effects of anteroposterior laxity on the range of movement and knee function in 55 patients following the e-motion cruciate-retaining TKR with a minimum follow-up of two years. The knees were divided into stable (anteroposterior translation, ≤ 10 mm, 38 patients) and unstable (anteroposterior translation, > 10 mm, 17) groups based on the anteroposterior laxity, measured using stress radiographs. We compared the Hospital for Special Surgery (HSS) scores, the Western Ontario MacMasters University Osteoarthritis (WOMAC) index, weight-bearing flexion, non-weight-bearing flexion and the reduction of flexion under weight-bearing *versus* non-weight-bearing conditions, which we referred to as delta flexion, between the two groups at the final follow-up.

There were no differences between the stable and unstable groups with regard to the mean HHS and WOMAC total scores, as well as weight-bearing and non-weight-bearing flexion ($p = 0.277$, $p = 0.082$, $p = 0.095$ and $p = 0.646$, respectively). However, the stable group had a better WOMAC function score and less delta flexion than the unstable group ($p = 0.011$ and $p = 0.005$, respectively).

Our results suggest that stable knees with laxity ≤ 10 mm have a good functional outcome and less reduction of flexion under weight-bearing conditions than unstable knees with laxity > 10 mm following an e-motion cruciate-retaining TKR.

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The range of movement (ROM) under weight-bearing conditions after total knee replacement (TKR) is an important indicator of outcome. Although TKR provides a good ROM in the knee under non-weight-bearing conditions,¹⁻⁵ some studies have reported that, under weight-bearing conditions like squatting or single-leg lunge activities, the ROM was decreased compared with that under non-weight-bearing conditions after a cruciate-retaining TKR.⁴⁻⁶ It has been speculated that this results from a decreased posterior femoral roll-back because of an ineffective posterior cruciate ligament (PCL) causing instability.^{3,7,8}

Many factors influence the anteroposterior (AP) laxity of a replaced knee. These include the geometry, the size and positioning of the prosthesis, soft-tissue balance and the posterior tibial slope.⁹ However, the functional status of the PCL may also play an important role in AP stability after a cruciate-retaining TKR. Some studies have questioned the role of the retained PCL in this situation.¹⁰⁻¹² Furthermore, the amount of AP laxity required for

good ROM and function after a cruciate-retaining TKR, continues to be debated.^{10,13-19} While studies have reported that a moderate AP laxity of 5 mm to 10 mm may provide a better movement and improved function, compared with a knee that is too tight or too loose,^{9,16} some studies have shown a strong positive correlation between AP laxity and ROM, suggesting that lax knees following a TKR had a better ROM.^{13,16,20}

Our aim, therefore, was to evaluate the effects of AP laxity on weight-bearing and ROM following a cruciate-retaining TKR. In addition, we wished to establish the correlation between AP laxity, ROM and function.

Patients and Methods

This is a retrospective study of 55 patients who underwent a primary cruciate-retaining TKR using computer-assisted navigation for degenerative osteoarthritis from January 2005 to September 2007. Patients who had a post-operative ROM of $\leq 90^\circ$ or those with a previous history of open knee surgery prior to the

TKR were excluded. There were nine men and 46 women with a mean age of 68.2 years (55.0 to 81.0) at the time of surgery. The mean follow-up period was 33 months (24.0 to 52.0). Ethical approval was granted for the study and informed consent was obtained from all the patients.

Surgical technique. The TKRs were performed by the senior author (EKS) using a medial parapatellar arthrotomy with patellar eversion and the Orthopilot version 4.08 computer-assisted navigation system (Aesculap, Tuttlingen, Germany).

After removing all osteophytes and performing the proximal tibial osteotomy at 0° in the coronal and the sagittal planes, adequate medial soft-tissue release was performed to achieve collateral ligament balance. The goal was to adjust the collaterals so that they were balanced to within 2° to 3° in extension. A distractor which had two flat independent plates for the medial and the lateral compartments was used to measure the gaps in extension after adequate ligament release. After recording the extension gaps, the distractor was placed in the joint at 90° of flexion and the flexion gaps were recorded. The distal femoral cutting block was placed for a cut perpendicular to the tibial shaft axis in the coronal and the sagittal planes and the cut was completed. The 4-in-1 cutting block was then placed for the chamfer cut, which was performed to equalise the flexion and the extension gaps. A variation in the mediolateral and the AP laxity of less than 2° to 3° after a trial insertion was confirmed in order to determine the required thickness of the polyethylene insert. The PCL was retained and a cemented e-motion prosthesis (Aesculap) was implanted with cement. The e-motion is a mobile bearing cruciate retaining prosthesis which achieves a large contact area, and its femorotibial articulation has a somewhat conforming design. The tibial base plate has a posterior slope of 3° and the polyethylene insert is slightly dished in the sagittal plane with a slightly elevated anterior tip.

