Intra- and postoperative fractures of the femur in total knee arthroplasty
Risk factors in 32 cases

Purpose of the study
We reviewed fractures of the distal femur occurring during or after total knee arthroplasty in order to identify risk factors.

Material and methods
Twelve intraoperative fractures occurred between 1990 and 2000 in 617 total knee arthroplasties performed during this period. The circumstances of these fractures were noted in comparison with other prosthetic implants. Twenty other fractures of the distal femur occurred in 20 patients who had had a total knee arthroplasty during the same time period. Mean patient age at surgery was 72 years (range, 69-77). In addition to demographic data, we noted risk factors: bone demineralization related to general condition, rheumatoid arthritis or corticosteroid therapy, trochlear notch prior to the trochlear cut, bone resorption under the femoral implant, repeated knee surgery, abnormal stress on the distal femur due to hip disease, periprosthetic osteolysis without loosening related to polyethylene debris or metallosis, loosening, type of prosthesis, loss of bone stock because of the femoral implant, and life of prosthesis.

Results
Intraoperative fractures usually occurred in specific circumstances: use of a posterior stabilized prosthesis, probably with insufficient preparation and position of the stabilization element, probably excessive impaction in osteoporotic bone (rheumatoid arthritis), difficult exposure (arthroplasty after prior osteotomy), fracture starting from the separator passing over the posterior aspect of the tibia and reaching the intercondylar notch. Independently of these intercondylar fractures, supra-
condylar or diaphyseal fractures were essentially observed for revision prostheses using a femoral stem. Postoperative fractures were observed in patients who had prior surgery of the distal femur (revision of femoral osteotomy, fracture of the distal femur, arthrodesis), in patients with significant loss of bone stock (posterior stabilized prosthesis), or poor bone quality (rheumatoid arthritis), and in elderly patients with neurological impairment and frequent falls. The trochlear notch did not appear to be sufficient to be the only cause of fracture but was nevertheless an element frequently associated with other risk factors.

Discussion and conclusion

This study shows that fracture of the distal femur occurs in certain preferential circumstances. Considering these elements, a certain number of preventive measures can be discussed for technical modifications or choice of implants.

Key words: Distal femur, total knee arthroplasty, periprosthetic fracture.

INTRODUCTION

Intercondylar or supracondylar fractures of the femur are rare complications of total knee arthroplasty. The frequency of such fractures is difficult to evaluate (between 0.3 and 3%) depending on the series [Aaron and Scott (1), Culp et al. (2)] and the type of implant [Hanks et al. (3), Rorabeck and Taylor (4)]. They can occur during surgery or during recuperation, with a more or less long delay. Therapeutic problems are certain and the complication rate is high, which itself makes them serious: the literature reports a complication rate between 25% and 75%, even when arthroplasty is performed by experienced surgeons [Henry and Booth (5), Figgie et al. (6), Merkel and Johnson (7)]. For this reason, risk factors in this type of fracture, in certain patients, should be evaluated so as to work out preventive measures. Indeed, the data in the literature suggest that a certain number of circumstances are the triggering factors. This study aims to identify the risk factors and, with a retrospective series, to investigate whether these fractures occur in particular circumstances and whether preventive measures can be taken in some cases.

MATERIAL AND METHODS

Intraoperative fractures

Twelve intraoperative fractures were observed between 1990 and 2000 in a series of 617 total knee arthroplasties performed during this period. The study identified the circumstances that led to an intraoperative fracture and compared them with other prosthetic implants.

- type of implant (posterior stabilized with a box or femoral component without a box);
- first implantation or changed knee implant;
- placement of implant with centromedullary stem or without centromedullary stem;
- normal exposure or difficult exposure because of certain circumstances (knee surgery antecedents, arthroplasty after prior osteotomy, etc.).

Postoperative fractures

Twenty fractures of the distal femur were treated between 1990 and 2000 in patients who underwent total knee replacement for osteoarthritis (14 knees) or rheumatoid arthritis (six knees). The mean age of the patients at the time of surgery was 72 years (range, 69–77 years).

