Published in final edited form as:

J Arthroplasty. 2018 February ; 33(2): 407–414. doi:10.1016/j.arth.2017.09.041.

Failure After Modern Total Knee Arthroplasty: A Prospective Study of 18,065 Knees

Michael Pitta, M.D.,

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021

Christina I. Esposito, Ph.D.,

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021

Zhichang Li, M.D.,

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021. Arthritis Clinic and Research Center, Peking University People's Hospital, Beijing, China

Yuo-yu Lee, M.S.,

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021

Timothy M. Wright, Ph.D., and

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021

Douglas E. Padgett, M.D.

Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021

Abstract

Background—The purpose of our study is to determine the mechanism of failure among primary TKAs performed at our institution. We asked the following research questions (1) What are the most common failure modes for modern TKA designs? (2) What are preoperative risk factors for failure following primary TKA?

Methods—From May 2007 to December 2012, 18,065 primary TKAs were performed in 16,083 patients at a single institution were recorded in a prospective TJA registry with a minimum of 5 year follow-up. We retrospectively reviewed patient charts to determine a cause of failure for primary TKAs. A cox proportional hazard model was used to determine risk of revision surgery following primary TKA.

Results—The most common reasons for failure within 2 years were infection and stiffness. The multivariable regression identified preoperative risk factors for TKA failure with the hazard ratios.

Corresponding author: Michael Pitta, Hospital for Special Surgery, 535 East 70th Street, New York, NY 10021, Michael.pitta@gmail.com.

All work was performed at the Hospital for Special Surgery.

Conflict of interest statement: Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.

Ethical Board Review statement: Institutional ethical board review was obtained for the present study.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

The hazard ratio is 4.68 for patients with reported drug abuse ($p=0.03$), 3.52 for preoperative deformity & mechanical ICD-9 diagnostic codes versus OA ($p<0.01$), 1.99 for patients with CCK poly versus PS ($p<0.01$) and 1.78 for posttraumatic and trauma preoperative ICD-9 codes versus OA diagnosis ($p=0.03$). Finally, advancing age was shown to be protective for failure with a 0.61 hazard ratio ($p<0.01$).

Conclusion—The major reasons for revision TKA were due to infection, instability, aseptic loosening and stiffness. Identifiable factors for revision TKA were, in decreasing order, history of drug abuse, deformity/mechanical preoperative diagnosis, having a CCK implant over PS implant, posttraumatic/trauma preoperative diagnosis and younger age.

Keywords

Primary total knee arthroplasty failure; aseptic loosening; arthrofibrosis instability; osteolysis

Introduction

Total knee arthroplasty (TKA) performed has dramatically increased over the last decade, and will continue to do so with some projection estimates to be around 3 million per year in the United States by the year 2030 [1]. With an ever increasing number of primary TKAs being performed, a predictable increase is occurring in TKA failures and thus revision total knee surgeries. Several studies attempted to elucidate pre- and postoperative factors and the influence of implant design to determine causes of TKA failure [2][3]. Bozic et al. studied the epidemiology of TKA revision surgeries using the Nationwide Inpatient Sample database and found that the three major reasons for revision were infection (25%), mechanical loosening (16%), and implant failure (10%) [4]. Fehring et al. found that early failures were attributed to infection 38% of the time, 27% to instability, 13% to failure of ingrowth of a porous –coated implant, and 8% to patellofemoral issues [5]. The authors advised against the use of cementless prosthesis because of the early failures in their series. In a similar paper by Sharkey et al [3], the major causes for revision were polyethylene wear (25%), aseptic loosening (24%), instability (21%), infection (18%), arthrofibrosis (15%), malalignment (12%), and extensor mechanism deficiency (7%). Those authors recommended the abandonment of tibial surface cementing, but could not explain why such a large polyethylene failure rate occurred in their series. Two limitations of these studies were most primary procedures were performed at other centers and the revision procedures were referred to tertiary centers. As such, generalizations about causes of primary knee failure would be subject to bias.

Current registry databases are an important tool for collecting patient related information for analytic purposes. Registry data are becoming recognized as significant in studying epidemiology, cost effectiveness, and payer reimbursement with regard to TKA [6][7]. The limitations to such databases are influenced by the quality of the collected data and the patient's commitment to providing follow-up surveys from the same institution.

Our institution has a prospectively collected database that includes all demographic and clinical patient information for patients who underwent TKA at our center over a five year span from May 2007 to December 2012. The data in the registry provided us the unique

opportunity to determine the causes of early failure among primary TKAs performed at a single institution, free from the bias inherent in data from revision total knee arthroplasty at tertiary referral centers. Our hope was that we might identify possible solutions to prevent early failure of TKAs at our institution. We asked the following research questions (1) What are the most common failure modes for modern TKA designs?; and (2) What are preoperative risk factors for failure following primary TKA?

