# Fatigue fracture of the femoral component in a mobile bearing knee prosthesis

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**Stress fracture of the femoral component is a rare complication following total knee arthroplasty. We report one such complication which occurred 6.5 years after primary implantation of an uncemented meniscal Low Contact Stress (LCS) prosthesis. The fracture affected the medial condyle of the femoral component, and a large osteolytic lesion was present in the underlying femoral condyle. The patient underwent revision arthroplasty with a cemented constrained condylar knee, which is still in place with a satisfactory result 12 years later.**

**This complication appears to be very rare, although a number of cases probably go unreported. From data available in literature, it appears that stress fractures of the femoral component have predominantly affected the medial condyle, following uncemented implantation of fixed-bearing as well as mobile-bearing knees. Different mechanisms may be involved : specific design features of the implant, failure of bone ingrowth in uncemented components, and osteolysis from particulate wear debris.**

Keywords : total knee arthroplasty ; stress fracture ; femoral component.

## INTRODUCTION

Fracture of the femoral component is an unusual complication of total knee arthroplasty (TKA) with a condylar prosthesis. Several cases were first reported with the cementless double-bead layered Ortholoc II prosthesis (Dow Corning Wright, Arlington, TN, USA) and the mechanism which lead to component failure was found to be related with design and manufacturing features of that implant (*18*). Stress fracture of a femoral component in TKA has subsequently been reported with other implants, although not to a similar extent. Fracture of the femoral component of a Genesis knee prosthesis (Smith&Nephew, Memphis, TN, USA) was reported by Luring *et al* (*10*) and also by Michos *et al* (*11*) ; Duffy *et al* (*4*) reported two femoral component fractures in PFC implants (DePuy, Johnson&Johnson, Raynham, Mass, USA). Huang *et al* (*7*) reported fracture of the femoral component of a Rotating Platform Low Contact Stress (RP LCS) prosthesis (DePuy, Johnson&Johnson, Raynham, Mass, USA), and Han *et al* (*6*) reported a similar complication with an Anterior-Posterior Glide Low Contact Stress (AP Glide LCS) prosthesis. We report a stress fracture of the femoral component of a meniscal LCS prosthesis.

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**Fig. 1.** — Preoperative radiographs (AP & lateral) of the right knee, showing severe destruction of the articular cartilage in the lateral compartment, with a valgus deformity. The HKA angle on full-leg standing film was 12° in valgus.

## CASE REPORT

A 58-year-old female patient with moderate valgus deformity of both knees and severe osteoarthritis mostly affecting the lateral femoro-tibial compartment of her right knee (fig 1) underwent total arthroplasty on her right knee in November 1990. A posterior cruciate ligament preserving meniscal bearing New Jersey Low Contact Stress prosthesis (DePuy, Warsaw, IND, USA) was implanted with standard plus cementless femoral and tibial components, and a cementless mobile bearing patellar prosthesis (fig 2). She had a satisfactory clinical result, with a pain free knee and a range of motion from full extension to 105° flexion. She had regular clinical and radiological follow-up at 3 months, 6 months and 12 months after surgery, then at one-year intervals, without any change in her clinical and radiological result. The only

abnormal finding was a persisting moderate knee effusion ; the knee was not inflammatory and she reported no pain at rest nor when standing or walking. She reported no limitation in her daily activities in relation with the operated knee, and she did not use walking aids.

In March 1997, she started complaining of increasing pain in her right knee and noted an increase in the volume of her knee effusion. On physical examination in May 1997, a marked non-inflammatory knee effusion was noted, and also, on the knee in flexion, a posterior sag which was not present at previous examinations. Standard AP radiographs of the knee showed direct contact between the medial femoral condyle and the tibial baseplate of the prosthesis, indicating severe wear of the medial meniscal bearing. The lateral view showed a break in the contour of the medial condyle of the femoral component, indicating fracture of the implant (fig 3).