Seventeen of the total knee arthroplasties were tricomartmental sliding prostheses and three were cemented. Five of them included a femoral anchoring stem. All implants were cemented. These fractures occurred between 4 and 12 years after arthroplasty (mean, 6 years).

The study gathered the epidemiological data (age), the risk factors having led to the fracture — bone demineralization related to general condition, rheumatoid arthritis or corticosteroid therapy, trochlear notch prior to the trochlear cut [Ritter et al. (8)], bone resorption under the femoral implant [Short et al. (9)], repeated knee surgery, abnormal stress on the distal femur due to hip disease, periprosthetic osteolysis without loosening related to polyethylene debris or metallosis [Rand (10)], loosening, type of prosthesis, loss of bone stock because of the femoral implant, and life of the prosthesis.

The risk factors were analyzed by comparing the patients who had had a fracture with those undergoing knee arthroplasty but not having had a fracture during the same period between 1990 and 2000 at the Henri-Mondor Hospital. The two groups were paired on etiology and the type of knee implant. The 32 postoperative fractures of the distal extremity of the femur occurred among 605 prostheses implanted at the Henri-Mondor Hospital during this period. The two groups for comparison were, respectively, the 20 fractures of the distal extremity of the femur occurring postoperatively and the 585 cases of knee arthroplasty that did not experience a fracture either during or after surgery.

The presence of a notch on the anterior side of the femur was evaluated by defining a notch as an imprint 3 mm or greater on the lateral x-ray. When possible, the origin of the notch was evaluated: notch attributable to a position of the femoral component with excessive rotation (either internal or external); notch occurring after use of ancillary equipment to prepare the cuts from the landmark located on the anterior side of the femur, or, on the other hand, a notch occurring after use of ancillary material defining cuts from a space in flexion and therefore from a posterior landmark. The number of notches, the date the fracture occurred after the notch, and the revision of the notches on successive x-rays (if done) were studied. Finally, the location of the fracture line in relation to the notch was studied when a
fracture occurred: the starting point from the notch or the fracture totally independent of the notch.

For the statistical analysis, the chi-square test was used to compare the groups. Significance was set at $p < 0.05$.

RESULTS

Intraoperative fractures

Intraoperative fractures occurred most often (6/12 times) during posterior stabilized implantation. The type of fracture was usually a medial condyle fracture, the fracture line beginning at the axial edge of the femoral casing and running toward the medial cortex (fig. 1).

When the fracture did not occur on the posterior stabilized implant, i.e., with femoral implants and no casing, fractures only occurred during implantation on knees with rheumatoid arthritis or on knees that were more than particularly difficult to expose, with the fracture starting from the counter-angled separator passing over the posterior aspect of the tibia (fig. 2). In this situation, the fracture also ran most often toward the medial cortex and therefore separated the medial condyle (three cases).

A single supracondylar fracture occurred during surgery: it occurred in a female patient who had had hip arthrodesis, after implantation of a test prosthesis and during the testing of laxity in flexion and extension.

Finally, two diaphysis fractures occurred at the end of the stem of the femoral component used in revision, with the fracture starting in the femur extremity that had a low curve radius, giving a substantial posterior concave arch and an overly flexed position of the revision femoral component and its stem.

Postoperative fractures

Epidemiology and risk factors

The type of fracture was a short oblique fracture in four cases, a transversal fracture in five cases, a long and spiral fracture in four cases, and for all others a comminuted fracture. In four of the knees, preoperative x-rays suggested the occurrence of implant loosening concomitant with the fracture (not present on the x-rays preceding the fracture). In 12 cases, the fracture line descended below the upper part of the prosthetic trochlea. The fracture occurred a mean of 6 months (range, 3-9 months) after arthroplasty in four cases, whereas for the other knees, the fracture occurred between 4 and 12 years after knee replacement. In three cases, the fracture seemed to originate from periprosthetic osteolysis.

