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Mid-term outcomes following primary semi-constrained total knee arthroplasty in patients less than 60 years old, a retrospective review☆

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ABSTRACT

Introduction: Total knee arthroplasty (TKA) is a successful operation for osteoarthrosis. Typically, the knee can be balanced using posterior stabilized or cruciate retaining implants. However, in patients with severe deformity or ligamentous laxity, this cannot be obtained, and more constrained devices are needed. Semi-constrained implants, such as the Total Condylar III (TCIII) provide increased coronal stability. Outcomes in young (<60 years old) patients, following a primary semi-constrained TKA are not well reported in the literature. The purpose of this study was to evaluate patient reported outcomes, functional recovery, and implant survival in this population.
Methods: We performed a retrospective review of 21 patients, under the age of 60 years, that underwent primary semi-constrained TKA. Patient demographics, postoperative outcomes, patient satisfaction scores, and implant loosening were reported.
Results: At an average follow-up of 66 months, Knee Society Scores (KSS) and Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores were 94.7 and 15.7, respectively. No difference in patient reported outcomes between 1 year and final follow-up were observed. Patient demographics such as age, BMI, and gender had no effect on functional outcomes. No cases of aseptic loosening were observed. Implant survivorship, patient satisfaction, and excellent or good results were reported in 100%, 85.7%, and 92%, respectively.
Conclusion: In young patients, in which the knee cannot be effectively balanced with standard releases, the use of a semi-constrained TKA as a primary implant lead to positive patient reported outcomes and no evidence of loosening at mid-term follow-up.

1. Introduction

Total knee arthroplasty (TKA) is a successful and reproducible operation that greatly improves patient quality of life [1]. However, primary TKAs are not without challenges. The overall revision rate in the first 10 years following a primary TKA is approximately five percent, [1,2] with 20% of patients being unhappy after primary TKA [3]. Instability and aseptic loosening are the two most common causes of

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revisions during the first two years [1,2,4,5]. Having a well-balanced and stable knee is the cornerstone of long-term success following TKA. Typically, this is achieved through soft tissue balancing and implant design. Constraint, or how motion restrictive an implant is, varies among implants and ranges from unconstrained cruciate retaining (CR) devices to fully constrained hinged articulations [6–8]. The majority of primary TKAs are amenable to soft tissue balancing, and the use of CR or posterior-stabilized (PS) implants. However, in more complex primary cases, in which patients have severe deformity, significant bone loss or collateral ligament laxity, a more constrained prosthesis may be required [7–13]. While increasing component constraint reduces instability, it may also cause a transfer of force to the prosthesis, leading to increased rates of aseptic loosening [8]. Semi-constrained prostheses are unlinked implants that provide increased coronal plane stability through a tall rectangular tibial post and a higher femoral box [9]. Multiple studies have demonstrated good results with semi-constrained implants in older patients without significant loosening or failure [9,10,14–17]. In these patients, few studies have demonstrated improved functional outcomes and patient satisfaction with use of a primary semi-constrained TKAs [18,19].

Young patients are receiving TKAs at increasing rates, and those less than 55 years old represent the fastest growing subset of arthroplasty patients in the United States [20]. Due to increased activity levels and longer expected survival, these patients require a more durable prosthesis, and instability cannot be accepted [20]. This creates an especially difficult task in the young, likely more active patient, with severe deformity and osteoarthrosis. Loosening and outcomes of semi-constrained implants have not been investigated in this younger cohort. Physician and patient expectations surrounding this implant in young patients are primarily speculative due to paucity in the literature.

To our knowledge, no previous study has evaluated the outcomes or survivorship of such implants in this younger cohort. In this study, we report on the outcomes and mid-term implant survivorship in patients less than 60 years old who were treated with a semi-constrained implant at their index procedure, in which instability precluded the use of typical PS or CR implants.