Patients and Methods

From May 2007 to December 2012, 18,065 primary TKA surgeries performed in 16,083 patients at a single institution were recorded in an IRB-approved prospective total joint arthroplasty registry. As of January 31, 2016, 417 primary TKAs returned to our institution to undergo revision surgery. Of the 417 primary TKAs that were identified as failures, 12 were excluded because they underwent isolated irrigation and debridement for hematoma without removal of components. Isolated polyethylene exchange for infection was included in the study. Therefore, we identified failure mechanisms in 405 knees in 400 patients (Fig. 1).

We retrospectively reviewed patient electronic medical records, paper medical charts, radiographic data, and laboratory results to determine a cause of failure for primary total knee arthroplasties. Radiographic data included pre- and post-operative radiographs and CT and MRI images (when available). Laboratory results included erythrocytes sedimentation rate (ESR), C-reactive protein (CRP), white cell count (WBC), and synovial fluid culture and cell counts.

We extracted clinical information about patient demographics, comorbidities including the Charlson Comorbidity Index, diagnosis for the primary TKA surgery, and TKA design using data from the arthroplasty registry and patient electronic medical records. Comorbidities and diagnosis were determined using ICD-9 diagnosis codes. A history of drug abuse was captured by both ICD-9 codes and in a preoperative questionnaire given to every patient in the study. We used four categories for original diagnosis for the primary TKA surgery: 1) osteoarthritis and avascular necrosis, 2) rheumatoid and inflammatory arthritis, 3) traumatic and posttraumatic arthritis, and 4) dysplasia, deformity, mechanical failure, or unknown reasons.

We categorized TKA designs into levels of constraint, including posterior-stabilized (PS), cruciate-retaining (CR), constrained condylar knee (CCK), hinge, or unknown. The implant models and numbers used in our study included: 26 Exactech (Gainesville, FL) non modular CCK, 62 Exactech PS, 3 Exactech Hi-flex, 70 Exactech Optetrak Logic, 1 Wright Medical Advance (Memphis, TN), 27 Zimmer (Warsaw, IN) NextGen LPS, 20 Zimmer NexGen LPS Flex, 4 Zimmer Nexgen Legacy CCK, 9 Zimmer Nexgen Gender Specific LPS flex, 11 Smith & Nephew (Memphis, TN) Journey, 102 Smith & Nephew Genesis II SPC, 24 Smith & Nephew Legion, 21 DePuy (Warsaw, IN) Sigma, 1 Depuy S-ROM Noiles Rotating Hinge, 3 Stryker (Mahwah, NJ) Triathlon, 1 Ortho Development (Draper, UT) Balanced knee, 1 Encore Medical (Austin, TX) and 19 Biomet (Warsaw, IN) Vanguard.

Statistics

Patient demographics, comorbidities, diagnoses, and TKA designs were compared between patients who failed and those who did not fail using Two-sample T-test or Chi-squared test. Time to revision after primary knee arthroplasty was analyzed using the Kaplan-Meier method. We also compared time to revision among diagnoses and TKA designs in failed TKAs. A Cox proportional hazard model was used to study the risk factors for increased risk of revision following primary TKA. Covariates that were significant in bivariate comparisons were included in the Cox model. Results were summarized using a hazard ratio and its 95% confidence interval (CI).

Results

In our study we had a total of 400 patients (405 knees) that underwent revision TKA while 17,660 TKAs that were not revised in our study period. Patients who were revised did not differ in terms of BMI, sex, or Charlson Comorbidity Index (CCI) compared to patients who were not revised. However, patients in the revised cohort were younger, more likely to have a post-traumatic/traumatic diagnosis, and/or a deformity diagnosis.

The average time to revision surgery for this study was 25 months (std dev 20 months). Our reasons for failure were infection (25.7%), instability (24.4%), aseptic loosening (21.2%), stiffness (14.1%), periprosthetic fracture (3.5%), osteolysis/polyethylene wear (2.5%), malalignment (2.5%), isolated loose patellar component (1.5%), pain (1.3%), polyethylene dissociation (1%), metal allergy (0.7%), patellar avascular necrosis (0.5%), peripatellar fibrosis (0.5%), extensor mechanism failure (0.2%), patellar component malposition (0.2%), and patellar instability (0.2%). More than 50 patients were revised for each of our top four reasons for failure (Table 1). Patients who were revised for stiffness, failed early with an average time to revision surgery of 16 months, compared to patients that failed for infection after 20 months, instability after 27 months and aseptic loosening after 37 months (Log-Rank P-value <0.0001) (Fig. 2). The rate of revision surgery was 2% for patients with osteoarthritis/AVN, 4% with RA/inflammatory arthritis, 6% with post-traumatic arthritis and 9% with a preoperative diagnosis for another reason (Log-Rank P-value <0.0001) (Fig. 3). Factors that increased the risk for TKA failure based on bivariate analyses were younger age, an original diagnosis of posttraumatic osteoarthritis, a history of drug abuse, simultaneous bilateral TKA surgery, and the use of a constrained (CCK) implant (Table 2). Applying Cox hazard analysis to our cohort of patients showed that advancing age was protective against TKA failure with a hazard ratio of 0.61 (95%CI 0.56–0.67; $p < 0.01$) for every 10 years of increasing age (Table 3). Compared to patients with the preoperative diagnosis of osteoarthritic or AVN patients, patients with posttraumatic/traumatic or dysplasia/deformity/mechanical diagnoses were 1.8 times (95%CI 1.0 – 3.0) and 3.5 times (95%CI 1.4 – 8.8) more likely to undergo revision surgery respectively. A patient with a history of drug abuse was 5 times (95%CI 1.2 – 19.0) more likely to undergo revision surgery. Patient gender, body mass index, Charlson comorbidity index, alcohol abuse, obesity, depression, diabetes, renal failure, cardiac disease, pulmonary disease, or neurological disorders were not associated with an increased risk of failure. CCK implants