Age did not appear as a risk factor if mean age at the time of surgery is compared in the 20 patients with a fracture (mean, 74 years) to mean age at surgery of those without a fracture operated on during the same period (mean, 75 years). However, age at the time of fracture was significantly higher for patients who did not present rheumatoid arthritis (81 years) than for those presenting rheumatoid arthritis (six cases, mean age, 60 years). Rheumatoid arthritis (six patients) or regular corticosteroid use for another reason (two patients) was a general risk factor since these patients

![Fig. 1. - Detachment of the medial condyle from the preparation of the box of a posterior stabilized prosthesis. The diagram clearly shows that the medial condyle fracture is the most frequent in this type of situation given the anatomy of the distal extremity of the femur.](image-url)
accounted for eight of the 20 cases of fracture; among all patients with rheumatoid arthritis and receiving a total knee replacement (72 cases), the risk of fracture was 8% (6/72). In two cases, the fracture was essentially related to neurological ailments in patients who experienced repeated falls.

Another significant risk factor from a statistical point of view was the existence of a previous hip surgery, whether arthroplasty (figs. 3 and 4), osteosynthesis for per trocan teric fracture (fig. 5), or hip arthrodesis. Five patients from this series had a an abnormal hip on the same side, and the risk of fracture in the 50 patients presenting knee prosthesis with an operated hip above (prosthesis, synthesis for fracture of the upper extremity of the femur, arthrodesis) was five out of 50 (10%), whereas the risk was evaluated at 3% for the other patients operated on in the same period with a normal hip on the same side. Repeated surgery on the femur’s distal extremity was also a risk factor, whether for changing the implant (two cases), for revision of femoral varization osteotomy with knee replacement (two cases), or sequela from a fracture of the femur’s distal extremity (one case).

None of the patients with a fracture in this series had as the sole risk factor a 3-mm superior anterior femoral notch. Among all patients undergoing surgery (between 1990 and 2000), an anterior trochlear notch measuring at least 3 mm was found in 4% of patients. Of the 10 patients presenting with an abnormal hip above (five cases) or repeated knee surgery (five cases), an anterior notch greater than 3 mm was present in four cases, and the fracture line went through the notch (fig. 6).

### DISCUSSION

The risk of intraoperative fracture during posterior stabilized implantation with box can be explained by the bone cut necessary for placing the implant. The intercondylar line most often separates the medial condyle for anatomic reasons, as shown in fig. 1. The distance from the medial cortex to the bottom of the casing is less than the distance from the lateral cortex to the bottom of the casing, both on the frontal x-ray and on the transversal slice of the femur. Prevention is based on verifying, when the box is cut, that the medial condyle is not approached too closely in the transversal plane; in addition, the bone must be cut widely enough and slightly larger than the strict dimensions of the box so as to prevent the initiation of a crack during impaction. If this occurs, it is usually treated with one or two transversal screws.

Intraoperative fractures occurring when the separator is placed behind the tibia to dislocate it from the front also occur most often when posterior stabilized prostheses are used because of cutting the box for the femoral component. However, they occur not when the femoral component is placed, but most often when the tibial insert is cemented, because the force brought on the separator behind the tibia is excessive. Prevention is based on superior exposure of the tibia, avoiding placement of the counter-angled separator when the distal extremity of the femur is too porous or overly weakened. This is usually obtained by disengaging the area surrounding the upper tibia so as to place the tibia in external rotation, while in the same movement pressure is maintained from behind on the distal extremity of the femur, so as to use the distal extremity of the femur as a counter-angle to frontally dislocate the tibia.

This study identified the risk factors for postoperative fractures of the distal extremity of the femur after total knee arthroplasty. The implants with fractures were compared to those with no fracture during the same time period. This study has the advantage of comparing the two groups on the same type of implant (a single site) and covering a long time period (a decade). For the record, in the other series reported in the literature, the number of fracture cases published remains limited. In France, in a multicenter study investigating total knee arthroplasty revision reported at the SOFCOT symposium in 2000, the series totaled 16 fractures of the femur out of a total of 490 cases [Letenneur et al. (11)]. Nevertheless, it should be noted that the frequency of the fracture is quite similar between the SOFCOT symposium multicenter series [Burdin et Hutens (12)] and our single-center series. The frequency of postoperative femur fractures on total knee arthroplasty is evaluated between 0.3% and 2.5% in the literature. Different factors are undoubtedly involved in the pathogenesis of this fracture: reduction of bone resistance related to corticosteroid use or decreased bone density in elderly patients, appearance over time of a stress shielding phenomenon under the knee implant, relative difference in the elasticity between the bone of the distal
extremity of the femur and the implant and the femoral cement, osteolysis of the distal extremity of the femur, which is not always easily seen or evaluated from polyethylene wear. The majority of these fractures are often related to torsion mechanisms occurring after a minor trauma such as a fall. Some cases have been described after anesthetized manipulation for knee stiffness. More rarely, the circumstances are the violent trauma of a traffic accident.

