Original Article

Total knee arthroplasty in young patients: Factors predictive of aseptic failure in the 2nd–4th decade

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ABSTRACT

Objective: In a recently published article we reviewed our long term outcomes of TKA in young patients (< 55) with end stage OA. The purpose of this study was to identify what additional factors may predict aseptic failure in these young patients.

Methods: A retrospective review of all patients in our young TKA database was performed, and included failure only for mechanical wear and loosening.

Results: The IB-II prosthesis, a thin polyethylene (< 9 mm), and higher Knee Society functional class at midterm follow-up was associated with higher failure rate.

Conclusion: This study helps better identify the etiology of failed young patient TKA.

1. Introduction

There has been a substantial growth in the number of total knee arthroplasties being performed in young patients (under 55 years of age). A recent study predicted that between 2006 and 2030 there will be a 17-fold increase in the number of TKAs performed in this age group.¹ A number of surgical procedures exist for the treatment of osteoarthritis (OA) in the young patient, such as arthroscopic debridement, realignment osteotomy, or arthrodesis, but these options typically only provide temporary relief of symptoms, and are fraught with functional limitations.² Several studies have shown that TKA in the younger patient provides better function and lasting pain relief.^{2,9} The concern of course is that these more active patients will demonstrate accelerated component wear or loosening, subsequently requiring a more difficult revision procedure. There has been little longterm follow up on this patient subset, but those studies that are available have shown variable results. Kim et al. ³ demonstrated survivorship of posterior-substituting implants as high as 97 percent at 16.8 year follow up in younger patients, which is comparable to 15 year survival rates in older patients. Using data from the Swedish Registry, W-Dahl et al. ⁴ found a 9 percent 10-year cumulative revision rate for patients younger than 55 years. Julin et al. ⁵ examined the Finnish Arthroplasty Registry, and follow-up of 32,019 patients showed that 5-year survival rates were only 92 and 95 percent in patients aged ≤55 and 56–65 years, respectively, compared to 97 percent in patients who were > 65 years of age ($P < 0.001$). Odland et al. ⁶ present 10-year outcomes from a

cohort of 59 active patients (67 knees) aged 55 years or younger, and show a 16 percent revision rate for aseptic loosening or component wear. Interestingly, a total of 65 percent of patients were still performing moderate labor or sport activities, which addresses the second potential pitfall of TKA surgery in this patient population; not only are patients aged 55 years or younger more likely to outlive their prosthesis and require revision surgery, but their higher activity level predisposes the implant to early failure.

Many studies suggest that implant failure is primarily related to joint use, rather than duration of implantation.⁷ That said, function following TKA is a significant concern for younger patients, whose activity expectations are substantially greater than their older counterparts. Although evidence exists to suggest that certain host factors, such as high activity level, and male sex, may predispose to higher rates of aseptic loosening in the total hip arthroplasty (THA) population, no such host factors have been shown to be associated with loosening after TKA.⁸ There is a paucity of evidence to guide advice on young patient activity level following TKA, and no good evidence to suggest if closer follow up is merited in those patients partaking in higher-level activities, or high-impact activities.⁹

In a recently published article we reviewed our long term outcomes of TKA in young patients with end stage osteoarthritis and post traumatic arthritis.¹⁰ The original cohort for that study, as described by Diduch et al. ¹¹ in 1997, consisted of 114 total knee arthroplasties performed in eighty-eight patients with an average age of fifty-one years (range, twenty-two to fifty-five years) from 1977 to 1992 by one

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of two surgeons.

We obtained follow-up in 95 percent of the 88 patients with 114 TKAs. A 70.6 percent survivorship for all cause failure was noted at 30 years. As part of our analysis we examined the differences in survivorship of the two implants used for the majority of the cases in this series. A statistically significant difference in survivorship was noted with the Insall Burstein I (IB-I; Zimmer, Warsaw IN) outperforming the Insall Burstein II (IB-II; Zimmer, Warsaw IN) with tibial or femoral aseptic loosening as the endpoint. The purpose of this study was to identify what other factors may predict failure in these young patients.

2. Materials and methods

Data collected in our previous study¹⁰ was reviewed, and for the purposes of this study was examined specifically for predictors of TKA failure, including prosthetic factors, patient factors, and Knee Society outcome scores.^{12,13} For this study we included failure only for mechanical wear and loosening. Other factors responsible for failure, including infections, were excluded. Patients were categorized based on a modified Charnley classification,¹⁴ which was assigned at the follow-up appointment in 1997. These classes are; A (a unilateral or successful bilateral TKA without symptoms in the contra-lateral knee), B (symptoms in the contra-lateral knee), or C (associated medical conditions that limited function).

2.1. Statistical analysis

For descriptive statistics, comparisons were made across knee scores using Student *t*-tests. Time to failure up to thirty years following total knee arthroplasty was analyzed using the method of Kaplan and Meier.¹⁵ Failure was defined in three ways: aseptic revision of the femoral or tibial component, aseptic revision of the femoral or tibial component, and revision of the femoral, tibial, or patellar component or any subsequent operation about the knee. Significance was defined at $p < 0.05$.