A revision operation was performed two days later. A tranverse fracture of the medial condyle of the femoral component was noted at the junction of its distal part with the posterior bevel (fig 4a). The posterior half of the medial meniscal bearing was grossly worn off, presumably due to abrasion by the edges of the femoral component fracture, and the bearing was no longer mobile in its trough (fig 4b), whereas the lateral bearing showed no macroscopic signs of wear and exhibited normal mobility. The edges of the medial trough on the tibial plate were severely scratched ; the tibial component was therefore removed as well as the femoral component. The patellar component was unremarkable. The posterior part of the medial condyle of the prosthesis was found to rest on a large osteolytic area in the medial condyle, whereas the rest of the femoral component was bone ingrown and was well fixed to the underlying bone ; the tibial baseplate and the patellar component were also ingrown and well fixed.

Pathologic analysis of the tissue from the osteolytic defect showed foreign body granuloma with abundant refringent polyethylene particles.

A posterior stabilized Insall-Burstein constrained condylar knee (Zimmer, Warsaw, IND, USA) with femoral and tibial stem augmentation and a 5 mm
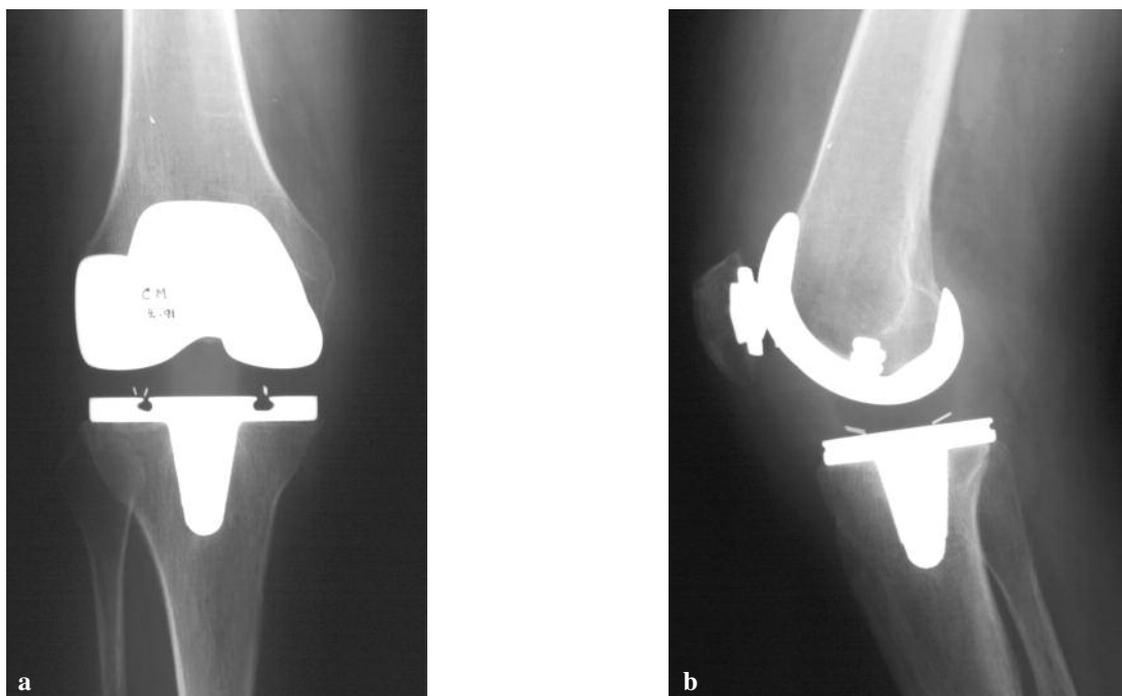
**Fig. 2.** — AP and lateral radiographs 3 months after cementless implantation of a meniscal PCL-preserving LCS prosthesis

medial femoral distal augmentation was implanted with all components cemented ; bone grafts were not used. The original uncemented mobile-bearing patellar component was exchanged for a cemented dome- shaped polyethylene implant.

