Complications resulting in prosthesis failure following total knee arthroplasty: a pictorial review

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Authors: N. M. Hughes¹, A. J. cassar-gheiti², J. Cashman², S. J. Eustace³, E. C. Kavanagh¹; ¹Dublin/IE, ²Dublin 11/IE, ³Dublin 4/IE
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Learning objectives

To illustrate the range of complications found on radiographs that are associated with prosthesis failure following total knee arthroplasty.
Background

Total knee arthroplasty is a common surgical procedure. It is a safe and effective procedure that improves function and quality of life in patients with severe arthritis. In most member countries of the Organisation for Economic Co-operation and Development (OECD), the number of total knee replacements performed has rapidly increased since 2000, with rates almost doubling between 2000 and 2015¹.

Total knee arthroplasty is performed predominantly in patients with arthritis, most commonly osteoarthritis. Joint replacement is indicated in patients who have failed non-surgical management and have persistent pain causing significant functional limitation impacting on quality of life in combination with radiological features of arthropathy. There are many risk factors for osteoarthritis include increasing age, female gender, obesity, previous trauma to the joint and repetitive mechanical stress and the prevalence of osteoarthritis is increasing because of a combination of the increasing elderly population and rising obesity rates.

A total knee replacement involves removal of the tibiofemoral condylar surface and placement of a distal femoral metal prosthesis, a tibial tray and a polyethylene bearing interposed inbetween. Patellar articular surface replacement can also be performed by fixing a polyethylene component to the patellar articular surface. There are many different variations in prosthesis type and design which include prostheses designed to substitute or allow for retention of the posterior cruciate ligament, those with fixed or mobile bearings, cemented or uncemented prostheses and constrained prostheses. Despite the range of prostheses available the complications that can result in prosthesis failure do not vary significantly in general.

Common causes of prosthesis failure evaluated for by the radiologist include periprosthetic fracture, prosthesis loosening (septic and aseptic), polyethylene bearing wear or displacement, metallosis, osteolysis and instability. Imaging follow-up for patients following total knee replacement is performed routinely in our institution. Serial radiographs are performed on all post-operative patients up to 10 years post joint replacement. This article will focus on the radiographic features of complications that can result in prosthesis failure and it is important that radiologists be aware of these features to allow for early and accurate diagnosis.
Findings and procedure details

**Periprosthetic fractures:**

Periprosthetic fractures can occur intra-operatively and post-operatively involving the femur, tibia or patella and by definition are located within 15 cm of the joint surface or 5 cm from the intramedullary stem (2, 3, 4). There are several risk factors associated with different fracture locations, which can relate to prosthesis type, surgical technique as well as patient factors.

**Periprosthetic femoral fractures:** Distal femoral fractures are the most common type of periprosthetic fracture, usually affecting the supracondylar region. These types of fractures are often seen with a well fixed femoral component following relatively low-impact trauma. There are many risk factors associated with supracondylar fractures some of which are demonstrable on plain radiographs such as the presence of anterior femoral notching whereby there has been excessive resection of the anterior femur intra-operatively, the use of a rotationally constrained implant and the presence of osteolysis.

There are several different fracture classification systems reported in the literature but the Lewis and Rorabeck classification is widely used and takes into account fracture displacement and prosthesis stability (5) which will ultimately determine how the fracture will be managed. Rarely undisplaced fractures with a stable prosthesis can be managed conservatively however periprosthetic fractures treated conservatively have higher rates of malunion or non-union (6). Therefore the majority of fractures, whether undisplaced (Fig. 1) or displaced (Fig. 2, Fig. 3) will require surgical intervention, either with internal fixation if the prosthesis remains stable or revision total knee arthroplasty if the prosthesis is unstable.

**Periprosthetic tibial fractures:** Proximal tibial fractures are less common occurring both intra-operatively and post-operatively. Post-operatively fractures are usually as a consequence of trauma (Fig. 4) however, stress fractures can occur, often related to malalignment or malposition of the prosthesis (7).

The most widely used classification system for tibial periprosthetic fractures is the Mayo classification system which takes into account the location and proximity to the prosthesis, whether the prosthesis appears fixed or loose radiographically and whether the fracture occurred intraoperatively (8). Management of these fractures is dictated by the fracture location and pattern, the stability of the prosthesis and the underlying bone
stock with conservative management and with surgical approaches including internal fixation, usually with locking plates and screws, or revision total knee arthroplasty.

**Periprosthetic patellar fractures:** Patellar fractures are uncommon, especially in the absence of patellar surface replacement. Risk factors visible radiographically include osteonecrosis of the patella, malalignment of the prosthesis and the type of prosthesis used, for example, a patellar resurfacing prosthesis with a large central peg (Fig. 5) is reported to be higher risk of fracture compared with smaller, more peripherally placed pegs (9).

