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The role of the posterior cruciate ligament in total knee replacement

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Objectives

The purpose of this study was to examine the effect of posterior cruciate ligament (PCL) retention, PCL recession, and PCL excision during cruciate-retaining total knee replacement.

Methods

A total of 3018 anatomic graduated component total knee replacements were examined; 1846 of these retained the PCL, 455 PCLs were partially recessed, and in 717 the PCL was completely excised from the back of the tibia.

Results

Clinical scores between PCL groups favored excision for flexion ($p < 0.0001$), and recession and retention for stairs ($p < 0.0001$). There was a mild difference in long-term all-cause aseptic survivorship between PCL-retained (96.4% at 15 years) combined with PCL-recessed groups (96.6% at 15 years) when compared with the PCL-excised group (95.0% at 15 years) ($p = 0.0411$, Wilcoxon; $p = 0.0042$, log-rank), as well as tibial or femoral loosening, which reported prosthesis survival of 97.8% at 15 years for PCL-retained knees, 98.2% for recessed knees, and 96.4% for excised knees ($p = 0.0934$, Wilcoxon; $p = 0.0202$, log-rank).

Conclusions

Despite some trade-off in clinical performance, if the PCL is detached at the time of operation, conversion to a posterior-stabilised prosthesis may not be necessarily required as long as stability in the anteroposterior and coronal planes is achieved.

Keywords: Knee, TKR, Posterior cruciate ligament, Recession, Release, Excision, PCL

Article focus

■ The focus of this study was to examine the various degrees of recession of the posterior cruciate ligament (PCL) (retained, partially-recessed, and excised) on the long-term clinical outcome and survivorship of total knee replacement

Key messages

- There was an observable increase in flexion for PCL-excised knees, and an increase in stairs score for -recessed and -retained knees
- We observed a mild difference in all-cause aseptic survivorship at 15 years, along with a mild difference in survivorship for aseptic tibial and femoral failure at 15 years favouring PCL-retained and -recessed knees
- Increase in the variability of the excised group may partially explain the ambiguity present in the literature; however, the

observations of this study do not necessarily justify the change to a posterior-stabilised prosthesis when the PCL is excised

Strengths and limitations

- Strengths include a large population and longer follow-up than previously reported in the literature
- Limitations include that this is a retrospective observational study and the determination of a direct and exclusive causal relationship between PCL excision and outcome cannot be directly proven, although these findings are important in this debate

Introduction

Total knee replacement (TKR) has provided success rates of > 90%,¹⁻¹³ with many studies reporting success rates > 95% after ten or

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more years.^{1,3,4,6,7,10-12} In order to further improve the procedure, debate has arisen regarding sources of failure in TKR, including examination of the role of the posterior cruciate ligament (PCL). Some studies have demonstrated less consistent success with retention of the PCL,^{9,14} while other studies have found advantages in proprioception¹⁵ and kinematics¹⁶⁻²⁰ when the PCL is retained. Studies examining recession of the PCL have found similarly conflicting results.^{11,21} Survivorship analyses have examined the success of each method,^{9,22} but taken collectively, the literature has not been able to recommend one procedure over the others.²³ Two studies using a cruciate-retaining prosthesis have shown that the PCL may not play a dominant role if the ligaments overall are balanced.^{8,21} The first study examined 129 knees with a mean follow-up of 4.8 years (4.7 to 6.0),⁸ and the second followed 211 knees for a mean of 3.5 years (1.0 to 6.5).²¹

This study was undertaken to determine whether knees treated with a cruciate-retaining TKR alongside different PCL treatments would produce different outcomes. We hypothesised that sacrificing the PCL in a cruciate-retaining TKR would not result in a different outcome compared with retention of the PCL with regard to survivorship and clinical results.