were two times (95%CI 1.5 – 2.7) more likely to undergo revision surgery than PS implants. No difference was found in failure among other implant designs.

There was an increased proportion of bilateral TKAs in the revised cohort compared to the non-revised cohort (Table 2). However, simultaneous bilateral TKA was not a significant risk factor in the multivariate analysis. The reasons why bilateral TKAs failed were instability (17 TKAs), aseptic loosening (13), infection (14), stiffness (8), fracture (3), malalignment (1), pain (1) and metal allergy (1) (Table 4).

Discussion

The reasons for failure for primary TKA have evolved as implant designs and materials and surgical technique have improved. Earlier studies revealed polyethylene wear and osteolysis [3] as a major cause for revision, while more recent studies have pointed to infection and instability as more frequent reasons [8]. Presumably, new forms of polyethylene manufacturing and sterilization have improved the material's wear behavior and thus decreased the rate of polyethylene related failures [9]. In our study, we defined failure as a primary total knee that went on to revision. We found the major causes for revision to be infection followed by instability, aseptic loosening, and stiffness. As expected, the time of revision was shorter for patients revised for stiffness, infection, malalignment, and patellar instability, and longer for patients revised for aseptic loosening, and isolated loose patellar component, and pain. Time to revision has been previously correlated with reason for failure, with previous studies showing early failures (<1 year) were predominantly from infection, while intermediate failures (1–3 years) were most commonly due to malalignment, and late failures (>3 years) were due to aseptic loosening [8].

Comparing studies on TKA failures can be challenging based on differences in classifying the reason for revision and in surgical technique and implant designs. We have provided a summary table, with the majority of studies showing either loosening or infection as the most common cause of TKA failure (Table 5). Comparing studies on TKA failures can be challenging based on differences in classifying the reason for revision and in surgical technique and implant designs. We have provided a summary table (Table 5). Fehring et al. [5], in their study of 440 patients who underwent revision TKA at their institution within 5 years of their index procedure, found the major reasons for early failure to be: infection (38%), instability (27%), failure of ingrowth of a non-cemented component (13%), and patellofemoral problems (7%). Sharkey et al. [3] retrospectively reviewed 203 patients that had revision TKA over a three year period at their institution and found the major reasons to be: polyethylene wear (25%), aseptic loosening (21.1%), instability (21.2%), infection (17.5%), arthrofibrosis (14.6%), and malalignment (11.8%). These authors published an updated review a decade later of 781 revision TKAs performed over a ten year period [10]; the reasons for revision had changed to be: aseptic loosening (39.9%), infection (27.4%), instability (7.5%), periprosthetic fracture (4.7%), and arthrofibrosis (4.5%). Similar to our study, they found the most common reason for early failure (< 2 years) was infection; however, their most common reason for later failure (> 2 years) was aseptic loosening, while in our study it was instability.

Schroer et al. [2] published on 844 patients that underwent revision knee arthroplasty from six high level joint replacement centers over a two year period. The authors found the major reasons for failure to be: aseptic loosening (31.2%), instability (18.7%), infection (16.2%), polyethylene wear (10%), arthrofibrosis (6.9%), and malalignment (6.6%). The mean time to revision surgery was 5.9 years, and nearly all (95%) of the TKAs had failed within 5 years of the index operation. Interestingly, their major reason for early failure (<2 years) was instability, while aseptic loosening was major reason between two and 15 years after the index operation. The late failures (>15 years) were related primarily to polyethylene wear, followed by instability. These results suggest a distinction between early and late instability [11].

Kasahara et al.[12] published their retrospective review on 140 revision TKAs done from 2006 to 2011 in a Japanese population. The authors reported the major reasons for revision to be: aseptic loosening (40%), infection (24%), polyethylene wear/osteolysis (9%), and instability (9%). The authors attributed the dominance of aseptic loosening to their patients' active lifestyles, with no correlation to BMI in their revision group. Le et al. [9] reviewed 253 revision TKAs over a ten year period and found little difference between early failures (<2 years) that were due primarily to instability (26%), infection (24%), and stiffness (18%), and late failures (>2 years) that were similarly due to infection (25%), instability (18%), and stiffness (14%). Dalury et al. [13] in a multicenter retrospective series of 820 revision TKAs found the major reasons for revision to be aseptic loosening (23.1%), infection (18.4%), polyethylene wear(18.1%), and instability (17.7%). Finally, Thiele et al. [8] published a case series of 358 revision TKAs that occurred at two high volume joint centers from 2005 to 2010. The most common reasons for revision were: aseptic loosening (21.8%), instability (21.8%), malignment (20.7%), and infection (14.5%). Furthermore, they found that time to revision correlated with reason for failure. Early failures (<1 year) were predominantly from infection, while intermediate failures (1–3 years) were most commonly due to malalignment, and late failures (>3 years) were due to aseptic loosening.