2.2. Source of funding

This study was funded by the Insall Scott Research Foundation. Funds were used to pay for the salaries for a research assistant and a biostatistician and for supplies and mailings. Also, one author (W.N.S.) received royalties from Zimmer, but not for the Insall Burnstein prostheses.

Institutional review board approval was obtained for this study.

3. Results

3.1. Implant factors

The average time to revision was 14.7 years (range 11–22).

As demonstrated in our previous study,¹⁰ there was a statistically significant difference ($P = 0.035$) in the rate of failure among the three implants used in the study, with the IB-II prosthesis showing a higher rate of failure than the IB-I and CCK (Table 1).

Table 1

Comparison of failure rates between IB-I, IB-II, and CCK components. $P = 0.035$.

			Implant			
			CCK	IB-I	IB-II	Total
Failure	No	Count	8	38	40	86
		% Patients	9.3	44.2	46.5	100
	Yes	Count	0	2	11	13
		% Failure	0	15.4	84.6	100
Total		Count	8	40	51	99

Table 2

Comparison of failure rates between KS A, B, and C patients. $P = 0.047$.

			Transformed KS Category 1997			
			A	B	C	Total
Failure	No	Count	44	10	32	86
		% Patients	51.2	11.6	37.2	100
	Yes	Count	8	4	1	13
		% Failure	61.5	30.8	7.7	100
Total		Count	52	14	33	99

The IB-II implant had a significantly higher failure rate than the IB-I implant and the Constrained Condylar Implant (CCK; Zimmer, Warsaw IN). In fact despite the increased conformity of the articulation, the non-engaging metaphyseal dangle stems used at this time, and the presumed increased complexity of the reconstruction, there were no failures associated with the CCK implant in this series.

3.2. Patient factors

Patient factors were examined, including age, sex, the number of previous procedures, and Knee Society class.¹³ A significantly increased rate of failure was seen in patients with a higher Knee Society (KS) Class (Table 2). If we infer that KS class A patients are more active, then this finding suggests that those patients with fewer co-morbidities, and who were more active, had a higher chance of implant failure due to wear, loosening and osteolysis.

3.3. Insall Burstein II implant sub-set analysis

As the IB-II implant had higher rates of failure, (all but 2 of the failures in our previous study,¹⁰), we examined all of the patient, outcome, and implant related factors for this subset of patients separately.

The first finding was of a trend towards increased rates of revision in women (Table 3). Although this was a trend, and did not reach statistical significance with the number of patients in the study, it does present data that differs from other studies and joint registries which have pointed to a higher rate of failure in young men. These other studies, however, have shorter follow-up, focusing on the first decade and not the 2nd-4th decades, which may account for the different trend identified in our study.

The second finding was that of a significantly increased failure rate in the IB-II design with thinner polyethylene (Table 4). As thicker polyethylene inserts are typically associated with more severe pre-operative malalignment, it is interesting to note that the poorer mechanical properties of the thinner inserts were more likely to lead to failure than the overall complexity of the reconstruction. The mean thickness in the failed polyethylene inserts was a mere 2 mm thinner than the non-failures, which suggests that the polyethylene used in this implant was particularly sensitive to thickness.

Table 3

Comparison of failure rates between male and female patients. $P = 0.072$.

			Gender		
			Female	Male	Total
Failure	No	Count	23	17	40
		% Patients	57.5	42.5	100
	Yes	Count	10	1	11
		% Failure	90.1	9.9	100
Total		Count	33	18	51

Table 4

Average polyethylene thickness between TKAs that failed, and those that did not.
P = 0.001

Failure	Polyethylene liner thickness			
	N	Mean	Std. Dev.	Std. Error Mean
No	40	11.113	2.4974	0.3949
Yes	11	9.091	1.3751	0.4146

4. Discussion

This study demonstrates several factors that were more likely to lead to aseptic failure in young patients (< 55) with TKA. We specifically excluded all other forms of failure (septic failures, fractures, instability) as we wanted to identify only TKAs exhibiting mechanical long term failure of the prosthesis.

From a prosthetic design aspect, we previously published the improved survivorship noted with the monoblock, net-shape molded polyethylene of the IB I prosthesis over that of the modular, machined, gamma irradiated in air polyethylene of the IB II design.¹⁰ What we also noted in this study was the superior survivorship of the CCK design. This prosthesis also featured a modular, machined, gamma irradiated in air polyethylene, suggesting that there were other factors contributing to the failures in the IB II knees. These may include the locking mechanism, the polyethylene thickness used, the modular holes in the tibial baseplate, and the tibio-femoral geometry of the topside articulation. It is of note that despite the increased conformity, and the non-engaging stems, the CCK design had no failures in this series, despite a presumed increase in preoperative deformity, ligamentous imbalance, bone loss, and an increased postoperative stress on the polyethylene and implant-bone interface.

