

TECHNIQUE

Knee Failure Mechanisms After Total Knee Arthroplasty

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ABSTRACT

Total knee arthroplasty is a highly successful procedure, with the percentage of patients requiring revision relatively small. However, when considering the large number of these procedures performed annually, this small percentage of failures constitutes a significant number of patients. Failure of total knee arthroplasty is devastating to the patient, frustrating for the surgeon, and comes at a significant cost to the healthcare system. Therefore, it is imperative to understand the mechanisms of failure in knee arthroplasty. The leading causes include polyethylene wear, loosening, instability, and infection. It is important to recognize each mode of failure not only to appropriately diagnose and treat patients, but also to improve the future success of total knee arthroplasty.

Keywords: total knee arthroplasty, failure mechanisms

INTRODUCTION

Total knee arthroplasty has been judged a highly successful operation when evaluated for pain relief and functional improvement.^{1–3} Current durability data report greater than 90% implant survival at 10 to 15 years.^{4,5} Unfortunately, a significant number of revision surgeries are performed yearly. In 1999 22,000 revision knee arthroplasties were performed at an estimated expense of \$262 million.⁶ The failure of these 22,000 primary knee replacements is devastating to the patient, frustrating for the surgeon, and costly to the healthcare system. The literature available on failure mechanisms of primary knee reconstruction is scant. Most of the literature focuses on the techniques and results of revision arthroplasty. Recent reports have emphasized isolated failure mechanisms such as tibial tray failure,⁷ accelerated polyethylene wear,^{8,9} metal-backed patellar compo-

nent failure,¹⁰ or histologic reaction to wear debris.^{11–13} However, recent reports by Fehring et al¹⁴ and Sharkey et al¹⁵ have further elucidated current failure mechanisms in knee arthroplasty.

Fehring et al¹⁴ reported on 440 patients who underwent revision surgery between 1986 and 1999; 229 patients were classified as early failures, which were defined as revision within 5 years of the index procedure. Thirty-eight percent (105) of patients were revised secondary to infection; 27% (74) were revised because of instability; 13% (37) were revised due to failure of ingrowth into porous components; 8% (22) had revision secondary to patellofemoral complications; 7% (21) were revised because of wear or osteolysis; 3% (8) were revised due to aseptic loosening; and 12 patients were revised for miscellaneous problems.¹⁴ Sharkey et al¹⁵ reviewed 212 consecutive revision knee arthroplasties performed between 1997 and 2000; 55.6% of revisions were done less than 2 years after the index procedure. Early failures were defined as less than 2 years from the primary procedure. Revision surgery in this group was performed primarily for instability or malalignment. Late failures were defined as occurring more than 2 years from the index procedure, and polyethylene failure was the most prevalent mechanism. Overall, the reasons for revision surgery were largely due to polyethylene wear, aseptic loosening, instability, and infection. Specifically, 25% were revised for polyethylene wear; 24.1% were revised for aseptic loosening; 21.2% were revised secondary to instability; 17.5% were revised because of infection; 14.6% were revised for arthrofibrosis; 11.8% were revised for malalignment; 6.6% were revised due to extensor mechanism deficiency; 4.2% were revised because of avascular necrosis of the patella; 2.8% were revised for periprosthetic fracture; and 0.9% were revised with isolated patella resurfacing. It is clear that infection, polyethylene wear, instability, and aseptic loosening comprise the leading mechanisms of failure.

INFECTION

In the series authored by Fehring et al,¹⁴ 38% of revisions were secondary to infection (Fig. 1), the leading

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FIGURE 1. Infected total knee arthroplasty.