The patient made an uneventful recovery and regained satisfactory pain free knee function. The yearly follow-up was continued.

In October 2001, the patient underwent total knee arthroplasty on her left knee with a cemented CERAGYR mobile-bearing prosthesis (Ceraver Osteal, Roissy, France) ; she made an uneventful recovery.

When last reviewed 19 years after the index operation and 12 years after the revision operation on her right knee, she reported no pain in either knee, the range of motion of the right knee was 0 to 110°, and 0° to 115° for the left knee. The patient reported no limitation in her daily activities and, although rather sedentary, she reportedly could walk on unlimited distances without external support. Radiographs showed no signs of polyethylene wear, osteolysis or loosening (fig 4).

## DISCUSSION

Fracture of the femoral component is an unusual complication of total knee arthroplasty. The fracture typically occurs by a fatigue mechanism, as demonstrated in metallurgical studies on retrieved fractured implants [3,6,14,18].

Design and manufacturing features of the implants have in specific cases contributed to the occurrence of stress fractures : Whiteside *et al* reported in 1993 [18] four personal cases of fracture of the femoral component with the double-bead layered Ortholoc II prosthesis ; he stated that 31 such fractures had been reported at the time of writing for that specific implant, of which 6172 specimens had been sold at that time, which translates into a fracture rate of 0.50%. The fracture rates were reportedly 0.82% for small-size components, 0.37% for medium-size, 0.29% for large-size and 0.09% for extra-large components [18]. Whiteside *et al* reported a 0.85% fracture rate in their personal experience with the double-bead layer Ortholoc II prosthesis [18]. Wada *et al* reported an occurrence
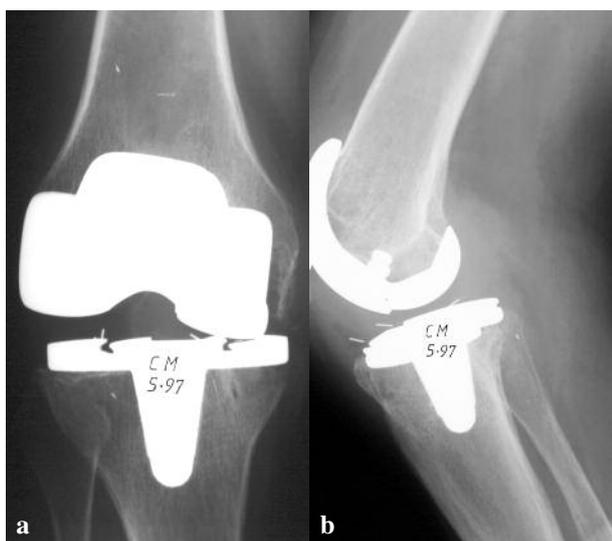
*Fig. 3.* — AP and lateral radiographs 6.5 years after the index arthroplasty, showing direct contact between the medial condyle of the femoral component and the tibial baseplate, with resulting tilt of the knee into varus.

rate of 3.3%, with 3 femoral component fractures among 92 small-size Ortholoc II femoral components (*17*). Cook and Thomas reported in 1991 a stress fracture of the femoral component of an Ortholoc II prosthesis which they studied after retrieval (*3*), and Swarts *et al* (*14*) reported the results of metallurgical studies on 6 retrieved femoral components, all from Ortholoc II prostheses. As shown in table I, the double-bead layered Ortholoc II femoral component is by far the component that has been most frequently affected by a stress fracture. Specific design features of that implant are considered to have played a major role in the mechanism leading to fracture of the femoral component. In 29 of 31 implants studied by Whiteside *et al*, the fractures occurred at the junction of the posterior bevel with the distal condylar part, at a point where the metal thickness was reduced below 3 mm ; this proved insufficient with respect to the local loads and stresses (*18*), particularly in small-size components which represented a majority of the components that fractured. The double layer of bead coating further weakened the implant, by notch effects of the beaded surface and also due to the sintering process which resulted in microstructural changes secondary to the heating process. Furthermore, a

unique feature of the Ortholoc II was that the bead coating did not extend to the anterior and posterior flanges.

