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Comparison of Polyethylene Thickness and Constraint in Traditional and Robotic-Assisted Total Knee Arthroplasty

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ABSTRACT

Introduction. Thicker polyethylene inserts in total knee arthroplasty (TKA) may be associated with increased wear rates, a higher risk of implant failure, and the need for revision surgery. The authors of this study aimed to compare polyethylene insert thickness in robotic-assisted TKA versus conventional manual TKA.

Methods. The authors conducted a cross-sectional study on patients with end-stage primary knee osteoarthritis who underwent TKA by a single fellowship-trained orthopedic surgeon over a two-year period. Patients with post-traumatic or inflammatory arthropathy or those undergoing revision arthroplasty were excluded. Demographics, implant manufacturer and type, and polyethylene insert thickness were recorded in an electronic database. Bivariate analyses, including *t*-tests, Mann-Whitney *U* tests, and Fisher's exact tests were used to compare robotic-assisted and manual TKA procedures.

Results. Data from 222 patients were analyzed, with 111 in each group. The mean (standard deviation [SD]) age at surgery was similar between groups: 64.3 (8.2) years for robotic-assisted and 62.3 (8.8) years for the manual group ($p = 0.398$). Polyethylene insert thickness differed significantly: the median was 9 mm (range 9-13 mm) in the robotic-assisted group versus 11 mm (range 9-16 mm) in the manual group ($p < 0.001$). The most frequently used thickness was 9 mm, used in 70.3% (78/111) of robotic-assisted cases compared to 34.2% (38/111) of manual cases ($p < 0.001$).

Conclusions. Robotic-assisted TKA was associated with significantly thinner polyethylene inserts compared to manual TKA, suggesting more precise, bone-sparing femoral and tibial cuts. These findings may support the use of robotic-assisted techniques by orthopedic surgeons seeking to optimize implant positioning and longevity.

INTRODUCTION

Total knee arthroplasty (TKA) is a common orthopedic procedure, with an overall prevalence of 1.5% in the United States.[1] Among females over 80 years of age, this prevalence rises to 10.4%.[2] As the population continues to age, the number of TKA procedures is expected to increase substantially.

Given the high cost of knee replacement, the technical learning curve, and the limited availability of implant designs, there is a continued need to develop and refine surgical techniques. Robotic-assisted TKA has emerged as a potential innovation that may enhance surgical precision and efficiency. Some studies have reported that robotic-assisted TKA improves accuracy in bone preparation,[3] while others suggest that both robotic-assisted and manual approaches yield similarly excellent patient outcomes.[4] However, a large database study indicated that robotic-assisted TKA is associated with lower one-year revision rates, reduced need for manipulation under anesthesia, fewer systemic complications, and decreased post-operative opioid use.[5]

Additional evidence suggests that robotic-assisted TKA offers improved implant positioning, better limb alignment, reduced post-operative pain, faster early functional recovery, and shorter hospital stays compared to conventional manual TKA.[6-8] Despite these promising short-term results, further research is needed to evaluate long-term functional outcomes, implant longevity, time to revision, and cost-effectiveness.

Implant wear remains a key factor in TKA failure, as it contributes to periprosthetic osteolysis.[9,10] While the ideal polyethylene insert thickness is still debated,[11,12] improper sizing can lead to accelerated wear, ultimately compromising implant survival.[13-16] Robotic-assisted TKA, with its capacity for more precise bone cuts, may allow for better polyethylene insert fit, potentially reducing wear rates.

The purpose of this study was to assess differences in polyethylene insert thickness between robotic-assisted and manual TKAs. We hypothesized that robotic-assisted TKA would result in decreased insert thickness and constraint due to more accurate femoral and tibial osteotomies.

METHODS

Study Design. A cross-sectional study was conducted using patient charts from a single fellowship-trained, community-based orthopedic surgeon who performed all TKAs. Data sources included inpatient records, outpatient charts, and computer-based office notes. To avoid the influence of the surgeon's learning curve, records were reviewed in reverse chronological order, excluding early cases performed during the initial adoption of the robotic-assisted technique. The study was approved by the university's Institutional Review Board (IRB).

Inclusion and Exclusion Criteria. Eligible participants included patients of any age or race who underwent primary TKA for end-stage knee osteoarthritis using either the traditional manual technique (between January 2018 and August 2018) or the robotic-assisted technique (MAKO robot, Stryker, Kalamazoo, MI) between November 2019 and May 2020. Exclusion criteria included preoperative diagnoses of post-traumatic or inflammatory knee arthropathy, as well as all revision arthroplasties.

Study Variables and Data Collection. The primary outcome was the type of surgical procedure (robotic assisted vs. traditional manual TKA). Covariates included age at the time of surgery, laterality (left or right), polyethylene insert thickness (mm), constraint type (categorized as cruciate-sparing [unconstrained], posterior-stabilized [semi-constrained], or revision [semi-constrained]), and implant manufacturer (de-identified). All data were entered and managed using

Research Electronic Data Capture® (REDCap®), a secure, web-based platform designed to support research data management.[17,18]

Power Analysis. A power analysis was conducted using IBM® SPSS® (Statistical Package for the Social Sciences®) SamplePower (version 3) to estimate the required sample size. For comparisons between the two surgical techniques and three constraint types (six total groups), a sample size of 37 per group, or 222 total patients, would provide 80% power to detect a clinically significant 2 mm difference in polyethylene thickness between techniques. This was based on prior published data, assuming a standard deviation of 3 mm and a significance level of $\alpha = 0.05$.[15,19]

RESULTS

Data were extracted from 222 patient charts, including 111 robotic-assisted and 111 traditional manual TKA procedures. Table 1 presents group comparisons by surgical approach.