FIG. 3. – Fracture having occurred under a total hip replacement prosthesis.

FIG. 4. – Example of a periprosthetic fracture of the distal extremity of the femur occurring under a abnormal hip.

FIG. 5. – Patient who presented with a periprosthetic fracture of the distal extremity of the femur after a periprosthetic fracture of the proximal extremity of the femur.

FIG. 6. – Fracture of the distal extremity of the femur showing clearly at the prosthetic trochlea, suggesting a relation with the notch made during surgery on the femur cortex.
Su et al. (13) confirmed a certain number of risk factors observed in our series: rheumatoid arthritis and/or oral corticosteroid treatment; old age; repeated surgery of the distal extremity of the femur, whether this be replacing the implant, or placing an implant on a previous osteotomy; and an increase in the rotation stresses on the distal extremity of the femur, or rotation that has disappeared at the knee because of a hinge prosthesis, or rotation stresses increased because of an abnormal hip (osteotomy, arthrodesis, fracture, above hip endoprosthesis). Finally, Ritter et al. (8) suggest that the anterior trochlear notch observed during implantation of certain prostheses may be the source of initiating a fracture secondarily. If each of these factors is reviewed point by point, it is possible to deduce a certain number of therapeutic strategies that could reduce the frequency of these fractures in certain situations.

Rheumatoid arthritis is an indisputable risk factor for periprosthetic fracture. In the series studied herein, the incidence of fractures of the distal extremity of the femur after total knee replacement was 8%. Bogash et al. (14) also reported that in a series of 16 patients with supracondylar fractures, 12 patients had rheumatoid arthritis and 10 of these 12 were on corticosteroid treatment. Figgie et al. (15) noted that 12 of their 22 patients presented with supracondylar periprosthetic fractures and rheumatoid arthritis and that nine of these 12 patients regularly took corticosteroids. These studies do not specify whether the patients had total hip replacements on the same side, but it is probable given the disease that many of them had in addition to the adjacent total hip prostheses. This is indeed the case for three patients of this series who also had total hip replacement on the same side. For these high-risk patients, the type of implant to use for knee replacement can be discussed. Using a femoral component with a centromedullary stem to bridge the supracondylar zone does not seem wise. Given that a large number of these patients already have a total hip prosthesis with a centromedullary stem on the same side, or risk having one secondarily, a risk of shaft fracture can be induced if a femoral component with a centromedullary stem is used from the start. This type of complication has already been reported many times in the last few decades where hinge prostheses were used. The risk persists today, as shown by this series, since fractures between the two femoral components appeared in a second phase in two patients treated in revision surgery with centromedullary stems at the knee. The most logical solution is undoubtedly to increase the bone stock of the distal extremity of the femur, perhaps by avoiding posterior stabilized femoral components, which drastically reduce the bone stock of the distal extremity of the femur, more than prostheses that preserve the posterior cruciate ligament and that also allow treating a later fracture with retrograde nailing of the femur. Similarly, in these patients, more than in other areas, a trochlear notch should be avoided during an anterior cut. This is even more easily avoided if the primary cut is approached anteriorly (fig. 7a) and if the size of the prosthesis is then

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**Fig. 7.** Depending on the operative technique and the sequence of bone cuts, the risk of anterior notching is greater in one of the cases. a) Primary anterior cut: little risk of notching; b) Secondary anterior cut adapted to the size of the implant: greater risk of notching.
adapted posteriorly. Posterior condylar cuts done before the anterior cut induce a more frequent risk of trochlear notch because the size of the prosthetic implants must be adapted to the morphology of the distal extremity of the femur (fig. 7b).