Patients and Methods

Between April 1987 and December 2007, 10 677 primary TKRs were performed at our center. Of these, 9930 used anatomic graduated components (AGC; Biomet, Warsaw, Indiana), a cruciate-retaining TKR. Of these, 3905 were performed by two surgeons involved in the study (MAR, JBM). A total of 3018 TKRs (2002 patients) were cemented and had complete information regarding the status of the PCL recorded in the database, as well as a minimum follow-up of two years. These 3018 TKRs met the inclusion criteria of the study.

This study group comprised 1144 females (57%) and 858 males (43%), with a mean age at surgery of 69.3 years (SD 9.8; 23 to 93), and a mean body mass index (BMI) of 28.7 kg/m² (SD 5.3; 16.5 to 53.4). Diagnoses included osteoarthritis in 2916 knees (96.6%), rheumatoid arthritis in 77 knees (2.6%), and osteonecrosis in 25 knees (0.8%).

In 1846 TKRs in 1214 patients (1833 TKRs undertaken by MAR, 13 by JBM), specific recession or release of the PCL was not required, and these procedures comprised the PCL-retained group. The intra-operative management of the PCL was uniformly based on obtaining minimal to no femoral roll-back. If any anterior tibial component lift-off at 90° of flexion was noted, the tight PCL fibers were selectively released from the proximal tibia until lift-off no longer occurred. At this point the PCL was considered to be balanced. The entire PCL was not released in this case. A thicker implant was never necessary, and a loose flexion gap or posterior insufficiency was never accepted intra-operatively. In 455 TKRs in 327 patients (all TKRs

undertaken by MAR), the PCL was progressively released off the posterior tibia until the above criteria were met, with these knees comprising the PCL-recessed group. In the remaining 717 TKRs in 461 patients (four TKRs undertaken by MAR and 713 by JBM), the PCL was completely released off the back of the tibia during the approach and not in a stepwise fashion. These knees comprise the PCL-excised group.

The tibial component of the AGC total knee system is a mono-block titanium-backed fixed-bearing component with nearly flat-on-flat geometry. This flat design was used for all three procedure types; no posterior-stabilised designs were used. The two surgeons used the same arthroplasty procedure, beginning with a standard medial parapatellar approach; each TKR differed only in treatment of the PCL (retention, recession or excision). All patients in all categories underwent an identical post-operative course of treatment, with walking initiated within one day post-operatively, and distance walked and range of motion increased on subsequent days.

Patients were evaluated pre-operatively, at six months, and at one, three, five, seven, ten, 12, and 15 years post-operatively using the Knee Society clinical rating system.²⁴ Knee Society knee and function scores; the pain, stairs, and walking subscores; range of motion; anatomic alignment with varus < 5° of anatomical valgus, neutral between 5° and 10°, and valgus > 10°; and anteroposterior and mediolateral stability were recorded prospectively. Each exam was performed by the attending surgeon.

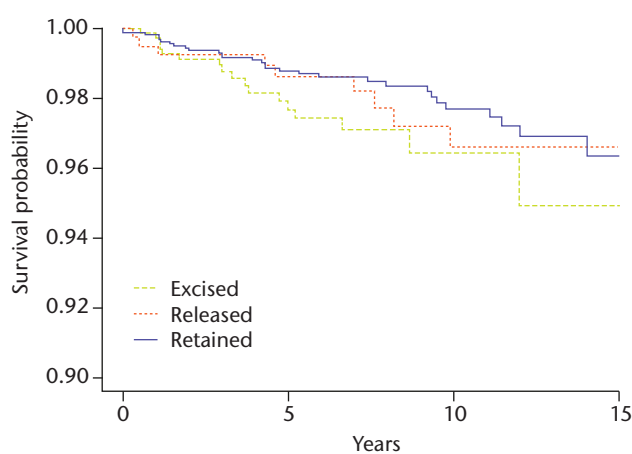
The mean follow-up was 7.8 years (SD 4.0, 2 to 21). Table I lists the demographic and pre-operative data between groups.