The most commonly used classification system for patellar fractures is the Ortiguera and Berry classification system which is divided into four categories based on a fixed or loose prosthesis, the quality of bone stock and the integrity of the extensor mechanism (10). A more conservative approach is taken for managing patellar fractures, especially for those with intact extensor mechanism and stable prostheses. Surgical intervention can be considered such as internal fixation, complete or partial patellectomy, repair of the extensor mechanism and revision of the total knee arthroplasty.

**Periprosthetic infection:**

Periprosthetic infection can be classified as acute within 2 months of surgery, intermediate between 2 months and 2 years after surgery, and delayed when it occurs more than 2 years following surgery. The route of infection is usually haematogenous spread from a distant site. Staphylococcus aureus and Staphylococcus epidermidis are the two most common pathogens. Unfortunately radiographs are not sensitive or specific for diagnosis of periprosthetic infection. The radiographic appearances can range from normal to osseous destruction, which is indistinguishable from osteolysis (Fig. 6). Other imaging modalities such as bone or leucocyte scintigraphy can be useful, however, ultimately diagnosis is confirmed by aspiration and analysis of joint fluid. Treatment usually involves removal of the infected prosthesis and insertion of an antibiotic impregnated spacer, followed by delayed reimplantation of a new prosthesis (two-stage revision) and accompanied by a prolonged course (4-6 weeks) of appropriate intravenous antibiotics. Other surgical options would include salvage procedures such as resection arthroplasty, arthrodesis and amputation.

**Osteolysis and aseptic prosthesis loosening:**
Osteolysis refers to progressive periprosthetic osseous destruction and results in aseptic loosening. Aseptic loosening is reported as the most common cause of prosthesis failure (11), usually late, and nearly always necessitates revision arthroplasty. The aetiology of osteolysis is complex and there are multiple mechanical and biological theories of how osteolysis develops but it is likely that both mechanical and biological events contribute to the osseous destruction (12). Risk factors include older patients, male sex, type of polyethylene used in the meniscal bearing and the implant design itself (13).

Patients are often asymptomatic in the early stages of the disease so radiographic detection is important on routine follow-up studies (Fig. 7, Fig. 8) to avoid complications such as prosthesis subsidence resulting in varus alignment of the tibia (Fig. 9, Fig. 10) and pathological fracture (Fig. 11).

Osteolysis is visible on radiographs as a new or enlarging radiolucency surrounding the prosthesis or at a cement-bone interface and should be differentiated from stress shielding (14). Stress shielding refers to demineralisation of bone secondary to the mechanical load of the prosthesis and tends to be located adjacent to the flanges of the femoral component or the tibial tray (15). Examination of serial radiographs is of the utmost importance to differentiate stress shielding from osteolysis as the periprosthetic lucency related to stress shielding remains stable in contrast to the progressive nature of osteolysis. Femoral component loosening is less common and femoral osteolysis can be difficult to assess for on plain radiographs, but it is possible to detect prosthesis loosening, without evidence of osteolysis on plain radiographs (Fig. 12).

**Polyethylene bearing-related complications:**

The most frequent complication that occurs with the polyethylene bearing is as a result of polyethylene wear. This is a common cause of revision arthroplasty which occurs as a result of mechanical load and is also influenced by the type and thickness of the bearing. Long term wear of the bearing results in osteolysis (as discussed previously), however with complete wear of the bearing and direct interaction of the femoral component on the tibial tray, a metal-on-metal reaction occurs resulting in metallosis.

Radiographic assessment of polyethylene bearing wear can be difficult. Weightbearing views are required and sequential assessment is important to assess for progressive loss of space between the femoral component and the tibial tray which is the earliest radiographic indicator. As wear progresses, osteolysis may be evident. With complete liner wear and metal-on-metal reaction, a joint effusion may be visible, which becomes more dense approaching metal density (Fig. 13).
Displacement of the polyethylene bearing from the tibial tray (Fig. 14) is rare with few cases reported in the literature. The aetiology is unclear but it is though that incomplete seating intra-operatively, a shallow tibial tray and trauma may be risk factors (16).
Fig. 1: A and B are AP and lateral radiographs of the right knee showing an undisplaced distal femoral (supracondylar) periprosthetic fracture (black arrows) with a stable prosthesis - Lewis and Rorabeck Type I. C and D are the post operative radiographs after the patient underwent open reduction and internal fixation with a distal locking plate with a retained prosthesis.