No fatigue fractures were reported in literature for several years with other types of femoral components, so that this complication was considered to have been related with specific design features of the Ortholoc II prosthesis. However, two cases were reported in 2006 and 2007 respectively with the Genesis prosthesis (*10,11*), and two cases with the PFC prosthesis were reported in 2007 (*4*).

The first case of a stress fracture affecting the femoral component of a mobile-bearing knee prosthesis was reported by Huang *et al* in 1999, in a Rotating Platform LCS New Jersey prosthesis (*7*). Han *et al* reported in 2009 a stress fracture affecting a similar component in an Anterior Posterior Glide LCS knee (*6*). The present case affecting a meniscal LCS knee adds to these two cases. The porous coated femoral component was similar in these three variants of the LCS knee prosthesis. The LCS New Jersey was the first mobile-bearing knee that was available on the marketplace, and it has been implanted on a large scale ever since ; this may be the main reason why it was involved in the only three cases of stress fracture of the femoral component reported so far in mobile-bearing knees.

Table I presents a list of the cases reported in literature. It is likely that more such fractures occurred but went unreported ; more cases have been reported in local journals with no English language abstract (*2,16*). The 2008 report from the National Joint Registry (NJR, England and Wales) reports 40 cases (1%) of "implant breakage", without further detail (*13*) ; they presumably also include cases of polyethylene bearing breakage. The 2009 report of the Australian Knee Registry more specifically mentions 16 cases (0.5%) of femoral implant breakage which were revised following known primary TKA (0.57% of 2814) and 96 cases which were revised for the same reason among all revision operations (1.07% of 9128) (*1*).

Although table I certainly does not give an exhaustive list of the cases of femoral component breakage which occurred in the history of total knee arthroplasty, it nevertheless allows some interesting observations :
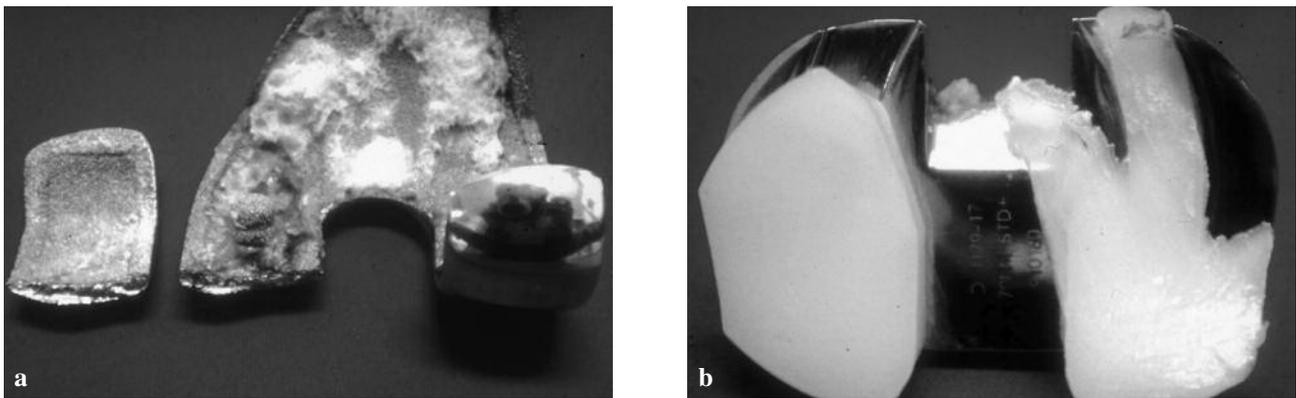
**Fig. 4.** — (a) View of the retrieved femoral component, with a fractured medial condyle at the junction between the distal part and the posterior bevel. (b) View of the retrieved tibial component, with complete wear of the posterior part of the medial polyethylene bearing while the lateral bearing is intact.

