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ORIGINAL ARTICLE

Comparison of Revision Rates of Non-modular Constrained Versus Posterior Stabilized Total Knee Arthroplasty: a Propensity Score Matched Cohort Study

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Abstract *Background:* Attaining stability during total knee arthroplasty (TKA) is essential for a successful outcome. Although traditional constrained total knee prostheses have generally been used in conjunction with intramedullary stems, some devices have been widely used without the use of stems, referred to as non-modular constrained condylar total knee arthroplasty (NMCCK). *Questions/Purposes:* The aim of this study was to compare revisions rates after total knee replacement with a non-modular constrained condylar total knee (NMCCK) compared to a posterior-stabilized (PS) design. *Methods:* Between 2007 and 2012, primary PS total knees were compared with NMCCK implants from the same manufacturer. Propensity score matching was performed, and implant survivorship was examined using a Cox proportional hazards model. The cohort consisted of 817 PS knees and 817 NMCCKs matched for patient demographics, surgeon volume, and pre-operative diagnosis. *Results:* All cause revisions occurred in 11 of 817 (1.35%) in the PS group compared to 28 of 817 (3.43%) in the NMCCK group ($p = 0.0168$). Excluding revisions for infection and fracture, 8 of 817 (0.98%) PS knees required revision for mechanical failure compared to 18 of 817 (2.20%) NMCCK knees ($p = 0.0193$). *Conclusions:* While revisions rates in both cohorts were low, there was a significantly higher revision rate with NMCCKs. Given that cases requiring the use of NMCCK implants are likely more complex than those in which PS implants are used, our findings support the judicious use of NMCCK prostheses.

Keywords total knee arthroplasty · revision total knee arthroplasty · constrained total knee arthroplasty · posterior stabilized total knee arthroplasty

Level of Evidence: Retrospective cohort study, III.

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Introduction

Attaining stability during total knee arthroplasty (TKA) is essential for a successful outcome. When substantial angular deformities about the knee result in attenuation of the collateral soft tissues and consequent instability, traditional soft tissue balancing techniques alone may be insufficient to achieve stability. As a result, increasing constraint in the prosthesis may be required. Some implant designs attempt to achieve this increased constraint at the level of the polyethylene insert, where the post is manufactured to conform intimately with the corresponding femoral box. The goal of this constrained articulation is to increase stability in the varus-valgus coronal plane in addition to limiting anteroposterior translation of the tibia on the femur compared to standard posterior-stabilized (PS) designs.

Although traditional constrained total knee prostheses have generally been used in conjunction with intramedullary stems, some devices have been widely used without the use of stems, referred to as non-modular constrained condylar total knee arthroplasty (NMCCK).

Multiple studies have shown successful short and mid-term outcomes using a non-modular constrained total knee device for valgus knees requiring additional stability [1, 2, 11]. However, a retrieval analysis has shown significant damage to the polyethylene posts of non-modular constrained prosthesis, and suggested that the mechanical loads may be too great for the insert to withstand [12]. As many of these NMCCK prostheses have been implanted at our institution, the goal of this study was to determine revision rates for this device and compare it to that for a traditional PS design from the same manufacturer using a propensity-matched cohort.

Patients and Methods

Through our institutional IRB-approved Total Knee Replacement Registry, we retrospectively identified a cohort of consecutive patients who received PS total knees and patients who received NMCCK implants (without stem extensions) from the same manufacturer (Exactech, Inc., Gainesville, FL, USA) (Fig. 1) between May 2007 and December 2012. Our institutional registry is a prospective collection of patient demographics, implant characteristics, and clinical outcomes of total knee reconstruction procedure. Registry data were supplemented with data from electronic health records and administrative database. The main outcome indicator evaluated of this study was "revision for any reason." To reduce the effect of selection bias and potential confounding in this observational study, we performed propensity score matching adjusting for the differences in baseline patient characteristics [3]. Propensity scores were derived using a nonparsimonious multiple logistic regression model, which includes all baseline patient characteristics as well as selected interaction terms. Baseline patient characteristics included age, sex, race, BMI, year of surgery, side of surgery, Medicare insured, Medicaid insured, commercial health insurance, self-pay health insurance, diagnosis of osteoarthritis, diagnosis of any systematic inflammatory diseases, American Society of Anaesthesiologists (ASA) status, Charlson-Deyo comorbidity index, and individual Elixhauser comorbidities. To control the individual surgeon effect, each surgeon's TKA volume was calculated for the 30 days prior to the day of the index procedure for each patient and was entered into the logistic regression in estimating propensity scores. The information available through the registry, electronic health records, and administrative databases did not allow for matching based on pre-operative knee deformity or instability. Each patient was assigned a propensity score that reflected the probability of receiving PS or NMCCK implants. Greedy matching algorithm [13] was performed in matching each patient who received NMCCK implant with one patient who received PS implant. SAS matching macro %GMATCH developed by Mayo clinic was adapted to complete the propensity score matching. The balance of the propensity score matching was evaluated using standardized differences. An absolute standardized difference less than 0.2 was considered adequate balance between groups. Imbalance was defined as absolute value of standardized difference greater than or equal to 0.2.