Registry data is useful because it provides large volume of patients and demographic data that can be used to follow patients longitudinally. However, the problems of using national registry data is that it is limited by how the data is collected and further classified. It often lacks accuracy of diagnostic data due to the inflexibility of ICD-9 coding schemes. For example, Bozic et al. [4] performed a study using the Nationwide Inpatient Sample (NIS) that included 60,355 revision TKAs with the reasons for revision identified using the ICD-9-CM diagnosis codes. The predominant causes for revision were infection (25.2%) and aseptic loosening (16.1%). However, this study was limited by small number of codes and inadequate documentation to represent the true reasons for failure, and roughly 15% of the revisions were coded for "other mechanical complications." Khan et al. [14] published a current concepts review based on worldwide National Joint Registries and found that the reasons for revision were aseptic loosening (29.8%), infection (14.8%), and pain (9.5%)the risk of failure of a primary TKA undergoing revision surgery at ten years was 5%.

We found the major causes for revision TKA at our institution to be infection, instability, aseptic loosening, and stiffness. Overall, the failure rate with primary TKAs undergoing revision TKA was 2.2%. Our infection rate in this series was roughly 0.48%, which is below

the published national average 0.92% [15]. Instability has multiple etiologies [11], but the fact that instability remains a dominant failure mode reinforces the continued attention to soft tissue balancing and component position as imperative for the long term success of primary TKA. Instability being a major cause in our series is difficult to explain. The majority of our TKAs used posterior stabilized implants and a measured resection technique with routine patellar resurfacing. Some data in the literature suggest that posterior stabilized designed TKAs have higher revision rates than cruciate retaining designs [16], while other data suggest no differences between these two common design types [17][18].

Interestingly, a higher rate of failure was found for patients who had a CCK implant versus a posterior stabilized implant, with a hazard ratio of 1.99. This may be due to those patients with CCK implants having poor bone stock, ligamentous deficiency, or large preoperative deformities. A large proportion of the CCK TKAs that failed in our series was a specific non-modular CCK without stem extensions that may be predisposed to aseptic loosening of the femoral component [19]. Previous literature provided evidence that use of a second generation CCK implant in primary TKA is safe in the short to medium follow up period [20][21][22], but contradictory reports exist that in long-term follow up, CCK implants have higher complication rates and decreased survival compared to standard TKAs, but again the majority of patients with a CCK primary TKA implant may have severe deformity or instability pre-operatively [23]. While the decision to use a more constrained implant such as a CCK is always based upon ability to obtain adequate soft tissue balance at the time of surgery, in our series using a CCK implant was a risk for revision surgery even after controlling for a variety of other factors. Our aseptic loosening rate of 0.4% with an average time to revision of 37 months is comparable to previously reported rates, where the cumulative incidence aseptic loosening rate was reported as 1.1% at 13 years post-operatively [24]. Aseptic loosening can be multifactorial influenced by patient, surgical technique, and implant design factors [25].

An elevated BMI has been debated as a risk factor for early tibia loosening [26][27]. In our study, patients who that underwent revision TKA for aseptic loosening had an average BMI of 31; obesity was not a significant risk factor for failure, a result that differs from previous studies [21][22][28]. In our analysis, other risk factors were found for revision surgery with drug abuse having the largest hazard ratio (4.7). Bozic et al. [29], in a Medicare database study, found a similar result with a hazard ratio of 2.1 for patients with drug abuse.

Patients with a primary diagnosis of deformity and mechanical ICD-9 codes had 3.5 hazard ratio compared to patients with primary OA ICD-9 codes. Berend et al. [30], in a retrospective study of 8598 TKAs, found that a preoperative deformity 3 degrees of varus on the tibia was a risk factor for medial bone collapse, while preoperative valgus deformity was associated with ligamentous imbalance and tibia component failure. Similarly, our patients with a posttraumatic and trauma preoperative diagnosis had a 1.8 hazard ratio compared to patients with OA preoperative diagnosis codes. Finally, we found that increasing age was protective for failure from TKA with a hazard ratio of 0.61. Previous studies found a similar trend with age and TKA failure [28][31]. For example, Vazquez-Vela Johnson et al. [28] found that age below 60 years was the most significant factor associated with lower ten year survival rate (82.4% versus 99.1%).