Finally, it should be noted that in our series, no periprosthetic supracondylar fractures occurred in patients suffering from rheumatoid arthritis combined with prostheses preserving the two cruciate ligaments with a primary anterior cut (54 protheses), while the fractures occurred in patients with rheumatoid arthritis who also had received posterior stabilized prostheses with a femoral box that indisputably reduces the bone stock. This information has been confirmed by Cain et al. (16) and Hirsh et al. (17), showing that the risk of periprosthetic fracture is greater in posterior stabilized prostheses than in prostheses that preserve the posterior cruciate ligament or both cruciate ligaments. If for one reason or another a centromedullary stem must be used (insufficient bone quality, intraoperative fracture, etc.), one must check that the centromedullary stem does not reach too high toward a femoral component that may be placed above, so as to retain 7-8 cm of diaphysis in the centromedullary zone free of prosthesis if possible. If the lower femoral centromedullary component is too close to the upper femoral stem, an osteosynthesis plate could be used to bridge the intermediary zone to prevent the risk of secondary fracture. For patients presenting with total hip replacement, a first-intention prosthesis should not use a centromedullary stem if possible, especially if it rises relatively close to the distal extremity of the hip femoral component.

Analyzing the data in the literature [Aaron and Scott (1), Culp et al. (2), Figgie et al. (6)], the frequency of notching in total knee arthroplasty varies between 3.5% and 26.9% in series including more than 250 knee protheses [Ritter et al. (8), Cain et al. (16), Hirsh et al. (17)]. According to the data in the literature, when specified, the frequency of notches may be on the order of 30% (50/164 fractures where the phenomenon is mentioned). However, a large share of these patients also had other risk factors such as rheumatoid arthritis, corticosteroid use, or surgical revision. According to the data in the literature, a notch can be a factor favoring fracture if associated with other risk factors, but alone does not seem to be a risk factor beyond the first few weeks after surgery. The most pronounced phenomenon is that when a fracture occurs from a notch, it usually occurs in the first few postoperative weeks or months, with the risk negligible thereafter.

For trochlear notches during the anterior cut, it is clearly best to avoid them, but when they do occur the best course to follow is currently not clearly defined in the literature. This series shows that even with a notch, the risk of secondary fracture is rare. A biomechanical study [Ritter et al. (8)] using a finite element method gives the impression that a 3-mm notch at least reduces resistance in rotation of the distal extremity of the femur by 30% and reduces its resistance in flexion by approximately 20%. Ritter et al. (8), in a review of a series of 670 total knee replacements, noted that 20.6% of these prostheses (138 knees) had a notch of at least 3 mm; nevertheless, a supracondylar fracture occurred in only two patients. It is probable that over the long term, the bone tissue of the distal extremity of the femur tends to modify and to reduce the risk of fracture after this notch. It is probable that the risk is greater in the immediate postoperative period (start of a stress fracture on the notch). If the notch is too large, three procedures can be discussed: start with a femoral component with a centromedullary stem to protect the distal extremity of the femur, given that fractures following a notch are usually short, oblique fractures with the notch as the starting point; have the patient use two crutches for 45 days, as when voluminous material is removed; reinforce the notch zone de with acrylic cement, keeping in mind that this may protect in the immediate postoperative period, but may prevent favorable modifications (corticalization) of the distal extremity of the femur over the long term.

Finally, for patients presenting a high level of osteolysis of the distal extremity of the femur, whatever its origin (metallosis, polyethylene debris, etc.) or substantial demineralization of the distal extremity of the femur under the trochlear shield, no therapeutic solution seems to have been discussed in the literature to date. A preventive change of a femoral component is certainly not as easy to propose as a change of a hip prosthesis component in case of osteolysis given the risks involved with knee replacement revisions. Nevertheless, it is not impossible that in the future the association of growth factors and bone grafts can be a possible solution on noncemented components to treat threatening periprosthetic osteolysis of the distal extremity of the femur.

In the same line of thought, given the risk of fracture in case of repeated surgical of the distal extremity of the femur, one may wonder whether a femoral stem should not be added systematically (after osteotomy or fracture).

References


