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Comparing cruciate-retaining total knee arthroplasty and cruciate-substituting total knee arthroplasty: A prospective clinical study

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Abstract
Background and Objectives: Total knee arthroplasty (TKA) is an effective and terminal surgical treatment for arthritis of knee joint. The aim of this study was to evaluate the influence of Posterior Condylar offset (PCO) ratio on range of motion after posterior cruciate ligament (PCL) retaining TKA and PCL substitution TKA.
Methods: This was a prospective trial, comparing PCL-substitution TKA with PCL-retaining PKA in patients requiring primary TKA. The study subjects were randomly allocated into two groups, 32 each. Baseline and endpoint Knee Society scores (KSS) were used to assess functional outcomes. Follow up assessments were conducted at baseline, 1 month, 3 months and 6 months after surgery.
Results: The mean age of study subjects was 61.52 ± 7.48 years. In the cruciate substituting group, 61.29% (19) were men. In the cruciate retaining group 60.61% (20) were women. The posterior condylar offset ratio was significantly lesser in the cruciate substituting group ($p<0.01$). A significant difference in improvement in flexion across time points was observed in cruciate-retaining group ($p<0.001$) and cruciate-substituting group ($p<0.001$). A significant difference in improvement in extension across time points was observed in cruciate-retaining group ($p<0.001$) and cruciate-substituting group ($p<0.004$). No significant association between PCO and improvement in flexion or extension was observed in patients undergoing PCL-retaining TKA or PCL-substitution TKA.
Conclusions: Significant improvement in flexion and extension after CR and CS TKA was observed. The difference in improvement in flexion and extension between CR and CS TKA was not significant. No influence of PCOR on flexion and extension was observed.

Keywords: cruciate-retaining, cruciate-substituting, total knee arthroplasty

Introduction
Total knee arthroplasty (TKA) is an effective surgical treatment for arthritis of knee joint. It is considered to provide significant pain relief and improves knee function in patients with arthritis with good long-term results [1-4]. The total condylar prosthesis developed in 1974 was modified to substitute only the posterior cruciate ligament, which was later substituted with a surgery to stabilize the posterior cruciate ligament. The modification of surgery and substitution of posterior cruciate ligament was associated with improved efficiency in climbing stairs, better range of knee motion and prevention of posterior subluxation [5]. Numerous retrospective studies of cruciate-retaining (CR) total knee arthroplasties have demonstrated consistently good clinical results and excellent intermediate and long-term outcomes. Many researchers in the past have contemplated if excising or retaining the posterior cruciate ligament (PCL) in total condylar knee prosthesis is good. In modern orthopedics, in most knee surgeries, PCL substituting prosthesis have replace the excised PCL [6, 7].
TKA gives good results during the first 15 years of implantation but the knee does not achieve its normal functional level. The range of flexion obtained after TKA is often limited and may be determined by several factors such as the length of quadriceps, capsular tightness, surgical technique, postoperative physiotherapy, and the implant design.
Several researchers have also compared the isokinetic strength and gait analysis between patients undergoing cruciate-retaining (CR) TKA and cruciate-substituting (CS) TKA [6, 7]. Most clinical studies comparing the results of Posterior cruciate-retaining (CR) versus

Posterior cruciate-sacrificing (CS) TKAs provide follow-up data between 1 and 5 years [8-12]. In addition, there are a very few comparative long-term studies of CR versus CS total knee arthroplasties that evaluate both implant survivorship and validated clinical outcomes [13-15].

When comparing the efficacy of CR with CS TKA, there is evidence to substantiate better efficacy of CR over CS or vice versa. Thus, the arguments between CR and CS prosthesis remain unsettled.

Preservation of the posterior condylar offset (PCO) and posterior condylar offset ratio (PCOR) was reported to be related to the degree of maximal flexion after TKA.[16,17,18] The PCO after TKA differs based on the referencing system used. Theoretically, the PCO or PCOR can be consistently preserved in the posterior referencing (PR) system because the same amount of resected bone is replaced by the femoral component. Thus, it is reasonable to speculate that the PR system could lead to greater flexion after TKA. However, besides the PCO, there are many factors that could be related to range of motion (ROM) after TKA, such as pre-operative ROM, posterior slope of the tibial component and the type of implant used [19, 20]. Therefore the purpose of the present study was to identify factors limiting active flexion after cruciate-retaining and cruciate-substitution TKA, and to compare the influence of PCO on the outcomes of cruciate-retaining and cruciate-substitution TKA. As per the previous studies, the role of PCO on range of motion is still a controversy. The aim of this study was to evaluate the influence of PCO ratio on range of motion after posterior cruciate ligament (PCL) retaining TKA and PCL substitution TKA.

