Pin track induced fractures around computer-assisted TKA

J. Beldame, P. Boisrenoult*, P. Beaufils

Department of Orthopaedic Surgery and Traumatology, Hospital Center, 177, rue de Versailles, 78150 Le Chesnay, France

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KEYWORDS
Femur; Iatrogenic fracture; Computer-assisted surgery; Total knee arthroplasty; Robotic-surgery complications

Summary
Background: Navigation tracker pins rigidly fixed to bone is a prerequisite for computer-assisted total knee arthroplasty. The first cases of fracture on navigation tracker pin sites have recently been reported.

Hypothesis: The risk of fracture depends first on diaphyseal placement of the tracker pins, and second on "transcortical" tangential route of the tracker pin as well as failure to obtain rigid fixation.

Material and methods: In a continuous series of 385 total knee arthroplasties, five patients (four women, one man) on average 73.2 years old (range: 65—79 years old) have sustained femoral fractures at the tracker pin site (incidence 1.3%). We investigated the demographic and radiological factors contributing to this complication.

Results: The patients with fractures were obese or overweight with an average body mass index of 32.56 (range: 25.14—39.45) but this was not statistically different from the BMI of the population of patients without fractures. The average delay from arthroplasty to fracture was 12.6 weeks (range 7—21). The fracture was always preceded by several days of thigh pain and occurred after a minor trauma. The fractures were always simple originating from the tracker pin site. In four out of five cases, the tracker pins were placed in the diaphyseal femur, and in all cases at least one pin was transcortical. Closed endomedullary nailing or ORIF were performed in five cases, with no bone graft. Union was obtained with functional results that were equivalent to those before the fracture.

Discussion: Fractures at the navigation tracker pin site are a complication which must be understood and explained to patients undergoing computer-assisted TKA because of the 1.3% incidence described in our series. The circumstances systematically associated with this type of fracture were: occurrence a certain amount of time after arthroplasty in obese patients who

* Corresponding author. Tel.: +33 1 39 63 94 31; fax: +33 1 39 63 87 38.
E-mail address: pboisrenoult@ch-versailles.fr (P. Boisrenoult).

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had pain before the fracture occurred. These fractures are favored by suboptimal placement of the tracker pins, especially in the lower diaphysis of the femur and transcortical fixation of at least one of the pins. Treatment included stable osteosynthesis and did not affect the results of total knee arthroplasty. The development of thigh pain some time after surgery in high risk patients (obesity, tracker pin site in the lower diaphysis, transcortical fixation) should suggest this diagnosis and weight-bearing should be avoided because these fractures are assimilated with stress fractures. Bicortical metaphyseal fixation should be the preferred tracker pin positioning for navigated total knee arthroplasty.

Level of evidence: Level IV retrospective study.

Introduction

Computer-assisted surgical techniques have been shown to be effective in total knee arthroplasty resulting in precise placement of knee components [1—6]. This technique requires the placement of navigation trackers which must be hard-fixed to the tibia and femur throughout surgery. At present these navigation trackers are attached either with a pin or a large diameter screw or by two thin pins placed fairly close together which may cause weakening of the bone and fracture. The first cases of postoperative fractures were described in 2006 by Ossendorf et al. [7] and Jung et al. [8].

Computer-assisted total knee arthroplasty has been systematically performed in our surgical unit since 2003. Five cases of femoral fractures at the tracker pin site have been observed since that date.

The main goal of this study was to identify the risk factors of tracker pin site fractures, as well as to analyse the results of osteosynthesis and to suggest preventative measures. Our hypothesis was that placing the tracker pins in the diaphysis of the bone, with transcortical rather than bicortical fixation, were the main risk factors for these fractures.

Materials and methods

Between January 2003 and December 2007, 385 primary total knee arthroplasties (TKA) were implanted by a standard medial parapatellar approach using the SAL prosthesis (Sulzer Orthopaedics, Baar, Switzerland) until January 2006 then the NEXGEN LPS Flex prosthesis (Zimmer, Warsaw, Indiana, United States) thereafter. The navigation system was NAVITRACK (ORTHOSoft, Montreal, Canada). Two different systems of fixation were used for the tracker pins. From January to September 2003, each tracker was attached with a single Schanz type 6-mm screw. After September 2003, trackers were attached with two 1.5-mm threaded pins (Fig. 1), for better rigidity. Initially and until 2006, the pins were placed on the femoral metaphysis and tibial diaphysis then thereafter pins were placed on the diaphysis of both the femur and the tibia, transcutaneously at a significant distance from the surgical field to facilitate evaluation of femoropatellar range of motion after placement of provisional components. All of our fractures occurred after 2006 when we began diaphyseal placement of both tracker pins.