O'Rourke et al.¹⁶ suggest that the finding of an increased prevalence of osteolysis in association with the Insall-Burstein II prosthesis compared with nonmodular prostheses is potentially the result of several variables, such as the modularity of the polyethylene with abrasive wear against the tibial tray, holes in the tibial tray designed to allow for augmentation, impingement and wear of the post, and surgical technical factors (flexion of the femoral component, posterior slope of the tibial component, or hyperextension from an overly large extension gap). Translational and torsional stresses at the interface between the polyethylene and the tibial tray likely cause increased micromotion and backside wear resulting in osteolysis.¹²

In contrast to O'Rourke et al.¹⁶, Lachiewicz et al.¹⁷ presented a cohort of 193 TKA's performed with the same modular IB-II prosthesis, and showed no loosening of the components after an average 5 year follow up, and only 8 TKA's (4 percent) showing minimal osteolytic lesions, all tibial sided, without loosening. Oh et al.¹⁸ provide a prospective study comparing the IB-II and the newer Zimmer Nexgen Legacy PS prostheses, demonstrating similarly low rates of osteolytic lesions in each group, no component loosening, and a 9 year survival of 100 percent in both groups. Unlike our current study, however, these studies have comparably short follow up, whereas all failures in this paper occurred between 10 and 30 years.

From a functional standpoint, it is not surprising that there was a higher rate of mechanical wear and failure in patients with a higher activity level. In fact there was only one failure in a Knee Society Class C patient, compared to 8 failures in Class A patients, and 4 in Class B patients. But the topic of activity restriction in young patient TKA remains controversial, due to conflicting results. Some studies have shown that only 63.6 percent of patients are able to return to sport following TKA.¹⁹ Amongst those patients who do return to sport after TKA, most return at a decreased frequency, and lower level.^{20,21} More than 40 percent of patients list physician imposed activity restriction as the reason for this limited return to activity,²² despite the fact that no good evidence exists correlating increased nonimpact athletic activity

with aseptic loosening.²¹ Dahm et al.²³ found that 12 percent of patients who underwent TKA participated in activities that were not recommended by their physician, and yet this group did not have a higher incidence of complications or failure. Mont et al.²⁴ recently compared the outcomes of high-activity versus low-activity patients following TKA, and at a mean follow-up of 7 years, the outcome score was 96 in low-activity patients and 95 in high-activity patients, with no difference in failure rate. The question of activity restriction remains unresolved, although our study indicates that patients in a higher functional class are more susceptible to aseptic loosening.

An unexpected finding in the IB II cohort was a trend towards increased failure rates in women. Though this did not reach statistical significance (p value 0.07), this may have been a result of the limited number of patients in the study. Other studies, and joint registries have demonstrated a higher failure rate in men,²⁵ but many of these failures occurred in the first decade. In this study we specifically focused on late aseptic failures; the mean time to failure was 12.5 years and the two first decade failures were not included in this analysis as they occurred prior to the 1997 follow up (Table 1).

The IB II patients also had a higher failure rate when a thinner polyethylene was used. The mean thickness in the revised cases was 9 mm and in the unrevised cases it was 11 mm. This was highly statistically significant with a p value of 0.001, suggesting that this particular polyethylene design was very sensitive to thickness. Although the design of the component used in their study was different, Hoffman et al.²⁶ similarly demonstrated that revision, in the form of polyethylene exchange, was associated with a mean polyethylene thickness of 8.5 mm. Typically a thicker polyethylene is used in cases with greater malalignment requiring a more significant soft tissue release to balance the knee. In cases where balance could not be achieved a CCK implant was used. It is interesting to note then, that there were no failures in the CCK group and in those with a thicker polyethylene. One can infer that the thickness of the polyethylene was more important than the pre-operative deformity, or complexity of the reconstruction, with the implants in this study.

There were a number of strengths to our study. The first was the long-term follow-up in a very high percentage of patients. The inclusion of only young patients with osteoarthritis and post-traumatic arthritis, and the fact that all cases were performed by one of two surgeons ([J.N.I.] and [W.N.S.], who is an author in this study), using one of two prostheses, simplifies the interpretation of the results. The limitations of the study are that it was retrospective, and that none of these prostheses are in current use, and therefore the findings in this study cannot be generalized to any other implant currently or previously in use.

5. Conclusions

Many implant modifications have occurred since the prostheses used in this study. However this information is important in providing young patients and their clinicians a perspective on the patient specific and implant specific factors most responsible for aseptic failure over the long-term, which ideally may help tailor better follow-up parameters, and activity restriction advice, for patients at higher risk. Based on our study's findings, KS class A patients with thin polyethylene, IB-II prostheses, and possibly females, should undergo closer follow-up in the second through fourth decades, and likely beyond. It will be important to continue to follow these young cohorts of patients to determine whether the many changes in implant designs lead to improved survivorship.

Conflict of interest

The authors declare that there are no conflicts of interest.

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