Methods

A prospective comparative 2-group clinical study was conducted in the Department of Orthopedics, M. S. Ramaiah Hospital, Bangalore from October 2015 to December 2017. Ethical clearance was obtained from M.S.Ramaiah Hospital, Bangalore The study was conducted among 64 adults who were randomly allocated into two groups 32 subjects undergoing cruciate-substitution and 32 subjects undergoing cruciate-retaining total knee arthroplasty (TKA). Patients fulfilling the inclusion and exclusion criteria were explained the purpose and nature of this study in a language they understood, and written informed consent was obtained. Patients undergoing primary TKA were included in the study. The study subjects requiring hinged prosthesis, secondary osteoarthritis, rheumatoid arthritis, post-traumatic osteoarthritis and post-infectious osteoarthritis were excluded from the study. The study subjects with difficulty in mobility like foot and ankle disorders were excluded.

Study assessments

Patient's demographic details, baseline and endpoint posterior condylar offset ratio, range of motion were compared at baseline and endpoint using clinical and radiological parameters to assess range of motion and its complications. Baseline and endpoint knee society scores were obtained to assess knee function. Preoperative fluoroscopic/radiological images were compared with postoperative fluoroscopic/ radiological images. All assessments were repeated at 2 weeks, 4 weeks, 12 weeks, and at 6 months after surgery.

Statistical analysis

Data was analyzed using R software version 4.0.3. Chi-square test was applied to compare the distribution of variables between groups. Friedman test was applied to compare flexion and extension across time points. Pairwise Wilcoxon test with holm adjustment was the post hoc test applied. Logistic regression was applied to determine the relationship between PCO ratio and flexion, and PCO ratio and extension, at 1 month in the cruciate-retaining group and cruciate substituting group. P-value ≤ 0.05 was considered statistically significant.

Results

The mean age of the study subjects was 61.52 ± 7.48 years. In the cruciate substituting group, 61.29% (19) were men. In the cruciate retaining group 60.61% (20) were women. The posterior condylar offset ratio was significantly lesser in the cruciate substituting group ($p<0.01$) (Table 1).

At baseline, a significant difference in flexion between groups was observed with 87.5% in the cruciate-substituting group demonstrating <100 degree while 62.5% ($p=0.02$) demonstrated <100-degree flexion in the cruciate-retaining group. At 3 months, large percentage of patients in the cruciate-retaining group showed significant improvement (40.6%, $p=0.03$). At 6 months, no difference between groups was detected.

No significant difference in improvement in extension between groups was observed across time points.

A significant difference in improvement in flexion across time points was observed in cruciate-retaining group and cruciate-substituting group. Following post hoc analysis, it was observed that in the cruciate-retaining group there is significant difference in flexion between all the time points ($p< 0.05$) except no improvement detected after 1 month until 3 months (p-value = 0.7055). In Cruciate-substituting group, significant improvement in flexion was observed from baseline at 1 month, and 6 months ($p< 0.001$).

A significant difference in improvement in extension across time points was observed in cruciate-retaining group and cruciate-substituting group. Following post hoc analysis, it was observed that in cruciate-retaining group there is significant difference in improvement in extension between 1-month and 3-months (p-value = 0.025), and between 1-month and 6-months (p-value = 0.025). In cruciate-substituting group, a significant difference in improvement in extension was observed from baseline at 6-months (p-values = 0.019) and between 1-month and 6-months (p-value = 0.032).

No significant association between PCO and improvement in flexion or extension was observed in patients undergoing PCL-retaining TKA or PCL-substitution TKA.

Table 1: Summary of demographic and clinical parameters

Factor		Cruciate-retaining group	Cruciate-substituting group	P-value
Age (in years)		60.97 ± 6.79	62.06 ± 8.18	0.56[T]
Gender	Male	12 (38.71%)	19 (61.29%)	0.08
	Female	20 (60.61%)	13 (39.39%)	
Side	Left TKR	18 (56.25%)	22 (68.75%)	0.30
	Right TKR	14 (43.75%)	10 (31.25%)	
Posterior condylar offset (mm)		29.59 ± 3.36	30.68 ± 3.38	0.20 [T]

Posterior condylar offset ratio	0.46 ± 0.03	0.47 ± 0.03	<0.01[T*]
Oxford knee score	21.44 ± 4.22	21.31 ± 4.18	0.90 [T]

[T] indicates t-test; * indicates significance; TKR, total knee arthroplasty

Table 2: Improvement in flexion and extension in CR group and CS group, within-groups and between-groups comparisons.

Groups	Sub-category	Time points				p-value
		Baseline	After 1 month	After 3 months	After 6 months	
Flexion in cruciate-retaining group	<100	20 (62.5%)	2 (6.3%)	0 (0%)	0 (0%)	< 0.001[F*]
	100–120	12 (37.5%)	19 (59.4%)	19 (59.4%)	17 (53.1%)	
	>120	0 (0%)	11 (34.4%)	13 (40.6%)	15 (46.9%)	
Flexion in cruciate-substituting group	<100	28 (87.5%)	0 (0%)	0 (0%)	0 (0%)	< 0.001[F*]
	100–120	4 (12.5%)	28 (87.5%)	27 (84.4%)	18 (56.3%)	
	>120	0 (0%)	4 (12.5%)	5 (15.6%)	12 (37.5%)	
P-value		0.0209[C*]	0.0340[MC*]	0.0261[C*]	0.8017 [C]	
Extension in cruciate-retaining group	0-degree lag	23 (71.88%)	21 (65.63%)	30 (93.75%)	30 (93.75%)	< 0.001[F*]
	5-degree lag	6 (18.75%)	6 (18.75%)	2 (6.25%)	2 (6.25%)	
	10-degree lag	3 (9.38%)	5 (15.63%)	0 (0%)	0 (0%)	
Extension in cruciate-substituting group	0-degree lag	20 (62.5%)	20 (62.5%)	26 (81.25%)	30 (93.75%)	0.0048[F*]
	5-degree lag	8 (25%)	8 (25%)	6 (18.75%)	2 (6.25%)	
	10-degree lag	4 (12.5%)	4 (12.5%)	0 (0%)	0 (0%)	
P-value		0.7356[MC]	0.8751[MC]	0.2739[MC]	1[MC]	