Clinical evaluation. The knees were divided into stable (< 10 mm, 38) and unstable (≥ 10 mm, 17) groups based on the total AP laxity. The Hospital for Special Surgery (HSS)²¹ score and the Western Ontario MacMasters University (WOMAC)²² osteoarthritis index were measured and non-weight-bearing and weight-bearing flexion radiographs were obtained in each patient at the final follow-up. In addition, the delta flexion was calculated as the difference in flexion while the patient was non-weight-bearing and weight-bearing. The former was measured with the patient in the supine position and the latter during a single-leg lunge, using a goniometer. One arm of the goniometer was placed parallel to the shaft of the femur, which was estimated from the location of the greater trochanter and the lateral femoral condyle, and the other arm parallel to the shaft of the tibia, which was estimated from the fibular head and the lateral malleolus.⁷ All the ROMs and clinical data were evaluated and recorded by a physiotherapy assistant.

Radiological evaluation. In order to evaluate post-operative stability, the AP laxity at 90° of knee flexion was measured

using anterior and posterior stress lateral radiographs taken in the lateral decubitus position (with a 9 kg load) with a Telos arthrometer (Austin and Associate Inc., Fallston, Maryland). Measurements of the AP laxity were obtained by tracing a line along the posterior border of the tibial component and then measuring the perpendicular distance to a point marked at the most posterior part of the posterior condyle on the femoral component (Fig. 1). The total AP laxity was calculated as the sum of the anterior and posterior laxity, because the resting position of the femoral component, in relation to the tibial component, varied. One observer (SJP), who was blinded to the patient's clinical outcome, performed the testing and measurements at the final follow-up.

The correlation between the total AP laxity and the three ROM parameters (weight-bearing, non-weight-bearing, and delta flexion) was evaluated as well as that between the total AP laxity and the HSS and WOMAC scores. There were no significant differences between the stable and the unstable groups with regard to the age at surgery, gender, the duration of follow-up and the body mass index (Table I).

The radiological indices measured included the femoro-tibial angle on the standing AP radiographs and the posterior slope of the tibia on the lateral radiographs obtained at the final follow-up. In addition, the difference in the posterior femoral condylar offsets pre-operatively was compared with that at the final follow-up. The posterior femoral condylar offset was evaluated by measuring the maximum thickness of the posterior femoral condyle projected posteriorly to the tangent of the posterior cortex of the femoral shaft on lateral radiographs.²³ In order to obtain accurate lateral views, these exposures were adjusted throughout the investigation under fluoroscopic control. All the measurements were performed by a resident (SJP) who was unaware of the results and the clinical outcome.

Statistical analysis. The sample size was determined based on values which were derived from the first 20 patients. With mean values of delta flexion of 7.7° (0° to 15°) for the stable group and of 12.5° (5° to 20°) for the unstable group, it was determined that a total of 17 knees would be needed in the unstable group to show a significant difference with a power (1-β) of 80% (α = 0.05). Statistical comparison of the clinical outcome, flexion parameters and total laxity between the two groups was carried out using the Mann-Whitney U test. The correlation between laxity and the flexion parameters was analysed using Pearson's correlation coefficient. All the analyses were performed using SPSS version 16.0 (SPSS Inc., Chicago, Illinois) with statistical significance set at a p-value ≤ 0.05.

Results

The mean AP laxity was 7.6 mm (0.6 to 9.5) in the stable group and 13.1 mm (10.2 to 15.3) in the unstable group. The mean pre-operative HSS and WOMAC scores, as well as the flexion parameters showed no significant difference between the two groups (Tables I and II). The mean post-

Fig. 1a

Fig. 1b

Anterior (a) and posterior (b) stress radiographs showing the measurement of the total anteroposterior laxity (difference of anterior and posterior displacement). Displacement was defined as the perpendicular distance between a line along the posterior border of the tibial component (A) and line at the most posterior part of the femoral component posterior condyle (B).