Figure 1  a and b: rigid femoral tracker with two 1.5 mm pins.
Pin track induced fractures around computer-assisted TKA

In this retrospective study, an independent observer managed follow-up including questioning patients about how the fracture occurred, performing a complete radiological evaluation (computerized standing full long leg radiograph + centered images) and measuring articular range of motion.

Evaluation of fractures included an analysis of the circumstances leading to the fracture: delay between knee arthroscopy and fracture, type of trauma, possible pre-fracture symptoms, morphological evaluation of the patient (BMI, morphology of lower limbs); as well as a prefracture post-TKA plain X-ray, in particular the position of the tracker pin sites. Two parameters were taken into account. First the location of the tracker pins in the diaphysis or metaphysis and second their intraosseous position. Two positions were identified: transcortical and bicortical (Fig. 2 and Fig. 3). A pin was defined as bicortical if it perforated the first cortex, went through the medullary canal and perforated the second cortex. It was defined as transcortical if it only passed through one cortex.

Finally, a plain X-ray was taken after osteosynthesis to evaluate fracture union and the axis of the lower limb.

Statistical analysis of the results was performed using the Mann & Whitney test to compare the demographic data of the five patients with fractures with the rest of the series with a significance threshold of 5%.

Results

Five femoral fractures (four women, one man) were observed during this period (no tibial fractures) (Table 1). The average age of patients with fractures was 73.2 (range 65–79). The distribution by age and sex was comparable to that of the rest of the population who received TKA, with a sex-ratio of one man to five women and an average age of 76 (Mann & Whitney, \( p > 0.05 \)). The patients with fractures were obese or overweight with an average body mass index of 32.56 (range: 25.14–39.45; median: 27.2). The average body mass index was higher in the group with fractures than in the group without fractures (mean: 28.4, median: 29), but the difference was not statistically significant (Mann & Whitney, \( p > 0.05 \)). The preoperative morphotype (evaluated by standing long leg radiograph) was not different from the population without fractures (Mann & Whitney, \( p > 0.05 \)).

The average delay between arthroplasty and the fracture was 12.6 weeks (7–21 weeks). The fracture was always preceded by a few days of unusual pain in the thigh during weight bearing. The fractures always occurred after minor or indirect trauma. In four cases, the fracture was diaphyseal and in one case it was metaphyseal. All fractures were simple and were predominantly transversal. All fractures originated from the tracker pin site (Fig. 4). The route of at least one of the two tracker pins was transcortical. There were additional tracker pin drill holes in two cases (initial failure in placing the pin) (Fig. 5).

Before fracture, post-TKA X-rays showed an axis of 0° and 3.5° varus in three patients in the third postoperative month. There was no significant clinical deformity in the three patients with fractures before the 3-month postoperative follow-up.

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Table 1

Summary of patients in our series.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Sex</th>
<th>BMI</th>
<th>Femoral pins</th>
<th>Tibial pins</th>
<th>Delay (weeks)</th>
<th>Treatment</th>
<th>Range of motion after union</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>79</td>
<td>F</td>
<td>39.45</td>
<td>T/T</td>
<td>T/B</td>
<td>12</td>
<td>Femoral nailing</td>
<td>0/−5/90</td>
</tr>
<tr>
<td>2</td>
<td>65</td>
<td>F</td>
<td>29.41</td>
<td>T/B</td>
<td>T/B</td>
<td>11</td>
<td>Femoral nailing</td>
<td>0/−5/115</td>
</tr>
<tr>
<td>3</td>
<td>71</td>
<td>F</td>
<td>29.41</td>
<td>T/B</td>
<td>T/B</td>
<td>7</td>
<td>ORIF (plate)</td>
<td>0/−5/115</td>
</tr>
<tr>
<td>4</td>
<td>78</td>
<td>M</td>
<td>25.14</td>
<td>T/T</td>
<td>T/T</td>
<td>21</td>
<td>Femoral nailing</td>
<td>0/0/110</td>
</tr>
<tr>
<td>5</td>
<td>73</td>
<td>F</td>
<td>29.38</td>
<td>B/B</td>
<td>T/B</td>
<td>7</td>
<td>ORIF (plate)</td>
<td>0/0/110</td>
</tr>
</tbody>
</table>

Average: 32.55

T: transcortical tracker pin site; B: bicortical tracker pin site.

Cases 2 and 5 had three pin holes.

Discussion

To our knowledge, this report of five femoral tracker pin site fractures represents the largest published series on this entity to date (Table 2). At the same time, because of the limited number of cases, the statistical results should be interpreted with caution. Nevertheless, these results show the common conditions under which the fractures occurred, favored by technical errors during the arthroplasty procedure, in a population whose characteristics were not statistically different, in our series, from the population without fractures. This series of fractures occurred when we changed our usual practices (number and position of pins) thus increasing the number of risk factors.

