Varus-valgus balance and range of movement after total knee arthroplasty

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We performed a randomised, prospective study of 80 mobile-bearing total knee arthroplasties (80 knees) in order to measure the effects of varus-valgus laxity and balance on the range of movement (ROM) one year after operation. Forty knees had a posterior-cruciate-ligament (PCL)-retaining prosthesis and the other 40 a PCL-sacrificing prosthesis. In the balanced group (69 knees) in which the difference between varus and valgus was less than 2°, the mean ROM improved significantly from 107.6° to 117.7° ($p < 0.0001$). By contrast, in the 11 knees which were unbalanced and in which the difference between varus and valgus laxity exceeded 2°, the ROM decreased from a mean of 121.0° to 112.7° ($p = 0.0061$). We conclude that coronal laxity, especially balanced laxity, is important for achieving an improved ROM in mobile-bearing total knee arthroplasty.

A satisfactory post-operative range of movement (ROM) is an important feature of a successful total knee arthroplasty (TKA) and is influenced by many factors. A successful outcome is also assumed to include satisfactory stability. While there is general agreement about the importance of varus-valgus laxity and proper soft-tissue balance at TKA, there is little appropriate information in the literature. Thus we investigated the effect of coronal laxity, varus-valgus balance and the type of implant on ROM after TKA.

Patients and Methods

We examined 80 low-contact stress TKAs (LCS; DePuy, Warsaw, Indiana) chosen from a group of patients who had no clinical complications. Forty knees (40 patients) were prospectively assigned to receive a posterior-cruciate-ligament (PCL)-retaining prosthesis. The mean age of the patients was 70 years,

their mean ROM before operation was 118° (SD 14°), and their mean pre-operative Hospital for Special Surgery (HSS) score¹ was 92° (SD 2°). Forty knees (40 patients) were prospectively assigned to receive a PCL-sacrificing prosthesis. Their mean age was 72 years, their mean ROM 116° (SD 14°), and the mean pre-operative HSS score 90° (SD 4°). Table I shows the clinical details of each group. All procedures were performed by one senior surgeon (YI) using a standard technique, including the necessary soft-tissue release required to obtain adequate balance. Proper intra-operative laxity was judged manually rather than measured. All the components were secured without cement. No cases of revision replacement or conversion from a high tibial osteotomy were included in the study.

Varus-valgus laxity was measured using a Telos arthrometer (Fa Telos; Medizinisch-Technische GmbH, Griesheim, Germany).

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Table I. Details of the patients in both groups

	PCLR†	PCLS‡
Patients (knees)	40 (40)	40 (40)
Male	6	2
Female	34	38
Mean flexion (°) (SD)	118 (14)	116 (14)
HSS* score (SD)	92 (2)	90 (4)
Mean posterior tibial slope (°) (SD)	10.5 (2.5)	9.6 (2.5)
Mean pre-operative posterior condylar offset ²⁵ (mm) (SD)	24.9 (1.9)	25.3 (1.4)
Mean post-operative posterior condylar offset ²⁵ (mm) (SD)	23.2 (2.0)	23.4 (2.5)

* HSS, Hospital for Special Surgery

† PCLR, posterior cruciate ligament-retaining design prosthesis

‡ PCLS, posterior cruciate ligament-sacrificing design prosthesis

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Radiographs showing a) varus, and b) valgus stress in a PCL-sacrificing TKA with balanced coronal laxity; and c) varus and d) valgus stress in a PCL-retaining TKA with unbalanced coronal laxity.

With the patient lying supine, 150 N were applied across the knee with the joint flexed at between 0° and 20° (Fig. 1) and the patella facing forward in order to minimise the rotational effect. The patients were told to relax and stan-

dard radiographs were taken after the force had been applied for one minute. In order to reduce interobserver variation, a single clinician (YM) performed all of the tests. Three measurements were made one year after operation

Table II. Mean (SD) laxity at varus and valgus angles in both groups one year after TKA

	Varus	Valgus	Total laxity
PCLR* (n = 40)	3.9 (1.2)	4.0 (1.4)	7.9 (2.3)
PCLS† (n = 40)	4.7 (2.2)	3.6 (1.4)	8.3 (2.9)
p value	0.1534	0.2222	0.9851

* PCLR, posterior cruciate ligament-retaining design prosthesis

† PCLS, posterior cruciate ligament-sacrificing design prosthesis

and their mean was calculated. The intrasubject error was less than 1°. Statistically, a paired *t*-test was used to compare the results for varus and valgus laxity within each group, and an unpaired *t*-test for the two groups. Values for $p < 0.05$ were regarded as being significant.