Table I. Comparison of pre-operative and post-operative details (mean, range) and knee function in the two groups

	Stable group (n = 38)	Unstable group (n = 17)	p-value
Age in years	68.0 (55 to 77)	68.8 (57 to 81)	0.855
Men:women	6:32	3:14	0.863
Duration of follow-up in months	33.3 (24 to 52)	32.4 (24 to 48)	0.963
Body mass index (kg/m ²)	25.3 (18 to 37)	25.8 (19 to 37)	0.509
HSS* score			
Pre-operative	63.2 (44 to 77)	64.6 (48 to 79)	0.663
Post-operative	91.4 (80 to 100)	89.8 (80 to 98)	0.277
WOMAC† score total			
Pre-operative	73.8 (59 to 100)	72.0 (57 to 95)	0.368
Post-operative	29.2 (24 to 43)	31.2 (27 to 42)	0.082
Function, pre-operative	50.4 (40 to 65)	50.8 (40 to 69)	0.552
Post-operative	19.8 (17 to 30)	21.6 (19 to 28)	0.011

* HSS, Hospital for Special Surgery

† WOMAC, Western Ontario and Macmasters University osteoarthritis index

operative non-weight-bearing maximum flexion was similar in the stable and unstable groups, 130.3° (110° to 140°) and 132.1° (100° to 140°) respectively (Mann-Whitney, $p = 0.646$, Table II). In addition, there was no

significant difference between the groups in the mean weight-bearing maximum flexion (Mann-Whitney, $p = 0.095$, Table II). The mean delta flexion was significantly less in the stable group compared with the unstable

Table II. Comparisons of pre-operative and post-operative range of movement (mean, range) in the two groups

	Stable group (n = 38)	Unstable group (n = 17)	p-value
Pre-operative flexion			
NWB*	127.9 (80 to 140)	123.8 (80 to 140)	0.302
WB†	123.0 (80 to 140)	117.4 (80 to 135)	0.254
Delta	4.1 (-5 to 20)	5.3 (0 to 20)	0.440
Post-operative flexion			
NWB	130.3 (95 to 140)	132.1 (110 to 140)	0.646
WB	120.5 (85 to 140)	115.9 (100 to 130)	0.095
Delta	9.7 (0 to 25)	16.2 (5 to 30)	0.005

* NWB, non-weight-bearing

† WB, weight-bearing

Fig. 2

Scattergram showing a positive correlation between delta flexion and the anteroposterior laxity.

group (9.7° (0° to 25°) *versus* 16.2 (5° to 20°); Mann-Whitney, $p = 0.005$, Table II). While the mean HSS and the mean total WOMAC scores showed no significant difference between the groups, the stable group had a better mean post-operative WOMAC function score compared with the unstable group (19.8° (17° to 30°) *versus* 21.6° (19° to 28°); Mann-Whitney, $p = 0.011$, Table I).

No correlation was found between the AP laxity and the non-weight-bearing ($r = 0.06$, $p = 0.645$) and the weight-bearing maximal flexion ($r = 0.26$, $p = 0.056$). However, there was a significant correlation between the delta flexion and AP laxity ($r = 0.51$, $p < 0.001$, Fig. 2). The HSS and the WOMAC scores showed no significant correlation with the AP laxity ($r = 0.29$, $p = 0.125$ and $r = 0.13$, $p = 0.346$, respectively).

The mean femorotibial angle measured at the final follow-up was 5.3° (0° to 10°) of valgus in the stable group and 4.7° (1° to 9°) of valgus in the unstable group, which was not significant (Mann-Whitney, $p = 0.511$). The mean posterior tibial slope at the final follow-up and the mean change in the

posterior femoral condylar offset after TKR were also similar (2.5° (-1° to 7°) in the stable and 2.2° (0° to 5°) in the unstable group; 1.1 mm (-4 mm to 7 mm) in the stable and 1.5 mm (-3 mm to 5 mm) in the unstable group, $p = 0.702$ and $p = 0.614$, respectively (both Mann-Whitney)).

Discussion

We evaluated the effects of the AP laxity on the three flexion parameters (weight-bearing, non-weight-bearing and delta flexion) as well as the clinical outcome following cruciate-retaining TKR. Our results showed that stable knees had less delta flexion and better function than unstable knees. A significant correlation was found between the delta flexion and the AP laxity, but there was no significant correlation between the HSS or the WOMAC scores and AP laxity.

Several studies^{3-5,8} have shown a significant decrease in weight-bearing flexion compared with the non-weight-bearing flexion, although various activities for weight-bearing flexion such as a single-leg lunge, squatting or kneeling have been used in different studies. This decrease in flexion under weight-bearing conditions following cruciate-retaining TKR may have been because of abnormal knee kinematics caused by a decreased femoral roll-back. It has been shown that following this procedure the femorotibial contact is translated anteriorly with increasing knee flexion.^{6,8} In our study, the weight-bearing flexion during a single-leg lunge activity and active non-weight-bearing flexion in the supine position were measured. The results of a decrease in flexion, under weight-bearing conditions, were comparable with those of other studies reporting on the outcome following cruciate-retaining TKR.³⁻⁵