Statistical analysis. Statistical analysis was performed to determine differences in survivorship, mean knee, function, pain, stairs and walk scores, flexion, and antero-lateral posterior stability as defined by the Knee Society knee score post-operatively after primary TKR. Kaplan-Meier survivorship analysis²⁵ over 15 years was performed for each type of arthroplasty with failure defined as re-operation of the femoral or tibial component for any reason except infection. P-values for survival analyses were given by Kaplan-Meier analysis, and Cox regression was not performed due to possible confounding between surgeon and PCL status.

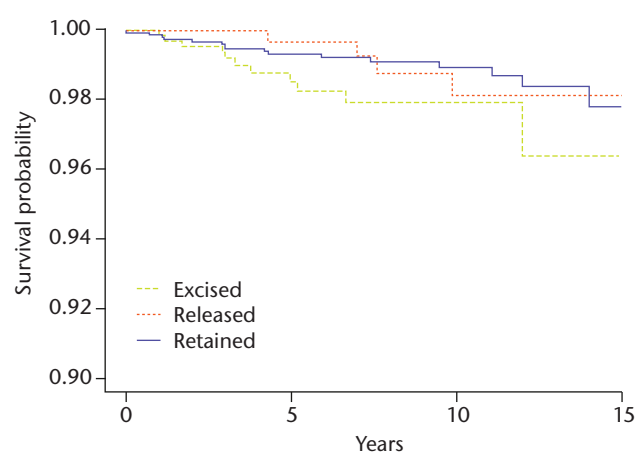
Due to a relatively large number of repeatedly returning patients after the index surgery (a mean of 3.1 post-operative clinical visits per knee), the clinical scores collected between one and ten years post-operatively were analysed by repeated measures linear regression. The authors selected an unstructured covariance structure in the model to allow the correlation of each patient to themselves to vary between each follow-up interval. Significant covariates analysed for each clinical outcome were age, gender, diagnosis, pre-operative BMI, pre-operative clinical score (matching the post-operative

Table I. Demographics and mean [SD] (range) pre-operative clinical scores for the posterior cruciate ligament (PCL)-retained, -recessed and -excised groups

	PCL-retained (n = 1846)	PCL-recessed (n = 455)	PCL-excised (n = 717)	p-values (1-way ANOVA, least squares means test)		
				PCL-retained vs PCL-recessed	PCL-retained vs PCL-excised	PCL-recessed vs PCL-excised
Age (yrs)	71.0 [9.2] (23 to 93)	70.0 [9.3] (39 to 89)	65.9 [10.2] (28 to 91)	0.0269	< 0.0001	< 0.0001
Body mass index (kg/m ²)	27.1 [3.4] (18 to 49)	26.6 [3.1] (19 to 37)	33.1 [6.5] (17 to 53)	0.6792	< 0.0001	< 0.0001
Female (%)	57.6%	57.9%	53.8%	0.1149	0.0558	0.9073
Follow-up (yrs)	8.0 [4.6] (2 to 23.2)	7.8 [4.0] (2.0 to 18.1)	5.8 [3.0] (2.0 to 14.8)	< 0.0001	< 0.0001	< 0.0001
Knee score	33.8 [13.9] (2 to 95)	34.7 [13.9] (3 to 81)	38.7 [10.6] (10 to 77)	0.0846	< 0.0001	0.0002
Pain score	4.4 [10.0] (0 to 50)	6.8 [10.5] (0 to 50)	9.0 [8.4] (0 to 50)	< 0.0001	< 0.0001	0.0006
Flexion (°)	113.7 [12.7] (30 to 150)	112.7 [13.5] (40 to 140)	106.0 [12.0] (45 to 135)	0.2275	< 0.0001	< 0.0001
Alignment (°)	0.1 [8.5] (-22 to 35)	-0.3 [8.9] (-22 to 30)	0.0 [2.9] (-15 to 20)	0.4568	0.8836	0.6585
Function score	45.9 [11.6] (0 to 100)	45.3 [13.2] (0 to 100)	47.6 [15.6] (0 to 100)	0.4816	0.0045	0.0073
Walking score	19.8 [6.8] (0 to 50)	20.1 [7.8] (0 to 50)	21.2 [9.2] (0 to 50)	0.4879	0.0004	0.0436
Stairs score	29.5 [5.0] (0 to 50)	28.7 [5.9] (0 to 50)	29.2 [7.8] (0 to 50)	0.0111	0.2556	0.1784