Finally, we found in our bivariate analysis that patients undergoing simultaneous bilateral TKAs had a larger proportion in the revised cohort compared to the non-revised cohort. However, in our multivariate analysis this finding did not reach significance. Previous literature is conflicting on complications and outcomes following simultaneous bilateral TKA. Several papers showed no differences in major complications between staged versus simultaneous bilateral TKA [32][33] while others showed that simultaneous bilateral TKA had lower readmission rates.[34] In a systematic review by Fu et al.[35] simultaneous bilateral TKA had lower risk of deep infection and lower revision rates, but higher rates of mortality, pulmonary embolism, and blood transfusion. Bolognesi et al. [36] in a Medicare study of 83, 441 patients found no differences in revision rate or infection; the three major reasons for failures were instability (29%), infection (24%), and aseptic loosening (22%), which were similar to unilateral TKAs. We intend to investigate our bilateral TKA failure patients further to identify possible risk factors for simultaneous bilateral TKA failure.

Our study has several limitations. First, ours is a high volume joint replacement center that may not be representative of the significant number of TKAs performed at low volume community hospitals in the U.S. According to Katz [37] et al., 25% of TKAs performed in a Medicare population were done by surgeons who performed 12 TKAs annually and surgeons who performed 50 TKAs annually had fewer adverse events. A second limitation is that when the reason for failure could not be identified through operative reports and clinic notes, pre and post-operative radiographs, CT scans, and MRIs were interpreted by the lead author and the senior author to determine the cause of failure. Though this was only done in 15 cases, some level of subjectivity and bias cannot be ignored. Third, although all our failures reported in this study had their index operations performed at our institution, we cannot account for patients who had revisions performed at outside institutions. We attempted to use a state specific database to capture some of these possible patients but this was not possible. Therefore our failure rate reported in this study likely underestimates the true failure rate. Another limitation is that in our study we defined failure as primary TKAs that went onto revision TKA, therefore this may not account for patients that have an unacceptable outcome and have not undergone a revision operation. Finally, multiple TKA designs from different manufacturers were used, which may not represent the trends in implant usage across the country.

Nonetheless, this is the largest study to our knowledge on reasons for TKA failures based on primary operations being performed at one institution, making our study free of referral bias that is present in previous published literature on total knee failures. Our findings add to the growing data that primary TKAs are no longer failing from polyethylene issues, but rather more commonly from infection and aseptic loosening. In the current practicing environment with the need to reduce overall health care costs and revision TKA [4] it is imperative to translate the data on reasons for revision to strategies for mitigating risk and therefore decreasing the overall cost and burden to the healthcare system.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

References

1. Kurtz SM, Ong KL, Lau E, Bozic KJ. Impact of the Economic Downturn on Total Joint Replacement Demand in the United States. *J Bone Jt Surgery-American Vol.* 2014; 96:624–30. DOI: 10.2106/JBJS.M.00285
2. Schroer WC, Berend KR, Lombardi AV, Barnes CL, Bolognesi MP, Berend ME, et al. Why are total knees failing today? Etiology of total knee revision in 2010 and 2011. *J Arthroplasty.* 2013; 28:116–9. DOI: 10.1016/j.arth.2013.04.056 [PubMed: 23954423]
3. Sharkey PF, Hozack WJ, Rothman RH, Shastri S, Jacoby SM. Insall Award paper. Why are total knee arthroplasties failing today? *Clin Orthop Relat Res.* 2002; :7–13. DOI: 10.1097/01.blo.0000036002.13841.32 [PubMed: 12439231]
4. Bozic KJ, Kurtz SM, Lau E, Ong K, Chiu V, Vail TP, et al. The epidemiology of revision total knee arthroplasty in the united states. *Clin Orthop Relat Res.* 2010; 468:45–51. DOI: 10.1007/s11999-009-0945-0 [PubMed: 19554385]
5. Fehring TK, Odum S, Griffin WL, Mason JB, Nadaud M. Early failures in total knee arthroplasty. *Clin Orthop Relat Res.* 2001; :315–8. DOI: 10.1097/00003086-200111000-00041 [PubMed: 11716402]
6. Dreyer N, Garner S, Dreyer Nancy A, Garner S. Registries for robust evidence. *Jama.* 2009; 302:790–1. DOI: 10.1001/jama.2009.1092 [PubMed: 19690313]
7. Graves SE. The value of arthroplasty registry data. *Acta Orthop.* 2010; 81:8–9. DOI: 10.3109/17453671003667184 [PubMed: 20170422]
8. Thiele K, Perka C, Matziolis G, Mayr HO, Sostheim M, Hube R. Current Failure Mechanisms After Knee Arthroplasty Have Changed: Polyethylene Wear Is Less Common in Revision Surgery. *J Bone Jt Surgery-American Vol.* 2015; 97:715–20. DOI: 10.2106/JBJS.M.01534
9. Le DH, Goodman SB, Maloney WJ, Huddleston JI. Current modes of failure in TKA: Infection, instability, and stiffness predominate. *Clin Orthop Relat Res.* 2014; 472:2197–200. DOI: 10.1007/s11999-014-3540-y [PubMed: 24615421]
10. Sharkey PF, Lichstein PM, Shen C, Tokarski AT, Parvizi J. Why Are Total Knee Arthroplasties Failing Today—Has Anything Changed After 10 Years? *J Arthroplasty.* 2014; 29:1774–8. DOI: 10.1016/j.arth.2013.07.024 [PubMed: 25007726]
11. Song SJ, Detch RC, Maloney WJ, Goodman SB, Huddleston JI. Causes of instability after total knee arthroplasty. *J Arthroplasty.* 2014; 29:360–4. DOI: 10.1016/j.arth.2013.06.023 [PubMed: 23896358]
12. Kasahara Y, Majima T, Kimura S, Nishiike O, Uchida J. What Are the Causes of Revision Total Knee Arthroplasty in Japan? *Clin Orthop Relat Res.* 2013; 471:1533–8. DOI: 10.1007/s11999-013-2820-2 [PubMed: 23385774]
13. Dalury DF, Pomeroy DL, Gorab RS, Adams MJ. Why are total knee arthroplasties being revised? *J Arthroplasty.* 2013; 28:120–1. DOI: 10.1016/j.arth.2013.04.051 [PubMed: 23886410]
14. Khan M, Osman K, Green G, Haddad FS. The epidemiology of failure in total knee arthroplasty: avoiding your next revision. *Bone Joint J.* 2016; 98-B:105–12. DOI: 10.1302/0301-620X.98B1.36293
15. Kurtz SM, Lau E, Watson H, Schmier JK, Parvizi J. Economic Burden of Periprosthetic Joint Infection in the United States. *J Arthroplasty.* 2012; 27:61–65. e1. DOI: 10.1016/j.arth.2012.02.022 [PubMed: 22554729]
16. Comfort T, Baste V, Froufe MA, Namba R, Bordini B, Robertsson O, et al. International Comparative Evaluation of Fixed-Bearing Non-Posterior-Stabilized and Posterior-Stabilized Total Knee Replacements. *J Bone Jt Surgery-American Vol.* 2014; 96:65–72. DOI: 10.2106/JBJS.N.00462
17. Bercik MJ, Joshi A, Parvizi J. Posterior Cruciate-Retaining Versus Posterior-Stabilized Total Knee Arthroplasty. *J Arthroplasty.* 2013; 28:439–44. DOI: 10.1016/j.arth.2012.08.008 [PubMed: 23433255]
18. Li N, Tan Y, Deng Y, Chen L. Posterior cruciate-retaining versus posterior stabilized total knee arthroplasty: a meta-analysis of randomized controlled trials. *Knee Surgery, Sport Traumatol Arthrosc.* 2014; 22:556–64. DOI: 10.1007/s00167-012-2275-0