1. Majority of the cases reported were in fixed-bearing knees, which reflects the larger number of such prostheses implanted to date ; mobile-bearing knees were however not immune to this complication. Excluding the Ortholoc II from the comparison leaves fairly similar numbers of fixed-bearing (4) and mobile-bearing knees (3).
2. The time interval between the index arthroplasty and the femoral component fracture has been in a large range, from 20 months to 11 years ;
3. Among 21 cases in which the patient's gender was reported, there was an almost even occurrence in male (12) and female (9) patients, with ages ranging from 51 to 75 years at time of the index procedure. The average age, at 58.1 years, is younger than in most TKA cohort studies, which is typically around 70 years. In the Norwegian Knee Register, the average age of patients undergoing primary TKA was 69.5 years (*12*) ; it was 70.2 years in the (UK) National Joint Registry (*13*) and 69 years for females and 68.3 years for males in the Australian Joint Replacement Registry (*1*). Younger age is presumably associated with a higher activity level resulting in higher stresses on the implants.
4. Fractures did not predominantly affect any specific implant size among the 13 cases in which this was specified.
5. The fracture predominantly affected the medial condyle of the femoral component (21 cases), whereas the lateral condyle and the trochlea were affected in only one case each. This may be related to the higher load share of the medial knee compartment, which may be made worse if the knee has been realigned with a slight varus deformity.
6. Of 23 femoral components which presented a stress fracture, 18 (78%) were uncemented and only 5 (22%) were cemented. This is in sharp contrast to the proportions of cemented and uncemented implantations in primary TKAs : despite marked local variations, there is indeed an overall predominance of cemented implantation. The 2009 report of the Swedish Knee Registry reports a 98.2% proportion of cemented TKAs (*15*) ; in the 6th NJR (UK) report, 83% of primary TKAs were cemented, 7% uncemented and 1% hybrid (*13*). In the Australian Joint Replacement Registry, 52.3% of the femoral components were cemented in primary TKA (*1*). All but one of the femoral component fractures reported by Whiteside *et al* (*18*) affected uncemented components. One may argue that the fractures with the Ortholoc II prosthesis, designed for cementless fixation, were essentially related with specific features of its femoral component ; however, a comparison restricted to prostheses other than

Table I. — Overview of femoral component stress fractures reported in literature following primary TKA

| First Author | Journal | Implant | FB/MB | M/L | Size | Fixation | PE | Patient gender/age | Delay |
|---|---|---|---|---|---|---|---|---|---|
| Cook | JBJS B 1991 | Ortholoc II | FB | Medial | NA | UNCEM | NA | M69 | 20 m |
| Whiteside | CORR 1993 | Ortholoc II | FB | Medial | Large | UNCEM | NA | M64 | 25 m |
| | | Ortholoc II | FB | Medial | Large | UNCEM | NA | M64 | 37 m |
| | | Ortholoc II | FB | Medial | XLarge | UNCEM | NA | M64 | 40 m |
| | | Ortholoc II | FB | Medial | Medium | UNCEM | NA | F59 | 43 m |
| Wada | Int Orthop 1997 | Ortholoc II | FB | Medial | Small | CEM | NA | F71 | 32 m |
| | | Ortholoc II | FB | Medial | Small | UNCEM | NA | F72 | 52 m |
| | | Ortholoc II | FB | Medial | Small | UNCEM | NA | F62 | 73 m |
| Chun | Korean Orthop Assoc | Ortholoc II | FB | Medial | NA | CEM | NA | NA | NA |
| | | Ortholoc II | FB | Medial | NA | CEM | NA | NA | NA |
| Swarts | JOA 2001 | Ortholoc II | FB | Medial | NA | UNCEM | NA | M73 | 5 y |
| | | Ortholoc II | FB | Medial | NA | UNCEM | NA | M71 | 4 y |
| | | Ortholoc II | FB | Medial | NA | UNCEM | NA | F75 | 7 y |
| | | Ortholoc II | FB | Medial | NA | UNCEM | NA | F69 | 7 y |
| | | Ortholoc II | FB | Medial | NA | UNCEM | NA | F51 | 10 y |
| | | Ortholoc II | FB | Lateral | NA | UNCEM | NA | M70 | 11 y |
| Michos | JOA 2006 | Genesis II | FB | Medial | Medium | UNCEM | NA | F72 | 3y |
| Luring | KSSTA 2007 | Genesis II | FB | Medial | NA | CEM | 10mm | M68 | 9 y |
| Duffy | JOA 2007 | PFC | FB | Medial | Size 6 | UNCEM | NA | M | NA |
| | | PFC | FB | Medial | Size 6 | UNCEM | NA | M | NA |
| Huang | JOA 1999 | LCS RP | MB | Medial | Large | UNCEM | 10mm | M63 | 42 m |
| Han | JOA 2009 | LCS APG | MB | Trochlea | NA | CEM | 10mm | M58 | 43 m |
| Lemaire | AOB 2010 | LCS Men | MB | Medial | STD+ | UNCEM | 10mm | F58 | 78 m |