**Fig. 1**

Kaplan-Meier curve showing the all-cause aseptic survival for total knee replacements with the posterior cruciate ligament retained, partially recessed and excised.

**Fig. 2**

Kaplan-Meier curve showing the survival of total knee replacements with the posterior cruciate ligament retained, released and excised, with aseptic femoral or tibial revision as the endpoints.

clinical score), differences between surgeons, pre-operative varus < -8°, pre-operative valgus > 11° and the variable of interest (status of the PCL).

Pre-operative score and patient demographics were analysed by one-way analysis of variance (ANOVA) for continuous variables (age, BMI, alignment and clinical score), and 2 × 2 contingency tables (the chi-square statistic) for categorical variables (gender and diagnosis). Level of significance was set at $p = 0.05$. All analyses were performed with SAS 9.1 (SAS Institute, Cary, North Carolina).

Results

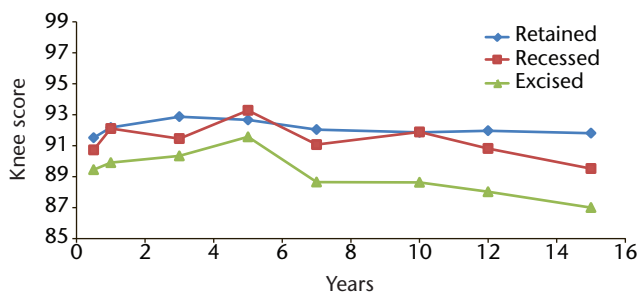
The all-cause aseptic failure survival at ten years was 97.70% (95% confidence interval (CI) 96.53 to 98.47) for the PCL-retained knees, 96.60% (95% CI 93.33 to 98.28) for the PCL-recessed knees and 96.46% (95% CI 93.88 to 97.96) for the PCL-excised knees (Fig. 1). The all-cause aseptic fail survival at 15 years was 96.36% (95% CI 94.21 to 97.71) for PCL-retained, 96.60% (95% CI 93.33 to

98.28) for PCL-recessed and 94.95% (95% CI 89.98 to 97.49) for PCL-excised knees (Fig. 1). Excised knees were found to have a statistically significant lower survival than the combined retained and recessed groups ($p = 0.0411$, Wilcoxon; $p = 0.0042$, log-rank), and the retained and recessed group were not found to be significantly different from each other ($p = 0.7020$, Wilcoxon; $p = 0.9543$, log-rank).

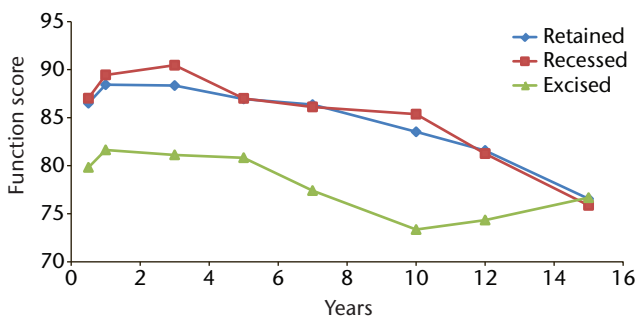
With aseptic femoral loosening ($n = 7$), failure of the tibial prosthesis ($n = 26$), and radiolucency failure ($n = 3$) as endpoints, the survival at ten years was 98.95% (95% CI 98.13 to 99.41) for the PCL-retained knees, 98.16% (95% CI 95.03 to 99.33) for the PCL-recessed knees and 97.94% (95% CI 96.12 to 98.92) for the PCL-excised knees (Fig. 2). The corresponding survival at 15 years was 97.84% (95% CI 95.74 to 98.91) for the PCL-retained, 98.16% (95% CI 95.03 to 99.33) for the PCL-recessed, and 96.41% (95% CI 91.23 to 98.56) for the PCL-excised knees (Fig. 2). Excised knees were found to have a statistically