19. Moussa ME, Lee Y yu, Westrich GH, Mehta N, Lyman S, Marx RG. Comparison of Revision Rates of Non-modular Constrained Versus Posterior Stabilized Total Knee Arthroplasty: a Propensity Score Matched Cohort Study. *HSS J.* 2017; 13:61–5. DOI: 10.1007/s11420-016-9533-5 [PubMed: 28167876]
20. Sabatini L, Risitano S, Rissolio L, Bonani A, Atzori F, Massè A. Condylar constrained system in primary total knee replacement: our experience and literature review. *Ann Transl Med.* 2017; 5:135.doi: 10.21037/atm.2017.03.29 [PubMed: 28462215]
21. Ye C-Y, Xue D-T, Jiang S, He R-X. Results of a Second-generation Constrained Condylar Prosthesis in Complex Primary and Revision Total Knee Arthroplasty: A Mean 5. 5-Year Follow-up. *Chin Med J (Engl).* 2016; 129:1334–9. DOI: 10.4103/0366-6999.182845 [PubMed: 27231172]
22. Maynard LM, Sauber TJ, Kostopoulos VK, Lavigne GS, Sewecke JJ, Sotereanos NG. Survival of primary condylar-constrained total knee arthroplasty at a minimum of 7 years. *J Arthroplasty.* 2014; 29:1197–201. DOI: 10.1016/j.arth.2013.11.018 [PubMed: 24411081]
23. Cholewinski P, Putman S, Vasseur L, Migaud H, Duhamel A, Behal H, et al. Long-term outcomes of primary constrained condylar knee arthroplasty. *Orthop Traumatol Surg Res.* 2015; 101:449–54. DOI: 10.1016/j.otsr.2015.01.020 [PubMed: 25952710]
24. Vertullo CJ, Lewis PL, Graves S, Kelly L, Lorimer M, Myers P. Twelve-Year Outcomes of an Oxinium Total Knee Replacement Compared with the Same Cobalt-Chromium Design. *J Bone Jt Surg.* 2017; 99:275–83. DOI: 10.2106/JBJS.16.00092
25. Gøthesen, Espehaug B, Havelin L, Petursson G, Lygre S, Ellison P, et al. Survival rates and causes of revision in cemented primary total knee replacement: A report from the Norwegian arthroplasty register 1994–2009. *Bone Jt J.* 2013; 95 B:636–42. DOI: 10.1302/0301-620X.95B5.30271
26. Abdel MP, Bonadurer GF, Jennings MT, Hanssen AD. Increased Aseptic Tibial Failures in Patients With a BMI 35 and Well-Aligned Total Knee Arthroplasties. *J Arthroplasty.* 2015; 30:2181–4. DOI: 10.1016/j.arth.2015.06.057 [PubMed: 26220103]
27. Parratte S, Ollivier M, Lunebourg A, Verdier N, Argenson JN. Do Stemmed Tibial Components in Total Knee Arthroplasty Improve Outcomes in Patients With Obesity? *Clin Orthop Relat Res.* 2017; 475:137–45. DOI: 10.1007/s11999-016-4791-6 [PubMed: 26992719]
28. Vazquez-Vela Johnson G, Worland RL, Keenan J, Norambuena N. Patient demographics as a predictor of the ten-year survival rate in primary total knee replacement. *J Bone Joint Surg Br.* 2003; 85:52–6. [PubMed: 12585577]
29. Bozic KJ, Lau E, Ong K, Chan V, Kurtz S, Vail TP, et al. Risk factors for early revision after primary TKA in medicare patients knee. *Clin Orthop Relat Res.* 2014; 472:232–7. DOI: 10.1007/s11999-013-3045-0 [PubMed: 23661301]
30. Berend ME, Ritter MA, Meding JB, Faris PM, Keating EM, Redelman R, et al. The Chetranjan Ranawat Award: Tibial Component Failure Mechanisms in Total Knee Arthroplasty. *Clin Orthop Relat Res.* 2004; 428:26–34. DOI: 10.1097/01.blo.0000148578.22729.0e
31. Hofmann AA, Heithoff SM, Camargo M. Cementless total knee arthroplasty in patients 50 years or younger. *Clin Orthop Relat Res.* 2002; 102–7. [PubMed: 12439246]
32. Seol J-H, Seon J-K, Song E-K. Comparison of postoperative complications and clinical outcomes between simultaneous and staged bilateral total knee arthroplasty. *J Orthop Sci.* 2016; 21:766–9. DOI: 10.1016/j.jos.2016.07.023 [PubMed: 27576110]
33. Sheth DS, Cafri G, Paxton EW, Namba RS. Bilateral Simultaneous vs Staged Total Knee Arthroplasty: A Comparison of Complications and Mortality. *J Arthroplasty.* 2016; 31:212–6. DOI: 10.1016/j.arth.2016.03.018 [PubMed: 27430183]
34. Lindberg-Larsen M, Jørgensen CC, Husted H, Kehlet H. Early morbidity after simultaneous and staged bilateral total knee arthroplasty. *Knee Surgery, Sport Traumatol Arthrosc.* 2015; 23:831–7. DOI: 10.1007/s00167-014-2880-1
35. Fu D, Li G, Chen K, Zeng H, Zhang X, Cai Z. Comparison of clinical outcome between simultaneous-bilateral and staged-bilateral total knee arthroplasty: a systematic review of retrospective studies. *J Arthroplasty.* 2013; 28:1141–7. DOI: 10.1016/j.arth.2012.09.023 [PubMed: 23518424]