2. Methods and materials

2.1. Patients

Between January 2001 and December 2016, 239 patients received semi-constrained, cemented Total Condylar III (TC III, Johnson & Johnson, Braintree, MA) TKAs by a single arthroplasty fellowship trained orthopedic surgeon. Of these, 62 were done in the revision setting and 124 were done on patients 60 years of age or older at the time of surgery. This left 52 patients, under the age of 60, who received primary TC III TKAs. Patients with less than 24 months of follow-up were also excluded. The final cohort included 21 patients with TC III primary TKAs. This group consisted of 11 females (52.3%) and 10 males (47.6%), with an average age of 54.2 years (range, 39–59 years). The mean follow-up was 66 months (range, 24–140 months). Complete demographic data can be found in Table 1.

2.2. Procedure

The decision to use a constrained prosthesis was determined by the senior author, a fellowship trained hip and knee surgeon. All procedures were done utilizing a medial parapatellar approach. A standard distal femoral cut in five degrees of valgus was made following intramedullary instrumentation. One patient had a distal femoral malunion that precluded the use of a femoral intramedullary guide. Navigated femoral cuts were used in this patient. The tibia was then cut orthogonal to its mechanical axis using the junction of the medial one third and lateral two thirds of the tibial tubercle in all cases. Additionally, computer navigation was utilized in 12 cases (57%) to insure accuracy of the tibial resection. Next, laminar spreaders were used to assess extension gaps, and provisional soft tissue releases were performed in full extension. Distal femoral rotation was then determined based on the transepicondylar axis, Whiteside's line, three views of the posterior condyles and tense rectangular flexion gaps. The knee was fine balanced utilizing soft tissue releases for both varus and valgus knees followed by the shift and resect technique for severely varus knees. At this point, if the knee was not adequately balanced or if the collateral ligamentous structures were not competent, the decision to proceed with a Semi-constrained TKA was made. This decision was made prior to surgery in two patients (9.5%), one secondary to previous trauma compromising the MCL and another for excessive MCL laxity preoperatively. Patellar resurfacing was performed in 20 patients (95%) at the index procedure. One patient did not undergo patellar resurfacing initially, however, revision surgery was required after 58 months to resurface the patella. Mobile Bearing Tray (MBT)

Table 1
Demographic data.

Variable		Male	Female	Overall
Age, mean (SD)	Years	54.3 (6.5)	55.1 (3.9)	54.2 (5.3)
BMI, mean (SD)	kg/m^2	34.8 (7.9)	39.7 (10.6)	37.1 (9.4)
Preoperative ROM	Degrees			
Extension (SD)		11.6 (10.4)	7 (6.7)	8.75 (7.9)
Flexion (SD)		90.6 (22.3)	107 (12.0)	100.8 (17.2)
Tobacco Use, N (%)	Yes	3 (30)	0 (0)	3 (14)
	No	7 (70)	11 (100)	18 (86)
Laterality, N (%)	Left	7 (70)	6 (54.6)	13 (62)
	Right	3 (30)	5 (45.4)	8 (38)
Follow-up, mean (N)	Months	56 (10)	75 (11)	66 (21)

SD — standard deviation.

revision tibial components with rotating platform polyethylene implants were used in all cases. Femoral stems were used in all but one case, in which a distal femoral malunion precluded its use. All implants were cemented into place. Postoperatively, patients were not braced and allowed to bear weight as tolerated.

2.3. Clinical evaluation

Patients were evaluated in the office by the senior author at regularly scheduled intervals. Clinical outcomes were collected prospectively using the Knee Society Score (KSS) (range, 0–100 total score) and Western Ontario and McMaster University Osteoarthritis Index (WOMAC) (range, 0–96 total score) at each visit. Additionally, patients were asked to fill out an arthroplasty satisfaction survey at least one year following surgery, as is routine in our practice. This survey consisted of the following questions: 1. Compared to before surgery, how would you rate your operative joint now? (Better, About the Same, Worse); 2. What is your overall satisfaction level with this joint replacement? (Satisfied, Neutral, Dissatisfied); 3. If you could go back in time and make the decision again, would you choose to have the joint replacement surgery? (Yes, Uncertain, No); 4. How would you rate the result of your joint replacement surgery? (Excellent/Good, Fair, Poor). Demographic data including age at the time of surgery, gender, body mass index (BMI), side of surgery (right/left), and smoking status were collected via retrospective chart review. Complications such as infection, DVT, aseptic loosening, arthrofibrosis and patellar clunk were also recorded.