(FB = fixed bearing ; MB = mobile bearing ; M/L = medial/lateral ; CEM = cemented ; UNCEM = uncemented ; PE = polyethylene bearing thickness ; NA = not available ; y = years : m = months).

the Ortholoc II shows a similar predominance in uncemented implants (5/7) over cemented implants (2/7).

Different mechanisms may have been responsible for femoral breakage in the reported cases : spe-cific design features in the case of the Ortholoc II prosthesis, failure of bone ingrowth in the two uncemented PFC knees reported by Duffy et al (4) and in an uncemented Genesis II reported by Michos et al (11), while osteolysis seems to have played a major role in the others, i.e. a cemented

*Fig. 5.* — AP and lateral radiographs after revision with an Insall-Burstein constrained condylar prosthesis with femoral and tibial stem augmentation and a 5 mm distal femoral augmentation.

Genesis II (*10*) and three LCS knees, of which one was cemented (*10*) and two uncemented. As a result of osteolysis, part of the femoral component becomes unsupported while being exposed to high repetitive stresses. A similar situation may prevail if an uncemented component is only partially bone ingrown. It may indeed be difficult to achieve full and stable contact with bone at the junction of the bevelled surfaces of the femoral component, while cement fixation makes it easier to achieve a uniform stress distribution.

It may appear paradoxical that all three types of a mobile-bearing prosthesis designed to reduce wear have each been affected by at least one stress fracture of their femoral component related with osteolysis. Although *in vitro* gravimetric studies of polyethylene wear have shown less wear with mobile-bearing than with fixed-bearing knees, Huang *et al* have reported a higher incidence of

osteolysis in failed mobile-bearing knee prostheses than in failed fixed-bearing prostheses (*8*) ; they also noted in retrieval studies that the size of polyethylene wear particles was smaller in mobile-bearing prostheses (*9*), whereas *in vitro* studies in a knee simulator showed similar particle morphology for mobile- and fixed bearing prostheses (*5*).

Stress fracture of a metal component following TKA is a major complication which imposes a major revision operation, but it remains an exceptional cause for revision TKA. Past experience has shown how implant design can help reduce the possibility for component fractures to occur. The risk can also be reduced if full and stable contact with bone is achieved for uncemented implants through perfect bone cuts ; cement fixation may however be preferred as it may provide a more effective barrier against polyethylene wear debris. Osteolysis in the distal femur may be difficult to diagnose on plain follow-up radiographs ; when in doubt, further diagnostic workup should be considered, as the threat of a possible component fracture may be an argument to proceed to revision without delay.

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