36. Bolognesi MP, Watters TS, Attarian DE, Wellman SS, Setoguchi S. Simultaneous vs staged bilateral total knee arthroplasty among Medicare beneficiaries, 2000–2009. *J Arthroplasty*. 2013; 28:87–91. DOI: 10.1016/j.arth.2013.05.039 [PubMed: 23932073]
37. KATZ JN, BARRETT J, MAHOMED NN, BARON JA, WRIGHT RJ, LOSINA E. Association Between Hospital and Surgeon Procedure Volume and the Outcomes of Total Knee Replacement. *J Bone Jt Surgery-American Vol*. 2004; 86:1909–16. DOI: 10.2106/00004623-200409000-00008

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Figure 1.
Flow diagram of patients included in the study

Figure 2.

Kaplan-Meier survival graph for reasons for failure. Log-rank test- nonparametric test that compares survival distributions. A $p < 0.05$ indicates there is a difference between survival curves.

Figure 3.

Kaplan-Meier survival graph for preoperative diagnosis. Log-rank test- nonparametric test that compares survival distributions. A $p < 0.05$ indicates there is a difference between survival curves.

Table 1

Mechanisms of failure

Reason for failure	# failures/% of failures	Avg time of implantation (months)
Infection	103/25.4%	20
Instability	97/24%	27
Aseptic loosening	86/21.2%	37
Stiffness	57/14.1%	16
Periprosthetic fracture	14/3.5%	29
Osteolysis/PE wear	10/2.5%	27
Malalignment	10/2.5%	13
Pain	5/1.3%	30
Isolated Loose Patella	6/1.5%	46
Documented Nickel Allergy	3/0.7%	23
Patellar AVN	2/0.5%	11
PE dissociation	4/1%	12
Extensor mechanism failure	1/0.25%	12
Patellar malposition	1/0.25%	19
Peripatellar fibrosis/"Clunk"	2/0.5%	20
Patellar instability	1/0.25%	7