2.4. Radiographic analysis

Preoperatively, all patients had a four-view radiographic evaluation including standing antero-posterior (AP), Rosenberg, lateral, and Merchant views. Postoperative AP, lateral and Merchant views were obtained at each office visit. Radiographs from the most recent follow-up were evaluated for knee alignment, component position, radiolucent lines, osteolysis and polyethylene wear. In evaluating femoral, tibial and patellar components, the Knee Society Roentgenographic Evaluation and Scoring System, as described by Ewald, was utilized [21]. Following this rating system, a score of <4 was defined as not significant; five to nine equivocal but should be closely followed; >10 signifying possible or impending failure, regardless of symptoms. Similar to previous reports, osteolysis was defined as a radiolucent lesion >5 mm in size with loss of the normal trabecular pattern and a sclerotic margin that were not present on perioperative radiographs [8,15,21].

2.5. Statistics

We reported the KSS and WOMAC scores at one-year follow-up and final follow-up using means, medians, standard deviations and interquartile ranges. After testing for normality of these variables using Shapiro–Wilk test we compared them using Wilcoxon-Signed rank test. Demographic and clinical characteristics of the patients were described using mean, medians and standard deviations for continuous variables, and frequency and percentages for categorical variables. Finally, the difference between varus/valgus alignment preoperatively and postoperatively will be used as a measure of degree of coronal plane correction. The correlation between degree of coronal plane correction and outcome scores (KSS and WOMAC) were assessed using Pearson correlation coefficient. A p-value <0.05 was considered statistically significant for all statistical tests.

3. Results

3.1. Clinical results

The mean KSS and WOMAC scores one year after surgery were 93.8 and 14.4, respectively. At final follow-up, mean KSS was 94.7 and the mean WOMAC score was 15.7; no difference between one-year and final follow-up was observed, $p = 0.56$.and $p = 0.08$, respectively. 62% of patients ($n = 13$) completed the satisfaction survey at least one year following surgery. Women completed the survey much more frequently than men during the office visit, 82% and 8% respectively. Of patients completing the survey, 92.3% reported improvement in the operative knee compared to preoperatively, 7.7% reported it to be the same, and no patients reported worsening symptoms. All patients were satisfied with their joint replacement. Moreover, 85.7% of patients report that they would choose to undergo the same operation again. Finally, 92% reported their outcome as good or excellent, one patient reported their outcome as fair. Complete clinical results and patient reported outcomes can be found in Table 2.

3.2. Range of motion

Preoperatively, patients had an average of 8.75 degrees of extension (range, 0–20°), and 100.86 degrees of flexion (range, 65–120°). One year postoperatively, the mean extension and flexion were increased to 1.94 and 117.11°, respectively (ranges; extension 0–10°, and flexion 95–125°). At final follow-up, the mean extension was 2.26° (range, 0–15°) and mean flexion 116.16° (range, 90–130°). Four patients did require manipulation at an average of 4.25 weeks postoperatively for decreased range of motion. At final follow-up, this subset of patients had an average extension of 2.6° (range, 0–8°) and average flexion of 111° (range 90–125°).

Table 2
Outcomes data.

Outcome scores		Male	Female	Overall
KSS 1 year, mean (SD)		94.7 (4.8)	93.2 (10.1)	93.8 (8.1)
KSS final follow-up, mean (SD)		91.9 (10.5)	97.9 (3.4)	94.7 (8.3)
WOMAC 1 year, mean (SD)		8.3 (10.8)	17.6 (20.5)	14.4 (17.9)
Median (IQR)		5 (0, 12)	11 (3, 41)	8 (2,14)
WOMAC final follow-up, mean (SD)		21.0 (22.5)	10.8 (15.4)	15.7 (19.3)
Median (IQR)		14.5 (6, 35)	8 (0, 15)	8 (2, 17)
Arthroplasty survey				
Compared to before surgery, how would you rate your operative joint now? N (%)	Better	3 (75)	9 (100)	12 (92.3)
	About the same	1 (25)	0	1 (7.7)
	Worse	0 (0)	0 (0)	0 (0)
What is your overall satisfaction level with this joint replacement? N (%)	Satisfied	4 (100)	9 (100)	13 (100)
	Dissatisfied	0 (0)	0 (0)	0 (0)
If you could go back in time and make the decision again, would you choose to have the joint replacement surgery? N (%)	Yes	3 (75)	8 (88.9)	11 (84.6)
	Uncertain	1 (25)	1 (11.1)	2 (15.4)
	No	0 (0)	0 (0)	0 (0)
How would you rate the result of your joint replacement surgery? N (%)	Good/Excellent	3 (75)	9 (100)	12 (92.3)
	Fair	1 (25)	0 (0)	1 (7.7)
	Poor	0 (0)	0 (0)	0 (0)