mode of failure in this study. The mean time from the index procedure was 19.42 months. In the report from Sharkey et al,¹⁵ 30 of 37 knee arthroplasties revised for infection were within 2 years from the index procedure. These early cases were most likely related to perioperative contamination. Persistent drainage, hematoma, and delayed healing have been shown to increase the risk of infection.¹⁶ Aggressive treatment of these postoperative complications has been shown to reduce the incidence of chronic infection and leads to implant retention in 50% of cases.^{17,18} Late infections are most likely from hematogenous seeding. Although controversial,¹⁹ prophylactic antibiotics preceding procedures such as colonoscopy, dental work, and abdominal surgery may reduce seeding of prosthetic joints. Patient nutrition is an often underappreciated factor in infection. Wound complications are related to a preoperative total lymphocyte count less than 1500 cells/mm³, serum albumin level less than 3.5 g/L, and a low serum transferrin level.¹⁴ Infection rates at major centers occur in less than 1% of cases. A reduction in this rate would be difficult to achieve. This can be attributed to meticulous sterile technique, the use of prophylactic antibiotics, limiting the flow of personnel through the operating room,^{20,21} and use of appropriate gowning and draping techniques.^{22–24} However, with careful technique and aggressive treatment of perioperative wound problems, revision with component removal attributed to infection could perhaps be reduced.

■ POLYETHYLENE WEAR

Polyethylene wear (Figs. 2, 3) accounted for 7% of revisions in Fehring et al's series¹⁴ and, at 25%, was the leading cause of revision in Sharkey et al's series.¹⁵ The average time to polyethylene failure was 7 years in the latter study compared with 41.4 months in the former study. This may account for the difference in the prevalence of this failure mechanism. Component design con-



FIGURE 2. Radiographic appearance of polyethylene wear.

tributes to bearing surface failure. Flat bearing surfaces have shown a high failure rate.⁹ Backside wear from modular metal-backed tray micromotion can generate biologically significant particles that lead to synovitis and osteolysis.^{25,26} This micromotion could be due to deterioration of the locking mechanism after implantation, as reported by Engh et al.²⁷ Metal-backed tibial components have shown an increased incidence of osteolysis when compared with all-polyethylene tibial designs.²⁸ Implant design also plays a role in the type of particle generated. Components with a highly congruent design wear via adhesive and abrasive wear. The size of the generated particles is related to the surface roughness

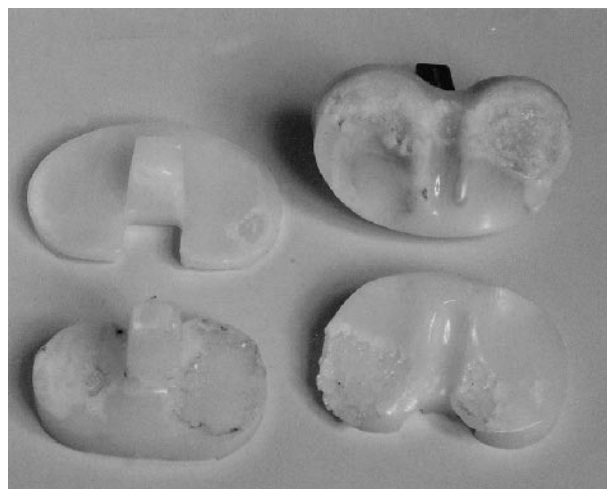


FIGURE 3. Retrieval polyethylene insert specimens demonstrating wear.

of the articulating surfaces. Particles generated from polyethylene fatigue, either from impingement or delamination, tend to produce larger particles.¹¹ Macrophages tend to phagocytose submicron particles and release factors that initiate bone resorption. However, larger particles generated through delamination induce third body wear that may produce smaller particles that are more easily engulfed by macrophages.¹¹ The biologic reaction to wear particles needs to be further elucidated. Prostaglandins, cytokines, metalloproteinases, and lysosomal enzymes are produced at prosthetic interfaces, but each of their relative roles is not yet clear.¹² In addition, other factors influence wear, such as patient activity and weight, polyethylene thickness and quality, method of sterilization, and overall alignment of the limb.¹¹

Regardless of the exact mechanism of polyethylene wear, osteolysis secondary to particulate matter results in loss of bone stock. This bone loss must be accounted for in preoperative planning. The degree of osteolysis may be underestimated using plain radiographs.²⁹ The surgeon must account for bone loss, have allograft bone available, and choose a revision system that allows for augmenting the remaining bone stock with metal.