Abbreviation: C – Chi square test; MC – Chi square test with Monte Carlo simulation; F – Friedman's test; * indicates statistical significance.

Table 3: Logistic regression to determine the relationship between PCO and improvement in flexion in patients undergoing posterior cruciate ligament (PCL) retaining TKA and PCL substitution TKA

Group	Variable	Estimate	p-value
CRG	Intercept	-9.791	0.322
	PCOR	17.076	0.422
CSG	Intercept	15.303	0.0588
	PCOR	-34.016	0.0502

Table 4: Logistic regression to determine the relationship between PCO and improvement in extension in patients undergoing posterior cruciate ligament (PCL) retaining TKA and PCL substitution TKA

Group	Variable	Estimate	p-value
CRG	Intercept	12.145	0.117
	PCOR	-28.266	0.101
CSG	Intercept	4.069	0.542
	PCOR	-9.710	0.493

Discussion

Both PCO and PCOR have been important measures of knee functions, particularly its articular kinematics, range of motion and joint stability. There is no conclusive evidence either supporting or refuting their applicability and therefore the debate is ongoing.[20,21] Nevertheless, given their ease of execution and reproducibility, PCO and PCOR are a good measure of joint anatomy.[22] In this study, patients were assessed for the influence of posterior condylar offset ratio on the range of motion during flexion and extension of knee after PCL-retaining TKA or PCL-substitution TKA.

In the present study, improvement in flexion at 6 months after PCL-retaining TKA or PCL-substitution TKA was not significantly different. Improvement in flexion was gradual and consistent in PCL-retaining TKA, while in PCL-substitution TKA, improvement was evident only at 6 months. Improvement in extension after PCL-retaining TKA or PCL-substitution TKA was comparable. Therefore, PCL-retaining and PCL-substituting TKL resulted in comparable outcomes. The argument on PCL excision in TKA remains controversial. The proponents of CR claim that it acts as a biologic stabilizer and is capable of absorbing the shearing forces and reduces the stresses at the prosthesis-bone interface [20, 23]. The opponents, however, state that the CS prosthesis was designed to improve stair climbing, better range of knee motion and prevention of posterior subluxation of the tibia [24]. Andriacchi *et al.* demonstrated that patients who received TKA with PCL preservation were better at stair climbing than those who sacrificed PCL. However, there were no significant differences on level walking with or without the PCL [25].

Wang JT *et al.* prospectively studied on flexion-extension gap in patients who had undergone primary TKAs for end-stage osteoarthritis. One year after the surgery, improvements in flexion contracture and extension lag were not significantly different between the two groups ($p>0.05$) [26]. This is in agreement with the findings of the present study where there was no significant difference in improvement in flexion and extension over 6 months after undergoing PCL-retaining and PCL-substituting TKA.

A study by Dejour *et al*. demonstrated a significantly higher rate of anteroposterior laxity in study subjects that underwent cruciate-retaining TKA when compared to those who underwent cruciate-substituting TKA [27].

A study by Straw *et al* reported no improvement in patients with release of the posterior cruciate ligament, but comparable results were noted between those that underwent CR TKA and CS TKA [27]. In our study, we did not stratify the cases with PCL release, however, clinical observation showed no significant differences in the patients with release of the Posterior cruciate ligament as compared with those without PCL release.

In the present study, improvements in extension and flexion were not associated with the PCOR in patients undergoing CR TKA or CS TKA. Arabori *et al*. 2008, reported improved flexion outcomes in patients with increased PCO after CR TKA. Kim *et al*. 2013, reported no significant relationship between improvement in flexion after CS TKA and the posterior femoral condylar offset difference (3.24±3.862 mm, R=0.105, p=0.493) and posterior femoral condylar offset ratio difference (0.039±0.029 mm, R=-0.163, p=0.284).

An important limitation of this study is that the follow-up duration was short. The study design was not randomized or double-blind to reduce bias. Data on the rate of complications and corrective surgeries should be recorded in future studies. Further studies should evaluate other scores to analyze clinical outcomes, activities of everyday living outcomes and quality of life outcomes after CR and CS TKA.

Conclusions

Significant improvement in flexion and extension after CR and CS TKA was observed. The difference in improvement in flexion and extension between CR and CS TKA was not significant. No influence of PCOR on flexion and extension was observed.

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