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Fig. 2: A and B are AP and lateral radiographs showing a comminuted displaced distal femoral (supracondylar) periprosthetic fracture with an unstable prosthesis - Lewis and Rorabeck III. C and D are the immediate post-operative radiographs following open reduction and internal fixation with a distal locking plate and a retained prosthesis. E and F are the most recent radiographs performed 4 months following the fracture showing ongoing healing at the fracture site.
**Fig. 3:** A and B are AP and lateral radiographs showing a displaced distal femoral (supracondylar) periprosthetic fracture with an unstable prosthesis - Lewis and Rorabeck type III. C and D are the immediate post-operative radiographs following revision using a distal femoral endoprosthesis.

**Fig. 4:** A and B show AP and lateral radiographs immediately post-operatively following total knee arthroplasty with normal alignment and no evidence of complication. C and D are the follow-up radiographs which show interval (although subacute) post-traumatic fractures of the proximal tibia and fibula. The proximal tibia fracture has resulted in prosthesis instability with medial and posterior subsidence of the tibial tray - Mayo
classification type IIb. E and F are the post-operative radiographs showing revision total knee arthroplasty with a constrained, long stem prosthesis.

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**Fig. 5:** A is lateral radiograph of the knee shows a mildly displaced fracture at the proximal pole of the patella adjacent to a patellar resurfacing prosthesis which has one large central peg and remains fixed (Ortiguera and Berry classification Type I). A constrained long stem revision total knee replacement is also in place.

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Fig. 6: A and B are normal radiographs post total knee replacement radiographs. C and D are radiographs performed following re-presentation with an erythematous, swollen knee, which show interval development of peri-prosthetic lucency surrounding both the tibial and femoral components (black arrows), femoral component loosening (white arrow) and patellar articular surface irregularity and destruction (white arrowhead), suggestive of periprosthetic infection. Synovial fluid aspirate was performed for confirmation and the patient was placed on a prolonged course of antibiotics and planned for a two-stage revision. E and F show removal of the prosthesis and placement of an antibiotic impregnated spacer. G and H show the subsequent revised constrained total knee arthroplasty.
Fig. 7: A and B are AP and lateral views of the knee with periprosthetic lucency demonstrated posteriorly in the medial tibial plateau, deep to the tibial tray, consistent with osteolysis (black arrows). There is normal alignment of the prosthesis with no subsidence.

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**Fig. 8:** A and B are AP and lateral radiographs showing periprosthetic lucency in the tibial plateau, deep to the tibial tray, consistent with osteolysis (black arrows). There is normal alignment of the prosthesis with no subsidence.

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**Fig. 9:** A and B are AP and lateral radiographs showing periprosthetic lucency in the tibial plateau deep to the tibial tray (A) and anterior to the tibial stem (B) consistent with osteolysis (black arrows). There is subsidence of the medial tibial tray with associated secondary varus alignment of the tibia.

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**Fig. 10:** A and B are the normal post-operative radiographs following total knee arthroplasty. C and D show interval development of periprosthetic lucency anteroinferior
to the tibial stem (C) and deep to the anterior part of the femoral component (D), consistent with osteolysis (black arrows). E and F show progressive lucency in the tibia and femur (black arrows) with new posterior and medial subsidence of the tibial tray and mild secondary varus alignment of the tibia.

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**Fig. 11:** A and B are AP and lateral radiographs showing periprosthetic lucency in the tibia, best demonstrated on the lateral view (black arrows), consistent with osteolysis, with resulting posterior and medial subsidence of the tibial tray, and secondary varus alignment of the tibia. C and D show progressive osteolysis (black arrow) with progressive subsidence and new periprosthetic fracture of the proximal tibia - Mayo classification Type IIB. E and F are the radiographs performed immediate post revision with a constrained long stem prosthesis. G and H performed 6 months after initial fracture show ongoing healing at the fracture site.

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Fig. 12: A and B are AP and lateral radiographs of a normal total knee arthroplasty. C and D are follow-up radiographs which demonstrate loosening of the femoral component (white arrow), without evidence of osteolysis.

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Fig. 13: A and B are AP and lateral radiographs performed post total knee arthroplasty demonstrating a joint effusion (white arrow). Subsequent radiographs C and D show loss of space between the femoral component and the tibial tray suggestive underlying wear of the polyethylene bearing and an interval increase in the size and the density of the effusion, which some areas approaching that of metal (white arrows), consistent with secondary metallosis.

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Fig. 14: A and B are AP and lateral radiographs performed post total knee arthroplasty demonstrating displacement of the polyethylene meniscal bearing (black arrow).

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Conclusion

There are a range of complications that can result in prosthesis failure following total knee arthroplasty and it is important that radiologists be aware of the imaging features to accurately diagnose these complications.
Personal information

Department of Radiology,
Cappagh National Orthopaedic Hospital,
Cappagh Road,
Finglas,
Dublin 11,
Ireland.
References