Table II. Details of failures in the knees with retention, recession and excision of the posterior cruciate ligament

Mode of failure (n, %)	PCL-retained (n = 1846)	PCL-recessed (n = 455)	PCL-excised (n = 717)
Instability	8 (0.4)	3 (0.7)	4 (0.6)
Tibial collapse	7 (0.4)	0 (0)	4 (0.6)
Loose tibial component	0 (0)	0 (0)	1 (0.1)
Femur	1 (0.1)	2 (0.4)	4 (0.6)
Radiolucency	2 (0.1)	1 (0.2)	0 (0)
Polyethylene wear	2 (0.1)	0 (0)	0 (0)
Patellar failure	3 (0.2)	0 (0)	0 (0)
Tibial bone fracture	0 (0)	1 (0.2)	0 (0)
Infection	4 (0.2)	2 (0.4)	4 (0.6)
Trauma	4 (0.2)	1 (0.2)	2 (0.3)
Total failed (n, %)	31 (1.7)	10 (2.2)	19 (2.6)

**Fig. 3**

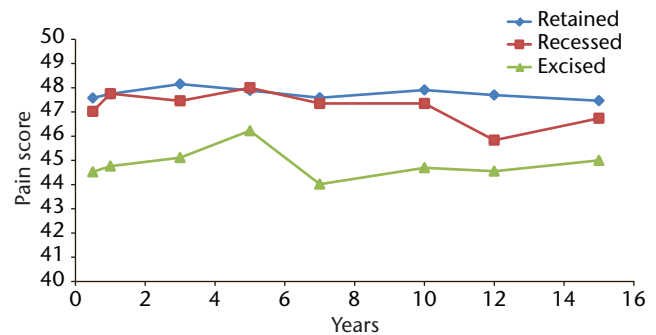
Graph showing the mean Knee Society knee scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

**Fig. 4**

Graph showing the mean Knee Society function scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

significant lower survival than the combined retained and recessed groups ($p = 0.0934$, Wilcoxon; $p = 0.0202$, log-rank), and the retained and recessed group were not found to be significantly different from each other ($p = 0.6000$, Wilcoxon; $p = 0.8330$, log-rank).

Failure rates of the additional all-cause failure mechanisms (infection in ten, trauma in seven, polyethylene wear in two, tibial fracture in one and patellar fracture in

**Fig. 5**

Graph showing the mean Knee Society pain scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

one) are described in Table II. The seven knees revised after trauma included a tibial collapse after a reported twisted knee in one, one loose tibia with polyethylene wear after stepping in a hole, a PCL tear exhibiting a 2 cm anterior-posterior instability after a motor vehicle accident, one patella found at the end of the endochondral notch after twisting the knee concurrent with a patient-reported “snap,” one medial tibial collapse after a fall, a loose femur and patella after a fall, and a clinical presentation of decreased flexion after being kicked by a cow.