Fig. 1. An anteroposterior radiograph of the non-modular constrained prosthesis in this study.

Baseline characteristics used in estimating the propensity scores were summarized using descriptive statistics and compared between the two groups before and after the propensity score matches were performed. Descriptive statistics were constructed with the use of means and standard deviations for continuous variables frequencies and proportions for categorical data. Continuous variables were compared with the use of two-sample Student's t test, and categorical variables were compared using Chi-square test or Fisher exact test, as appropriate.

In the propensity-matched cohort, survival curves were constructed using Kaplan-Meier estimates. The differences in survival curves were compared with log-rank test. The risks of revision were compared using Cox proportional hazard regression accounted for the matched nature of the data. Hazard ratio (HRs) and 95% CIs were reported. Crude revision rates and risk of revision of all-cause and mechanical failure were calculated separately. All analyses were performed in SAS for Windows 9.3 (Cary, NC, USA). All tests were two sided with a critical p value of 0.05 regarded as statistically significant.

The final cohort consisted of 817 PS total knees propensity-matched with 817 NMCCKs. After matching, baseline characteristics did not differ significantly between the two groups (Table 1). The mean age of the PS group was 73.0 years (SD ± 8.7) and 72.6 years (SD ± 9.6) in the NMCCK group. There were 549 (67.2%) females in the

Table 1 Demographic data of matched cohort

	PS $N = 817$ Mean ± Std	NMCCK $N = 817$ Mean ± Std	All $N = 1634$ Mean ± Std	*p* values
Age	73.0 ± 8.7	72.6 ± 9.6	72.8 ± 9.1	0.038
BMI	29.1 ± 5.6	29.3 ± 6.1	29.2 ± 5.9	0.039
Gender				0.6722
Male	268 (32.8%)	260 (31.8%)	528 (32.3%)	
Female	549 (67.2%)	557 (68.2%)	1106 (67.7%)	
Surgical site				0.6894
Right	469 (57.4%)	461 (56.4%)	930 (56.9%)	
Left	348 (42.6%)	356 (43.6%)	704 (43.1%)	
OA diagnosis	787 (96.3%)	786 (96.2%)	1573 (96.3%)	0.006
ASA				
1–2	592 (72.5%)	599 (73.3%)	1191 (72.9%)	0.019
3–4	225 (27.5%)	218 (26.7%)	443 (27.1%)	0.019
Procedure time	76.6 ± 18.4	80.8 ± 20.0	78.7 ± 19.3	<0.0001

PS group, and 557 females (68.2%) in the NMCCK group. The pre-operative diagnosis was osteoarthritis in 787 (96.3%) of the PS group and 786 (96.2%) in the NMCCK group (Table 1). The absolute standardized differences ranged from a low of 0 to a high of 0.051, indicating the baseline characteristics were very similar between PS and NMCCK groups in the propensity-matched cohort. The reasons for revision were also identified using the corresponding ICD-9 code, and further details surrounding revision were corroborated by a detailed chart review.

Results

The average follow-up was 52.3 months. The minimum time to revision in the cohort was 8 days; the maximum time was 79 months. With regards to revisions for all causes, 11 of 817 (1.35%) PS knees required revision compared to 28 of 817 (3.43%) in the NMCCK group (hazard ratio 2.36; 95% CI, 1.17–4.78; $p = 0.0168$) (Fig. 2). After revisions for infection and fracture were excluded, 8 of 817 (0.98%) PS knees required revision for mechanical failure compared to 18 of 817 (2.20%) NMCCK knees (hazard ratio 2.13; 95% CI, 1.13–3.996; $p = 0.0193$) (Fig. 3). There were three infections in the PS group, and seven infections and three periprosthetic fractures in the NMCCK group. In the PS group, the eight mechanical failures were characterized as follows: stiffness (three), loosening of femoral or tibial component (two), component malrotation/patellar maltracking (two), and instability (one). The mechanical failures of the NMCCK group were as follows: loosening of femoral or tibial component or both (12), instability (2), failure of locking mechanism (2), stiffness (1), and patellar maltracking (1) (Table 2). NMCCK knees took a mean of 4.2 min longer to perform than PS (80.8 ± 20 vs 76.6 ± 18.4 min; $p < 0.0001$).