The ROM for all patients was measured before and one year after surgery. It has been reported that the ROM after TKA does not change significantly after one year.^{2,3} Considering our results (Table II), and those in previous reports,^{4,5} approximately 4° of unidirectional laxity and 8° of total coronal laxity were considered to be the optimal degrees of laxity for both the posterior cruciate ligament retaining and sacrificing designs. Both forms of the prosthesis have iden-

tical radii of curvature from 0° to 30° of flexion in the anteroposterior and mediolateral planes, although the contact area in the two designs differs slightly.

All the patients were divided into balanced and unbalanced groups according to whether the difference in varus-valgus laxity was $< 2^\circ$. An unpaired *t*-test was used to compare the two groups.

Three separate subgroups in terms of total laxity were analysed and compared. They were defined as tight ($< 6^\circ$), adequate ($\geq 6^\circ$ but $\leq 10^\circ$), and loose ($> 10^\circ$).

Results

Table II gives the mean measurements under varus and valgus strains in both groups one year after TKA. There was no significant difference between the two groups ($p > 0.05$). The ROM data for both groups are summarised in Table III. There was a statistically significant improvement in the ROM 12 months after surgery for both groups.

The relationship between total coronal laxity and the ROM is summarised in Table IV. All three laxity groups showed an improved range compared with the pre-operative measurements. The improvement between the pre- and

Table III. Mean (SD) range of movement (°) one year after TKA with the *percentage* improvement

	Pre-operative (°; SD)	Post-operative (°; SD)	Improvement (%; SD)	p value
PCLR* (n = 40)	109.1 (18.0)	117.6 (14.4)	7.8 (21.5)	0.0087
PCLS† (n = 40)	109.9 (18.8)	116.3 (14.0)	5.8 (15.8)	0.0123
p value	0.8571	0.6933	0.5528	

* PCLR, posterior cruciate ligament-retaining design prosthesis

† PCLS, posterior cruciate ligament-sacrificing design prosthesis

Table IV. Mean (SD) flexion and range of movement (°) in the tight, adequate, and loose groups with the *percentage* improvement

	Pre-operative (°; SD)	Post-operative (°; SD)	Improvement (%; SD)	p value
Tight (n = 9)	107.5 (20.0)	109.4 (13.2)	1.8 (21.7)	0.4704
Adequate (n = 60)	107.4 (18.3)	115.8 (13.9)	7.8 (19.6)	0.0005
Loose (n = 11)	122.3 (12.3)	126.8 (13.1)	3.7 (14.6)	0.4275

Table V. Mean (SD) range of movement (°) in the balanced and unbalanced groups with the *percentage* improvement

	Pre-operative (°; SD)	Post-operative (°; SD)	Improvement (%; SD)	p value
Balanced (n = 69)	107.6 (17.6)	117.7 (13.6)	9.4 (18.5)	< 0.0001
Unbalanced (n = 11)	121.0 (18.6)	112.7 (17.5)	-6.8 (17.4)	0.2131
p value	0.0515	0.2839	0.0061	

Table VI. Mean (SD) laxity and range of movement (°) in both the balanced and unbalanced groups with the *percentage* improvement

	Pre-operative (°; SD)	Post-operative (°; SD)	Improvement (%; SD)	p value
Balanced				
Tight (n = 9)	107.5 (20.0)	109.4 (13.2)	1.8 (21.7)	0.4704
Adequate (n = 54)	106.9 (18.2)	117.3 (13.3)	9.7 (18.8)	< 0.0001
Loose (n = 6)	114.2 (8.6)	128.3 (12.1)	12.3 (9.9)	0.0228
Unbalanced				
Tight (n = 0)				
Adequate (n = 6)	111.7 (20.2)	102.5 (12.1)	-8.2 (21.0)	0.3718
Loose (n = 5)	132.0 (8.4)	125.0 (15.4)	-5.3 (14.4)	0.4684

post-operative ROM was only statistically significant for the adequate group.

Table V shows the mean ROM before and at one year after surgery for the balanced and unbalanced groups. The ROM only improved significantly for the balanced group. For the unbalanced group it decreased. There was no significant difference between the pre-operative ROM and that immediately after surgery between the two groups.