SD- Standard deviation; IQR – Interquartile Range.

3.3. Radiographic results

Preoperative standing radiographs demonstrated a varus deformity in 16 patients (76%), averaging 6.63 + 4.95° (range, one to 16°). Five patients (24%), were found to have an excessive valgus deformity averaging 14.2 + 2.05° (range, 12–16°). The mean postoperative tibiofemoral alignment was 0.24 + 1.04 degrees of valgus (range, three degrees of valgus to two degrees of varus). Radiolucent lines were seen in 11 patients (52%) at final follow-up, with an average Knee Society Roentgenographic Evaluation Score of 2, indicating no significant loosening, as defined by Ewald [21]. No obvious polyethylene wear or osteolysis was noted in any patient at any time point.

3.4. Complications

The most commonly encountered complication was arthrofibrosis, diagnosed in five patients (23.8%). Four of these patients underwent postoperative manipulation for decreased range of motion. The fifth patient was diagnosed after having revision surgery for concern of loosening or indolent infection. They had an equivocal CRP 0.58 mg/dL (normal range 0–0.29 mg/dL), a normal ESR (seven millimeters), and negative synovial fluid cultures, however, the femoral component did demonstrate increased uptake on bone scan. During revision surgery, extensive arthrofibrosis was identified, and both the femoral and tibial components were well fixed without evidence of loosening. One patient did have significant patellofemoral clunk but refused arthroscopic surgery. There were no reported superficial or deep infections, hardware failures, deep vein thromboses (DVT), or periprosthetic fractures.

3.5. Implant survivorship

At final follow-up we demonstrated an implant survivorship of 100%. While two patients underwent revision surgery, the components were found to be well fixed, and were not explanted. The first patient underwent revision surgery for increasing pain and was found to have arthrofibrosis intraoperatively; the second patient needed revision surgery to resurface the patella, which was not done at the index procedure. At an average of 66 months (range, 24–140 months), there were no cases of aseptic loosening or implant failure in this cohort.

4. Discussion

Patients with severe deformity or ligamentous laxity pose unique challenges in primary TKA. The most important findings of this retrospective study were positive patient reported outcomes as well as clinical outcomes in patients less than 60 years old who received a primary semi-constrained TKA. Furthermore, there was no evidence of aseptic loosening in this cohort. Early reports have demonstrated favorable outcomes of primary semi-constrained TKAs in the elderly, which may not be applicable to the young patient with severe deformity or ligamentous laxity [18,19,22]. We demonstrate no incidence of implant loosening or failure in the mid-term follow-up in this unique and challenging cohort.

The presence of severe deformity or ligamentous laxity may prohibit the use of the less constrained CR and PS TKAs. Use of such implants in this setting may lead to early failure or dissatisfaction secondary to instability. In fact, revision TKA within five years of primary TKA is secondary to instability in nearly 27% of cases [23]; other studies have supported these findings [10,24]. Longer-term studies continue to claim instability as a major cause of revision TKA [25]. Thus, less constrained implants, namely CR or PS, may not be indicated in cases of severe deformity or ligamentous laxity, as instability can compromise outcomes and survivorship. In particular, knees with severe

varus or valgus deformity, with incompetent lateral or medial collateral ligaments respectively, and those with significant flexion contractures that cannot be appropriately balanced intraoperatively may benefit from a more constrained TKA [26,27]. However, the amount of instability that merits utilization of a more constrained implant is not clearly defined; some suggest that a persistent laxity exceeding seven millimeters warrants a Semi-constrained TKA [7].