■ INSTABILITY

Instability secondary to inadequate ligamentous balancing is a significant and preventable complication leading to revision. Improper intraoperative decision making without proper attention to varus–valgus alignment and flexion–extension gaps results in instability. This was the cause for revision in 26% of cases reported by Fehring et al¹⁴ and 21.2% of cases reported by Sharkey et al¹⁵ This is a significant revision rate for a preventable problem. Proper attention to soft tissue tensioning is mandatory.³⁰ It is important to remember that current instrumentation systems are precise but do not guarantee perfect alignment, soft tissue balancing, and resultant stability. The surgeon should select an implant that allows tailoring of constraint to the patient's need for constraint. In the future, improved instrumentation and computer-assisted surgery may reduce the prevalence of instability leading to revision in total knee arthroplasty.

Patellofemoral maltracking is also another form of instability. This can be avoided by careful assessment of femoral component rotation by using Whiteside's line, the epicondylar axis, and the posterior femoral condylar axis. Tibial rotation is equally important. The surgeon should ensure that the Q-angle is not increased by errant external rotation of the tibial component. It is important to medialize the patella component. Finally, adequate repair of the medial retinacular structures and the vastus medialis obliquus tendon is paramount. If the above con-

ditions are satisfied and the patella tracking is still poor, lateral release should be considered.

■ ASEPTIC LOOSENING

Aseptic loosening (Fig. 4) led to revision in 16% of cases in Fehring et al's study.¹⁴ However, 13% of revisions performed were due to failure of ingrowth into an uncemented prosthesis. Three percent of revisions were performed for loosening in cemented components. As a result, the authors reviewed the literature, and in concert with their results, they found no justification for using uncemented components in total knee arthroplasty. In the series by Sharkey et al,¹⁵ aseptic loosening accounted for 24.1% of revisions. The average time to failure was 4 years after the index procedure. Twenty-one percent of these failed components were uncemented. This further supports cementing all total knee arthroplasties. Surface cementing accounted for a large percentage of failures within this subset. Surface cementing technique involves cementing the undersurface of the tibial base plate and leaving the keel uncemented. This method accounted for 10.5% of loose revised components in this series. Bert and Kelly reported a 6.2% revision rate for surface cemented prostheses at an average 3.2 years after implantation.³¹ However, the majority of aseptic loosening was attributed to malalignment. In Sharkey et al's study, 44% of aseptic and loose components were in malaligned knees.¹⁵ This points to an interrelationship between modes of failure.

■ MISCELLANEOUS

Extensor mechanism problems such as extensor lag and disruption can lead to revision. Furthermore, aseptic ne-



FIGURE 4. Radiographic appearance of aseptic loosening three years after the index procedure.

crisis of the patella can follow resurfacing³² and is difficult to treat in a satisfactory manner. However, patients with un-resurfaced patella may continue to complain of anterior knee pain, and isolated revision for patella resurfacing may be needed. Resurfacing of the patella occurred in 0.9% of revision knee replacements in Sharkey et al's series.¹⁵ Peripatella fibrosis (patella "clunk"), while not necessarily the only cause of revision, may require further operative intervention such as arthroscopy.

Periprosthetic fracture, arthrofibrosis, and patient factors are additional failure mechanisms. Patients with a poor preoperative mental health score had increased risk of suboptimal outcome following total knee arthroplasty.³³ The surgeon should always attempt to identify a cause for failure prior to revision surgery to optimize outcome.

■ SUMMARY

Infection, polyethylene wear, instability, and aseptic loosening are the preeminent factors necessitating revision of primary total knee arthroplasty. The rate of infection is difficult to reduce below a 1% incidence. Surgeons should continue to be vigilant in preventing infection preoperatively and aggressive in treating postoperative wound complications. Polyethylene wear can be reduced by rigorous industry monitoring and standards for quality, including appropriate sterilization methods. Surgeons must achieve proper alignment intraoperatively and encourage patients to achieve and maintain proper weight control thru appropriate postoperative knee activities. Implant selection is paramount to success. Proper prosthesis selection should ensure accurate instrumentation, intelligent design, and multiple constraint options. Aseptic loosening can be reduced dramatically by ensuring proper alignment and through proper fixation techniques. Proper fixation involves cementation of primary components and abandonment of surface cementing and uncemented components. Furthermore, evaluation of the extensor mechanism and stability throughout a range of motion of the joint must be performed. Most importantly, in failed primary total knee arthroplasty, one must identify a mechanism of failure to maximize the success of revision surgery.

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