A number of studies have attempted to evaluate laxity following cruciate-retaining TKR. One of the problems with the data from these studies is that various instruments and angles have been used for measuring laxity. Another problem is that the definition of the neutral position when measuring anterior and posterior displacement is varied. In our study, the total AP laxity was measured as the sum of the anterior and posterior laxity at 90° of flexion using a

Telos device (Austin and Associate Inc). The results showed a mean 8.3 mm of total AP laxity and more than 10 mm in one-third of patients, at a minimum follow-up of two years. Matsuda et al,¹⁰ using a KT-2000 arthrometer at 75° of flexion, reported a laxity of 8.1 mm and of more than 10.0 mm in half the knees in their series of cruciate-retaining TKRs. In addition, Ishii et al¹³ reported AP laxity of 4.5 mm at 75° of flexion.

Many studies have examined the relationship between AP laxity and the ROM or clinical outcome.^{10,13-20,24} A better post-operative ROM with less pain in patients with stable knee prostheses has been described in some reports^{13,19,20} whereas others have found a better functional outcome and ROM in knees with a lax prostheses.^{14,16} Most studies^{10,13-20,24} have evaluated the relationship between AP laxity and passive or non-weight-bearing ROM. However, the weight-bearing ROM is more important for the function of the knee following a TKR. It is well known^{3-5,8} that weight-bearing flexion of the knee is significantly decreased compared with non-weight-bearing flexion following a TKR, especially following a cruciate-retaining TKR, but there are variations in the way in which weight-bearing flexion has been evaluated. With our method of evaluation no differences were found between the stable and the unstable groups in terms of non-weight-bearing and weight-bearing flexion. However, the stable knees with less than 10 mm of AP laxity had a smaller delta flexion compared with the unstable knees (9.7° versus 16.2° in stable and unstable knee groups, respectively). These findings are similar to the results of Matsuda et al¹⁰ and Ishii et al.¹³ In both studies a total AP laxity of 9 mm to 10 mm was found in well-functioning mobile knees and this amount of laxity was recommended at 30° flexion in the knee.

While Yamakado et al¹⁹ found no correlation in cruciate-retaining TKR knees between AP laxity and the HSS score, with a mean total AP laxity of 9.7 mm at 30° of flexion, Warren et al²⁰ found that anterior laxity of more than 10 mm had a poorer outcome when measured using the Knee Society functional score after cruciate-retaining TKR at follow-up of three to four years. We found that stable knees (≤ 10.0 mm) after cruciate-retaining TKR had a better WOMAC function score than unstable knees. Concerning the relationship between the AP laxity and flexion parameters, only delta flexion showed a significant positive correlation with AP laxity ($r = 0.51$). However, no significant differences between the two groups with regard to the HSS and WOMAC total scores were found. Moreover, the mean HSS and the mean WOMAC scores showed no significant correlation with AP laxity, ($p = 0.125$ and $p = 0.346$ respectively).

Massin and Gournay²³ investigated the potential effects of the posterior femoral condylar offset and tibial slope on the range of knee flexion and showed that a decrease in the posterior condylar offset of 3 mm reduced flexion by 10° before tibiofemoral impingement occurred. Furthermore, a simultaneous decrease in the tibial slope of 5° reduced the range of flexion by a further 5°. However, our results have

shown that there was no significant difference in the change in the posterior femoral condylar offset following a TKR and the tibial posterior slope at the final follow-up between the two groups.

We recognise the limitations of our study. First, there is a potential for bias because of its retrospective nature. However, it should be noted that a prospective study is difficult to carry out because it is difficult to predict how much laxity patients will have following surgery, which would make a power analysis difficult. Secondly, laxity was evaluated only for one type of cruciate-retaining implant. Hence, laxity of 10 mm may not be appropriate for other cruciate-retaining designs, because it can be influenced by complex interactions between the implant and the soft-tissue structures which surround the knee. Thirdly, the ROM was measured in all the patients by one physiotherapy assistant using a goniometer rather than radiographs. However, several studies have reported on the reproducibility of measurements obtained with a goniometer and have shown a high intra- and inter-observer correlation.^{25,26} Therefore, the flexion data were deemed to be reliable and suitable for the purpose of this comparative study.

In conclusion, stable knees (AP laxity ≤ 10 mm) showed a better functional outcome and less reduction of flexion under weight-bearing conditions compared with unstable knees (AP laxity > 10.0 mm), following a cruciate-retaining TKR. Moreover, reduction of flexion under weight-bearing conditions was significantly related to the AP laxity. Based on our results, laxity of more than 10.0 mm after e-motion TKR should be avoided if a good functional outcome including flexion under weight-bearing conditions is to be achieved.

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