Table 2

Patient factors and risk of failure after primary TKA

Patient Factors	All Patients N = 18,065	Not revised N = 17,660	Revised N = 405	p-value
Age (mean $\pm$ sd)	67 $\pm$ 10	68 $\pm$ 10	62 $\pm$ 10	<0.001
% Female	63.9%	63.9%	62.8%	0.62
BMI (mean $\pm$ sd)	31 $\pm$ 6	31 $\pm$ 6	31 $\pm$ 6	0.25
Bilateral knees	11%	11%	14%	0.04
Primary Diagnosis	97% OA, 1% RA, 1% Posttraumatic 0.3% Other	97% OA, 1% RA, 1% Posttraumatic 0.3% Other	93% OA, 2% RA, 4% Posttraumatic 1% Other	<0.001
% Drug Abuse	0.1%	0.1%	0.5%	0.01

Table 3

Cox Hazard Analysis

Parameter	Std Err	P-value	Hazard Ratio	95% CI	
				0.56	0.67
Sex	0.005	0.7948	---	---	---
BMI	0.11	0.8909	---	---	---
RA/inflammatory vs OA+AVA	0.01	0.9801	---	---	---
	0.39	0.9801	---	---	---
	0.27	---	1.78	1.04	3.02
	0.47	---	3.52	1.41	8.76
	0.15	---	1.99	1.48	2.67
CR vs PS	0.58	0.7456	---	---	---
CS vs PS	1.002	0.0519	---	---	---
Hinge vs PS	1.03	0.7706	---	---	---
Others vs PS	272.74	0.9673	---	---	---
Bilateral vs Unilateral	0.15	0.6614	---	---	---
Surgery	1.01	0.9257	---	---	---
Alcohol abuse	0.71	---	---	---	---
	4.68	---	---	1.15	18.95

Table 4

Reasons for revision surgery after unilateral or bilateral TKA

Reason for failure	Unilateral TKA n = 347	Bilateral TKA n = 58
Infection	88/25%	14/24%
Instability	80/23%	17/29%
Aseptic loosening	73/21%	13/22%
Stiffness	48/14%	8/14%
Periprosthetic fracture	11/3%	3/5%
Osteolysis/PE wear	10/3%	0
Malalignment	9/2.6%	1/1.7%
Isolated Loose Patella	6/1.7%	0
Pain	4/1.2%	1/1.7%
Polyethylene Dissociation	4/1.2%	0
Metal Allergy	2/0.6%	1/1.7%
Patellar AVN	2/0.6%	0
Peripatellar fibrosis/"Clunk"	2/0.6%	0
Extensor mechanism failure	1/0.3%	0
Patellar malposition	1/0.3%	0
Patellar instability	1/0.3%	0

Author Manuscript

Author Manuscript

Author Manuscript

Author Manuscript

Table 5

Summary of previous literature

	Number of revisions	Average time to revision (months)	Loosening	Infection	Instability	Periprosthetic fracture	Arthrofibrosis /stiffness	PE wear /osteolysis	Malalignment	Ext Mech Deficiency	Patella AVN	Patellar resurfacing	Patellofemora l issues	Failure of ingrowth	Implant Failure	Dislocation	Other	Conversion of UKA
Our study	405	26	21.50%	25.70%	24.40%	3.50%	14.10%	2.50%	2.50%	0.25%	0.50%	N/A	N/A	N/A	N/A	1%	N/A	N/A
Sharkey et al. 2014	781	N/A	39.90%	27.40%	7.50%	4.70%	4.50%	0.00%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sharkey et al. 2002	203	44.4	24.10%	17.50%	21.20%	2.80%	14.60%	25.00%	11.80%	6.60%	4.20%	0.90%	N/A	N/A	N/A	N/A	N/A	N/A
Fehring et al. 2001	279	N/A	3%	38%	27%	N/A	N/A	7%	N/A	N/A		N/A	8%	13%	N/A	N/A	5%	N/A
Schroer et al. 2013	844	70.8	31.20%	16.20%	18.70%	3.20%	7%	10%	6.60%	1.20%	0.20%	4.10%	N/A	N/A	N/A	N/A	1.50%	N/A
Thiele et al. 2015	358	48	21.80%	14.50%	21.80%	3.30%	4.50%	7%	20.70%	0.60%	N/A	5.90%	N/A	N/A	N/A	N/A	N/A	N/A
Kasahara et al. 2013	140	N/A	40%	24%	9%	4%	N/A	9%	N/A	N/A	N/A	N/A	N/A	N/A	6%		8%	N/A
Bozic et al. 2010	60,355	N/A	16.10%	25.20%	N/A	1.50%	N/A	8.10%	N/A	N/A	N/A	N/A	N/A	N/A	9.70%	7.10%	15.40%	N/A
Hossain et al. 2010	349	84	14.90%	32.70%	7.70%	8.30%	2.60%	12.70%	6.60%	1.40%	N/A	N/A	N/A	N/A	0.80%	N/A	N/A	8%
Dalury et al. 2013	820	N/A	23.10%	18.40%	17.70%	1.40%	9.30%	22.60%	2.90%	N/A	N/A	1.70%	N/A	N/A	N/A	N/A	2.9	N/A