The mean (standard deviation) age at the time of surgery was similar between groups: 64.3 (8.2) years for the robotic-assisted group and 62.3 (8.8) years for the manual group ($p = 0.398$). Polyethylene insert thickness ranged from 9 to 13 mm in robotic-assisted cases and from 9 to 16 mm in manual cases. The median thickness was significantly lower in the robotic-assisted group (9 mm) compared to the manual group (11 mm; $p < 0.001$). In both groups, 9 mm was the most frequently used insert thickness, observed in 70.3% (78/111) of robotic-assisted cases and 34.2% (38/111) of manual cases ($p < 0.001$).

Laterality (left vs. right knee) was equally distributed between groups. However, implant constraint type differed significantly ($p < 0.001$): most robotic-assisted cases (92%) used cruciate-sparing, unconstrained implants, whereas all manual cases used posterior-stabilized, semi-constrained implants. No other constraint types were observed in the sample. The statistically significant difference in implant manufacturer between the two groups reflects the senior author's exclusive use of the MAKO robotic system (Stryker, Kalamazoo, MI) at his primary hospital site.

DISCUSSION

Robotic-assisted TKA enables surgeons to perform more precise femoral and tibial osteotomies,[20,21] which may allow for the use of thinner polyethylene inserts. Our study found that polyethylene components used in robotic-assisted TKA were significantly thinner compared to those used in traditional, jig-based manual TKA, supporting the hypothesis that robotic techniques are more bone-preserving. Notably, more than 70% of robotic-assisted cases used a 9 mm polyethylene insert, demonstrating both smaller and more consistent insert sizes. Thinner polyethylene inserts may correlate with reduced wear and increased implant longevity.

A significant difference in implant constraint type was observed between groups: the manual TKA group predominantly received posterior-stabilized implants, whereas most robotic-assisted procedures used cruciate-retaining designs. This difference could be seen as a limitation, as all posterior-stabilized TKAs were performed before the adoption of robotic-assisted TKA. However, the limited number of posterior-stabilized implants used during the robotic era suggests that the surgeon became increasingly confident in preserving the posterior cruciate ligament (PCL), likely due to improved bone-cut precision and preoperative knee balancing afforded by robotic assistance.

Table 1. Comparison of characteristics by surgery type.

Characteristic	Robotic n = 111 (50%)	Manual n = 111 (50%)	p-Value
Mean age at surgery (SD)[1]	64.3 (8.2)	62.3 (8.8)	0.398
Median polyethylene thickness; mm (min, max)[2]	9 (9, 13)	11 (9, 16)	<0.001
Polyethylene thickness (mm)[3]			
9	78 (70.3)	38 (34.2)	<0.001
10	13 (11.7)	16 (14.4)	
11	14 (12.6)	32 (28.8)	
12	3 (2.7)	8 (7.2)	
13	3 (2.7)	9 (8.1)	
15	0 (0)	7 (6.3)	
16	0 (0)	1 (0.9)	
Laterality[3]			
Left	56 (50.5)	58 (52.3)	0.893
Right	55 (49.5)	53 (47.7)	
Implant type[3]			
Cruciate retaining	102 (91.9)	0 (0.0)	<0.001
Posterior stabilized	9 (8.1)	111 (100.0)	
Implant Type[3]			
Company A	111 (100.0)	9 (8.1)	<0.001
Company B	0 (0.0)	102 (91.9)	

[1]Student's t-test for equality of means (equal variances assumed)
[2]Mann-Whitney *U* test
[3]Fisher's exact test

This shift in implant selection may reflect a growing trend: with the use of curved polyethylene inserts (employed in all cases), some surgeons now opt to preserve the PCL even without selecting posterior-stabilized designs, relying instead on insert geometry for stability. Although this study did not assess clinical outcomes due to limited follow-up duration, prior research has shown that robotic-assisted TKA is associated with reduced post-operative pain, shorter hospital stays, and improved early functional recovery.[5,6,8]

Potential disadvantages of robotic-assisted TKA also must be acknowledged. These include the possibility of a larger incision to accommodate tracking arrays (depending on surgical technique), longer operative times during the learning phase, and increased costs related to preoperative computed tomography (CT) imaging.

CONCLUSIONS

This study highlights evolving surgical trends associated with the use of robotic-assisted TKA, including tighter control of polyethylene insert thickness, more conservative bone resection, and a shift from posterior-stabilized to cruciate-retaining implant designs. While these findings suggest potential advantages of robotic-assisted techniques, a formal clinical outcomes study is needed to determine whether these changes translate into improved long-term results.

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