The details of both balanced and unbalanced groups are summarised in Table VI. By one year after surgery all three subgroups for the balanced knees had a better ROM when compared with their pre-operative ROM. Both the adequate and loose knees achieved a significantly better ROM. In contrast, for the unbalanced group, both the adequate and loose knees lost movement.

Discussion

Adequate soft-tissue balance has a greater effect on the outcome of a mobile-bearing TKA than on that of a fixed-bearing one.^{6,7} However, the post-operative ROM is important for maintaining the activities of daily living, such as squatting or sitting.⁷ According to Kettelkamp et al⁸ and Laubenthal, Smidt and Kettelkamp⁹ the normal ROM of the knees is 0° to 140°; 67° of flexion is required in the swing phase of walking, 80° for climbing stairs, 90° for descending stairs and 93° for sitting on a chair. Significant factors affecting the outcome include pre-operative flexion,^{3,10-13} the tibiofemoral varus-valgus angle,^{3,11} the age of the patient,³ body-weight,¹² the technique of surgical closure¹⁴ and the design of the implant.^{15,16} Based upon a review of the literature, most clinical series have studied patients who were considered to be clinically successful and showed no significant instability. We have evaluated the 80 LCS knees as one group and present the results in a simpler manner.

Tables I and III show that both groups had similar clinical results in terms of the HSS score and post-operative ROM. Furthermore, Table II shows that both also had similar varus-valgus laxity, although the posterior cruciate ligament is thought to be the second stabiliser and to contribute 25% of the varus-valgus stability as compared with the collateral ligaments.^{17,18}

As to whether laxity influences the ROM, Edwards, Miller and Chan¹⁹ reported that patients with stable knees had a mean maximum flexion of 105° whereas those with lax knees had a mean maximum flexion of 111°, although the difference did not achieve statistical significance. We presume from this that some degree of laxity is an important factor. In our study, the ROM was improved in all the laxity groups, but the improvement was only significant in the adequate group. These results clearly demonstrate that a better ROM is to be expected in those patients with adequate knee laxity and may support published opinions that less laxity, or tightness, places excessive shear forces on the component-bone interface. However, greater laxity places greater force on the restraining soft tissues and results in the risk of too large a shift of the contact points, thereby rock-

ing the components.²⁰ In our loose laxity group, a better, albeit insignificant, ROM was achieved, although the pre-operative ROM was greater than in the tight and adequate laxity groups.

Although there is general agreement about the importance of obtaining soft-tissue balance in TKA, it has not been critically measured. Our study indicated that patients with balanced laxity had a higher probability of achieving a better ROM than those with unbalanced laxity ($p < 0.0001$). Furthermore, the rate of improvement was significantly greater for the balanced than the unbalanced group, although the latter had had a greater pre-operative ROM. There are two possible reasons for these results. First, the unbalanced group had fewer knees of adequate stability (54.5%) and more loose knees (45.5%) than the balanced group, which include tight (13.0%), adequate (78.3%) and loose (8.7%) knees. The other reason is that the design of the LCS implant affected these results. Some authors²¹⁻²³ have reported a mean post-operative ROM of between 102° and 120° using the LCS prosthesis. This may reflect the fact that unbalanced laxity is undesirable since it may produce eccentric loading of the implant²⁴ and soft-tissue impingement.

Table VI shows that the ROM decreased by 8.2% in patients with unbalanced laxity, even in those with adequate laxity. Our results indicate that balanced laxity is essential for achieving a better ROM after TKA. Furthermore, Table VI also demonstrates that a better ROM is to be expected in balanced knees. However, it is very difficult to achieve balance with loose laxity. In our loose laxity group, five of 11 (45.5%) knees were unbalanced and the ROM decreased from 132.0° to 125.0° (5.3%).

There are some limitations in our study. This was a static analysis of coronal laxity, undertaken on one occasion, 12 months after surgery. We only measured varus-valgus laxity with the knee in extension, because of the characteristics of the arthrometer. Although the contact areas between the two designs differed, our study was performed under static, non-weight-bearing conditions, so that these differences were minimal in this effect.

We conclude that both coronal laxity and varus-valgus balance affect the ROM after TKA. An adequate degree of laxity and balance should contribute positively to the outcome of TKA.

Supplementary material

A further opinion by Mr Tim Wilton is available with the electronic version of this article on our website at www.jbjs.org.uk

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

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