We were unable to detect significant differences between PCL groups for Knee Society knee score ($p = 0.3533$; Fig. 3), function score ($p = 0.4535$; Fig. 4), pain score ($p = 0.9217$; Fig. 5), walking score ($p = 0.7195$; Fig. 6) or anteroposterior stability ($p = 0.9899$; Fig. 7). Flexion and stairs scores reported significant differences (both with $p < 0.001$; Figs 8 and 9), with flexion favouring the PCL-excision group with a mean flexion of 119.2° (SD 10.7; 40° to 150°) for the excised group compared with 112.2° (SD 11.3; 30° to 150°) for the combined PCL retention and recession group, and stairs favouring PCL

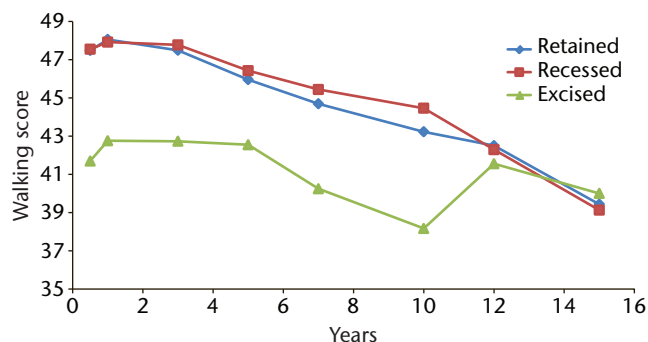


Fig. 6

Graph showing the mean Knee Society walking scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

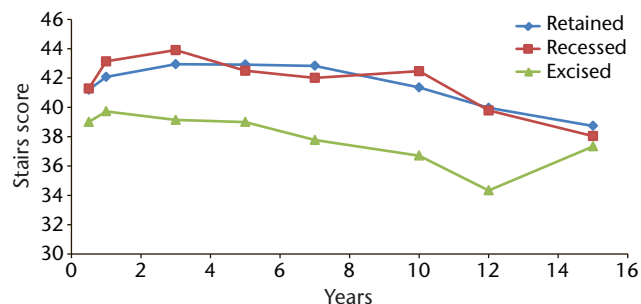


Fig. 9

Graph showing the mean Knee Society stairs scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

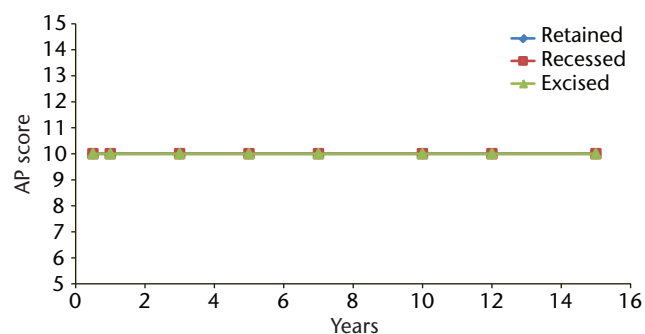


Fig. 7

Graph showing the mean Knee Society anteroposterior (AP) scores²⁴ for the groups with retention, recession and excision of the posterior cruciate ligament.

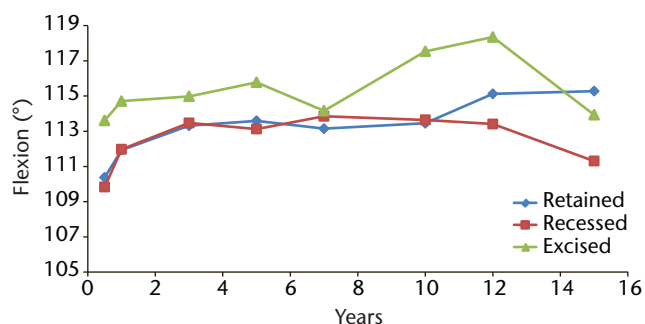


Fig. 8

Graph showing the mean flexion for the groups with retention, recession and excision of the posterior cruciate ligament.

retention and recession with overall mean stairs score of 40.6 (SD 9.7; 0 to 50) for the combined retention and recession groups compared with 38.8 (SD 11.1; 0 to 50) for the excised group. Comparisons for each clinical measure are shown in Table III.