Young patients are receiving primary TKAs at a growing rate and represent the fastest growing subset of arthroplasty patients [3,20,29]. These patients are often more active, raising the concern for longevity and durability of implants in this cohort [3,30–33]. Previous studies have shown high implant survivorship for standard primary TKA implants in younger patients [34]. Although long-term follow-up on TKAs in the young cohort is promising, some knees are not amendable to use of the less constrained prosthesis. In such cases, the survivorship and outcomes of a more constrained TKA are unknown. No study has investigated outcomes specifically in the young, more active patient. At a mean of 5.5 years, we show a patient rated good or excellent outcome in 92.3% of patients. Additionally, postoperative outcome measures for KSS and WOMAC were 94.7 and 15.7, respectively. This is similar to the reported 47-point increase in KSS, to a mean of 90.9, as reported by Keeney et al. [34] in young patients using standard implants. Moreover, despite concerns for implant loosening and survivorship with the more constrained prosthesis in this cohort, we report no evidence of loosening and 100% implant survivorship.

Few reports have published on the utilization of semi-constrained prostheses in primary TKA [10,15,26]. No report, to our knowledge, has published on semi-constrained TKA outcomes in the young, often active patient. Although use of a primary semi-constrained TKA may address instability, increasing component constraint may lead to early aseptic loosening [8]. This is believed to occur secondary to increased force transmission at the prosthesis-cement or cement-bone interfaces [15]. However, in a prospective study of 43 primary semi-constrained TKAs, the ten-year survival, defined as component revision for loosening, was 96% [26]. Additionally, in a larger study of 192 constrained condylar TKAs, only one case of aseptic loosening was reported at a mean of 47 months [22]. Other studies have supported these findings [15,18,22,28]. However, the young, often active patient, poses a unique challenge in the severely deformed or ligamentously-lax knee. Implant survivorship and functional outcomes in this cohort have not been clearly reported in the literature.

While we demonstrate overall positive results at mid-term follow-up, the use of a more constrained implant in a younger patient was not without complications. Arthrofibrosis, a complication of excessive scar tissue formation, can severely limit range of motion and functional outcomes [35]. Previous reports cite an incidence of one to 13% following primary TKA [35–40]. However, in our study of primary semi-constrained TKAs, we demonstrate a higher incidence of arthrofibrosis; 23.8% ($n = 5$). Despite this higher incidence, good functional outcomes and patient satisfaction were reported. Often, arthroscopic or open debridement, manipulation under anesthesia (MUA) or revision TKA may be indicated in such cases. MUA is most commonly employed when ROM is unsatisfactory following physical therapy. In our report, those patients which required MUA, had an overall ROM and outcome scores that were not significantly different from the remainder of the cohort.

There are several limitations to our study. First, a single surgeon, at a single institution performed all primary TKAs in this study. Postoperative results may differ with variation in technique, learning curve, and implant selections. Additionally, only one implant was used in this study, and outcomes cannot be extrapolated to other semi-constrained prostheses. Also, despite being the largest reported study of primary semi-constrained TKAs in this aged patient cohort, this study is inadequately powered. Larger prospective, multicenter studies are needed. Additionally, although postoperative outcomes were reported, the attending surgeon does not routinely collect preoperative outcome measures.

5. Conclusion

In conclusion, we report on the mid-term outcomes following primary semi-constrained TKAs in a young cohort of patients (<60 years old). We demonstrate no evidence of loosening, high patient satisfaction and post-operative outcome measures in this retrospective analysis. A high rate of arthrofibrosis, 23.8%, was also seen in this select cohort. We believe that utilization of a more constrained TKA in the setting of severe deformity or ligamentous laxity provides a reasonable alternative with satisfactory mid-term outcomes.

CRediT author statement

David Johnson: Conceptualization, Methodology, Writing — Original Draft, Writing — Review and Editing, **Jacon Triplet:** Writing — Original Draft, Writing — Review and Editing. **Daniel Gaines:** Validation, Resources, Writing — Review and Editing. **Anand Gupta:** Formal Analysis. **Kurt Unverferth:** Conceptualization, Writing — Review and Editing, Supervision, Validation.

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