Discussion

The results of the current study show that while revision rates for NMCCK implants are quite low overall, it is about a two times higher than for traditional PS knee replacements at greater than 4-year follow-up. While this difference is somewhat concerning, given that cases requiring the use of NMCCK implants are usually more complex than those in which PS implants are used, our findings support the judicious use of NMCCK prostheses.

Using registry data provided a major strength of this study, allowing for the analysis of the largest cohort of patients with NMCCK to date; however, this also contributed to several limitations to this study. The mean follow-up of 51 months is relatively short-term, and longer-term follow-up is necessary. In addition, our institutional database and

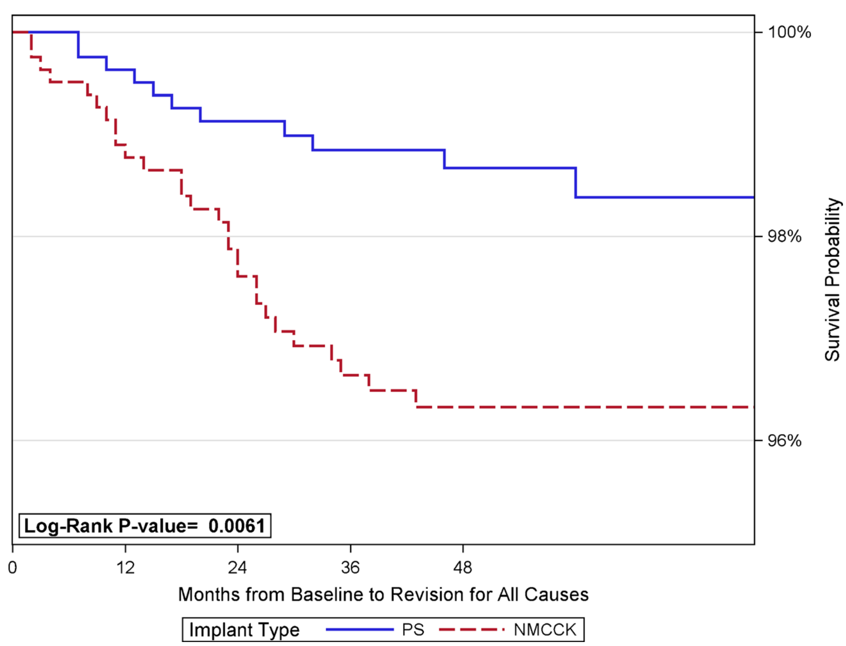

Fig. 2. All cause revision Kaplan-Meier (K-M) survival curves between PS (*blue*) and NMCCK (*red*) in the matched cohort.

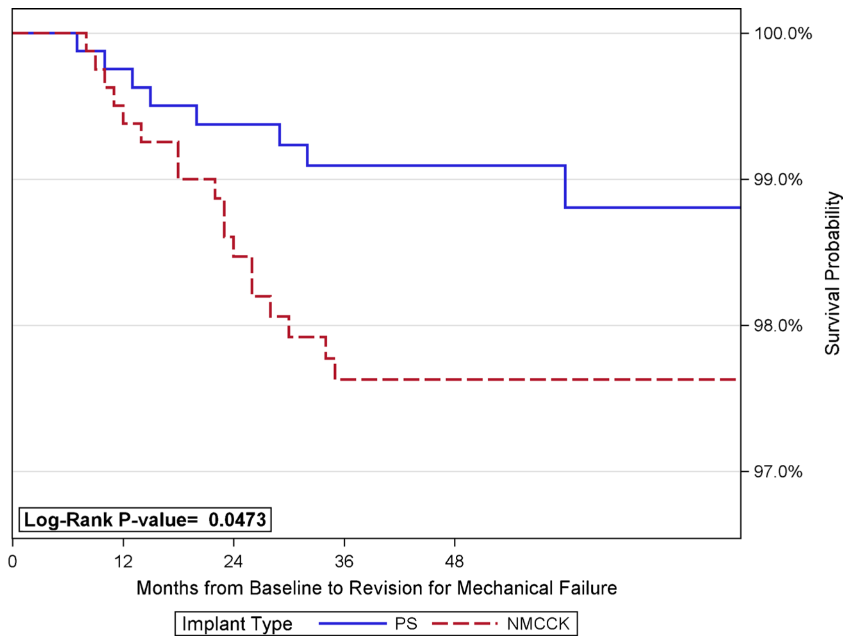

Fig. 3. K-M survival curve for revisions limited to mechanical failures, after exclusion of infection and periprosthethic fracture (PS = *blue*, NMCCK = *red*).