The observed numerical differences in the PCL-excised group for clinical scores were found to be multifactorial, primarily caused by the effects of 1) *age* (older patients

Table III. Differences in mean Knee Society²⁴ scores between knees with excision of the posterior cruciate ligament (PCL) and those with retention/recession of the PCL

Mean (SD) outcome score	PCL-retention/recession	PCL-excision	p-value*
Knee score	88.8 (9.0)	89.7 (10.3)	0.3533
Pain	45.1 (7.1)	45.3 (8.2)	0.9217
Flexion	112.2 (11.3)	119.2 (10.7)	< 0.0001
Anteroposterior stability	10.0 (0.3)	10.0 (0.0)	0.9899
Function score	80.0 (19.1)	77.3 (21.1)	0.4535
Stairs	40.6 (9.7)	38.8 (11.1)	< 0.0001
Walk	41.0 (10.2)	40.3 (12.7)	0.7195

* repeated measures linear regression

scored lower for function score ($p < 0.0001$), higher for flexion ($p = 0.0495$), lower for stairs score ($p < 0.0001$) and lower for walking score ($p < 0.0001$), 2) *gender* (males scored higher for function score, higher for flexion, higher for stairs and walking scores (all $p < 0.0001$)), 3) *surgeon differences* (flexion ($p < 0.0001$) and walk score ($p = 0.0007$)), 4) *diagnosis of rheumatoid arthritis* (lower than osteoarthritis for function score ($p = 0.0003$), lower for stairs score ($p = 0.0201$) and lower for walk score ($p < 0.0001$)), 5) *diagnosis of osteonecrosis* (lower than osteoarthritis for pain score ($p = 0.0168$)), 6) *pre-operative BMI* (higher BMI scored lower for function ($p < 0.0001$), better (higher) for pain score ($p = 0.0006$), lower for flexion ($p = 0.0094$), lower for stairs score ($p = 0.0447$) and lower for walk score ($p < 0.0001$)), 7) a *pre-operative clinical score* positively correlated with post-operative clinical outcome (function score ($p < 0.0001$), flexion ($p < 0.0001$), stairs ($p \leq 0.0007$) and walking scores ($p = 0.0015$)), and 8) *pre-operative valgus deformity* $> 11^\circ$ (lower for knee score ($p = 0.0217$), lower for function score ($p = 0.0001$), lower for walk ($p = 0.0150$), higher for flexion ($p < 0.0001$) and lower for stairs ($p < 0.0001$)).

There was an increase in the variability of clinical outcome between PCL groups indicating a somewhat wider dispersion for the excised group about the mean in clinical outcome scores. The observed differences were

+49% variance for knee score ($p < 0.0001$), +140% variance for function score ($p < 0.0001$), -23% variance for flexion ($p = 0.0026$), +56% variance for pain score ($p \leq 0.0001$), +12% variance for stairs ($p = 0.0302$), +96% variance for walk score ($p < 0.0001$) and +0% for antero-posterior stability ($p = 1.000$).

Discussion

The fate of the posterior cruciate ligament in TKR has remained unclear since the first TKR designs. Some have argued that the PCL should be retained, either partially or completely, because it aids knee joint proprioception¹⁵ and results in a closer approximation of normal knee kinematics.^{16,18-20} Others have not found an increase in proprioception with preservation of the PCL,^{26,27} possibly as a result of marked degenerative changes in the PCL of osteoarthritic patients.²⁸ Some studies have found that TKRs that sacrifice the PCL, such as posterior-stabilised prostheses, provide more natural kinematics with appropriate posterior femoral translation.²⁹ Clinical results also have not definitively supported either preserving or removing the PCL, as studies have demonstrated similar clinical outcome scores for retention and excision of the PCL.^{8,13,21,30,31}

We were unable to find any differences in the clinical outcome of retention or recession of the PCL in AGC TKR. Flexion (in favour of PCL excision) and stairs subscore (in favour of PCL retention and recession) were found to be influenced by the presence or absence of the PCL, and some differences were found both in the all-cause and femorotibial failure rates between knees with and without the PCL. We are continuing to study if those differences were a consequence of excision or some other factor related to knees requiring excision.