follow-up may not have captured all revisions performed at outside institutions. While this raises the possibility that we underestimated the true revision rate, our findings are in line with previous studies, so the number of cases we missed may not alter our findings or conclusions. Finally, although we were able to propensity match for baseline patient characteristics, we were unable to match for many clinically relevant variables, including pre-operative knee deformity and/or instability, technical complexity of the case, and individual experience or skill of the surgeon, as such clinical details were not available through the registry database. Because NMCCK designs are typically used in cases with ligamentous instability or other destabilizing deformity, the higher rate of failure in NMCCK knees may be based upon the native knee instability or residual ligamentous instability and not the type of prosthesis per se. Although we compared outcomes in NMCCK to the traditional PS as a "gold" or typical standard, we realize that the two types of prostheses may not be considered for the same patient. Future studies comparing different implants in patients matched for specific degrees of deformity and/or contracture could address this question. Another future approach might be to compare the types or extent of wear in the retrieved implants from each type that were revised.

Numerous soft tissue balancing techniques have been described in the setting of severe deformity that provide the balance necessary for an excellent outcome with posterior-stabilized designs [4, 6, 7, 16]. However, when these techniques prove inadequate, increasing constraint is necessary. One option is to use stemmed, constrained condylar knees, which, performed in the primary setting, have excellent long-term outcomes [5, 8–10]. Lachiewicz et al. showed 96% survival at 10 years [8], and another recent report by Maynard et al. showed 97.6% survival at minimum 7-year follow-up [9]. On the other hand, traditional constrained condylar designs with stemmed extensions can pose their own problems, including increased operative time, increased prosthetic cost, increased bone resection, and invasion of the intramedullary canal. As such, the NMCCK is an attractive alternative for the treatment of these knees because it avoids the use of intramedullary stems [14]. Although our follow-up was shorter than the studies of Lachiewicz and Maynard on stemmed implants, we found similar excellent survival rates for NMCCK, further supporting their use. From a technical standpoint, compared to its PS counterpart, the technique for this NMCCK design involves the creation of a slightly deeper femoral box cut to accommodate a higher post in the polyethylene insert (though the medial and lateral dimension is the same). The tibial preparation also requires an extension on the drill to accommodate a post-stiffening screw. In our study, this added only a minimal amount of time to the surgery (about 4 min).

Numerous reports have shown midterm clinical success with NMCCK design prostheses [1, 2, 11] and our

Table 2 Reasons for revision in both PS and NMCCK groups

Reason for revision	PS	NMCCK
Infection	3 (27.3%)	7 (25.0%)
Periprosthetic fracture	0	3 (10.7%)
Loosening of femoral or tibial component or both	2 (18.2%)	12 (42.9%)
Stiffness	3 (27.3%)	1 (3.6%)
Instability	1 (9.1%)	2 (7.1%)
Component malrotation/patellar maltracking	2 (18.2%)	1 (3.6%)
Failure of locking mechanism	0	2 (7.1%)
Total	11	28

study, showing low revision rates, is consistent with these previous reports. However, others have advocated for the use of intramedullary stem extensions with constrained prostheses to improve load-sharing, as there are concerns for early component loosening secondary to stress transfer of bending and rotational forces at the implant bone interface [12, 15, 17]. Indeed, while the overall revision rate was low for NMCCK, it was, nonetheless two times higher than for the PS implants, and this is consistent with the possibility of mechanical problems. Future studies comparing stemmed and NMCCK implants may provide further insight into the best alternative for patients with severe deformity.

Analysis of a large cohort of patients with NMCCK implants revealed an overall low revision rate; however, it is higher when matched to a traditional PS design. As such, efforts should be made to optimize soft tissue balancing techniques and increase the threshold to switch to the NMCCK unless absolutely necessary. As component loosening has been noted in some cases of NMCCK, stemmed fixation may be more appropriate in certain clinical situations such as compromised osteoporotic bone or morbid obesity. The higher rate of revision in NMCCK is not surprising, given that they are likely to have been used for patients with greater pre-operative knee deformity or instability than those treated with PS implants. Although the effect of pre-operative knee pathology could not be discerned through our study, overall, NMCCK appears to be a safe option in the management of knees requiring moderate constraint.

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Compliance with Ethical Standards

Conflict of Interest: Mohamed E. Moussa, MD, Yuo-yu Lee, MS, and Nabil Mehta, BSE have declared that they have no conflict of interest. Stephen Lyman, PhD reports grants from Agency for Healthcare Research and Quality, during the conduct of the study; personal fees from Journal of Bone & Joint Surgery, outside the work. Geoffrey H. Westrich, MD reports personal fees and non-financial support from Exactech, personal fees from Don Joy Orthopedics and Stryker Corporation, during the conduct of the study. Robert G. Marx, MD, MSc, FRCSC reports personal fees from Journal of Bone & Joint Surgery, Springer and Demos Health, outside the work.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed Consent: Informed consent was obtained from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

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