For the clinical data, we used repeated measures multiple linear regression on data up to ten years both to control the loss of late follow-up that we did encounter, and because data up to ten years after surgery is sufficiently stable to prove reliable.³² This statistical method also accounted for the demographic and pre-operative differences between the PCL groups (Table I), decreasing the chance that such differences could influence the results.

Kinematic analyses have examined the motion paths and weight loads of various TKR designs, including those that retain and excise the PCL.^{17,18,24,33-37} One study found no difference between PCL retention and excision with regards to the position and movement of the lateral and medial femoral condyles on the tibial component.¹⁸ Another study found PCL-retained TKR to be more efficient due to decreased muscle activity.¹⁷ Other analyses have found paradoxical anterior femoral translation on the tibia in PCL-retained arthroplasties.³⁵⁻³⁷ One analysis of axial rotation during stair-stepping found a wide range of internal rotation patterns in PCL-retained knees³³; however, all knees selected for the study provided excellent clinical results, suggesting that “a

range of knee motion patterns are well accommodated by patients”.³³ The present study did not examine the kinematics aspect of the PCL debate; however, we report PCL-retained and PCL-recessed TKRs with noticeably greater stair-stepping outcomes compared with arthroplasties that excise the PCL. This implies that the PCL may be necessary for obtaining optimum function after TKR, regardless of the internal rotation patterns of knees with a retained or recessed PCL. Additionally, the PCL-excised knees exhibited increased flexion, indicating the possibility that the kinematics of the excised knee may be somewhat different than that of the retained or recessed knee.

The literature has not yet exposed one treatment of the PCL as the best method in TKR. A systematic review²³ of the literature found eight randomised controlled trials.^{8,21,26,30,34,38-40} Of these, three studies^{8,21,30} examined the results of the same implant with and without the PCL, two of the groups included in our study. A best-evidence synthesis found no differences in the Hospital for Special Surgery score,⁴¹ range of motion or patient satisfaction between PCL-retained and PCL-excised TKR. The wider meta-analysis of the data from all eight studies demonstrated no significant difference in range of motion between PCL retention and PCL excision with use of the same prosthesis. This was the only conclusion the meta-analysis could produce because of the methodological inconsistencies between the eight studies; also, it could not conclude anything about PCL recession because it was not studied separately. Our study agrees with the meta-analysis in that there is no significant difference in objective knee score, using the Knee Society score instead of the Hospital for Special Surgery score.

The limitations of this study include retrospective analysis of prospectively-gathered data without a radiological review. There is no way for us to determine whether the state of the PCL directly caused higher or lower scores; however, our finding of the lack of differences between groups with PCL retention, recession, and excision remains important to the debate over its preservation. We excluded patients from our study who did not have an AGC implant or complete data required for analysis, and who were not treated by one of the two surgeons involved with the study, which may introduce a slight selection bias into our results. However, given the high number of joints that remained in the study, the data provided should prove valuable.

One could express concern that by 15 years we had lost a significant amount of patients over the study period. However, that conclusion requires an assumption that all surgeries were performed within a short time period, which is not the case in this study. We examined patients with surgeries that occurred between 1987 and 2007, so knees that had an operation in the latter part of the study period were not lost to follow-up; they simply would not reach the longer follow-up levels that knees which underwent earlier procedures could.

Knees with PCL retention or recession with an AGC prosthesis had improved stairs subscores compared with those with excision of the PCL, whereas greater motion was attained in knees with PCL excision. Post-operative pain was not found to be different among PCL groups. Although difficult to quantify here, the effect of surgeon appeared to weigh heavily on the effect of PCL status, more so than previously thought. If the PCL is detached at the time of operation, conversion to a posterior-stabilised prosthesis may not necessarily be needed as long as anteroposterior and coronal plane stability is achieved.

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