The incidence of these fractures in our series was 1.3%. Therefore, this complication is not rare and should be mentioned to patients when they are informed of the risks of the intervention because the incidence rate is similar to that of deep infections of the surgical site, and because management requires a second intervention [9].

All of the patients with fractures were overweight and obese, a factor which has also been mentioned by Ossendorf et al. [7], Bonutti et al. [10], Li et al. [11] and Wysocki et al. [12]. However, in our study, the BMI of patients with fractures was not statistically greater than that in the total knee arthroplasty patients without fractures. All of the fractures occurred some time after surgery in patients who had recovered satisfactory knee function with replacements that were correctly implanted with no axis defects. This long delay between surgery and fracture has also been mentioned in the literature; it was 5 weeks for Jung et al. [8] and 12 weeks for Ossendorf et al. [7] or Bonutti et al. [10]. The association of unusual pain preceding the fracture by several days and the occurrence of the fracture after a minor trauma suggests a similar mechanism to that found in stress fractures. This mechanism was also mentioned by Jung et al. [8] who identified hyperfixation on bone scintigraphy in a patient who was experiencing mechanical pain at tracker pin sites and by Li et al. [11] who diagnosed an incomplete fracture 5 weeks after a patient experienced unusual pain, and which fractured completely 2 days later despite removal of all weight from the leg. Care should therefore be taken during surgery in obese patients, and during rehabilitation in case of the development of pain after a pain-free period.
All of our fractures were femoral. The predominance of femoral fractures is also found in the literature [7,8,10—12]. Femoral fractures may predominate for biomechanical reasons. The femur mainly undergoes mechanical stress during torsion and flexion while the tibia mainly undergoes stress by compression [13]. The type of mechanical stress endured by the femur makes it more sensitive to cortical bone loss and in all our cases at least one of the pins was placed in the transcortical position.

The danger of transcortical notches has been emphasized by Jung et al. [8], and by Culp et al. [14] who have stated that a 3-mm groove in the anterior cortex of the supracondylar femur reduces resistance to torsion by 29.2%. Thus, pin insertion should be bicortical which does not increase the risk of weakening the bone any more than a monocortical pin, but which provides more stable anchoring [15] as long as the bicortical pin is perpendicular to the axis of the bone.

Increasing the number of drill holes which are adjacent to one another and/or to the cortex; causing "postage stamp" type multiple drill holes, increases the risk of fracture and explains, in part, the case of metaphyseal fracture in our study (Fig. 5) [16].

The predominance of diaphyseal fractures is similar to that found in the literature since the seven femoral fractures reported to date were diaphyseal [7,8,10—12]. The metaphyseal-dyaphyseal femur is known to be a zone of transition, and its fragility has been mentioned in the literature in particular by Aaron and Scott [13]. Weakening is proportional to the ratio of the diameter of cortical bone loss (d) (created in the present case by the diameters of the pin sites) over the diameter of the bone (D). Thus for Hipp et al. [17], although bone weakening is minimal for a ratio of d/D below 10%, resistance to torsion is only 60% of normal when d/D = 10% and 31% when d/D = 60%. It would therefore seem to be important to follow the recommendations in the literature which suggest placing tracker pins in the metaphysis of the femur [7,10,11], even if placing the pins in this location can make the evaluation of femoropatellar kinetics more difficult when the provisional prosthesis is in place.

The fracture line was generally simple, short and transverse or oblique as mentioned by Aaron and Scott [13]. Fractures occurred during torsion [15] on unloosened prostheses. These simple fractures facilitated reduction and made it possible to perform stable osteosynthesis with endomedullary nails [10—12] or plates [8] (Table 2) guaranteeing union without malunion (Fig. 6). Managed in this way, early rehabilitation was possible so recovery of function was excellent over time [8] and articular range of motion was equivalent to that in the population that underwent total knee arthroplasty without fractures.
Table 2  Reports in the literature on tracker pin site fractures.

<table>
<thead>
<tr>
<th>Authors</th>
<th>Fracture location</th>
<th>Age (years)</th>
<th>Sex</th>
<th>BMI</th>
<th>Delay surgery/fracture (weeks)</th>
<th>Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ossendorf et al. [7]</td>
<td>1 diaphyseal femoral fracture</td>
<td>65</td>
<td>woman</td>
<td>36.9</td>
<td>12</td>
<td>Orthopaedic</td>
</tr>
<tr>
<td>Li et al. [11]</td>
<td>1 diaphyseal femoral fracture (incomplete at first, then complete)</td>
<td>53</td>
<td>woman</td>
<td>37</td>
<td>5</td>
<td>Femoral nailing</td>
</tr>
<tr>
<td>Bonutti et al. [10]</td>
<td>2 diaphyseal femoral fractures</td>
<td>71</td>
<td>woman</td>
<td>42</td>
<td>9</td>
<td>Femoral nailing</td>
</tr>
<tr>
<td>Wysocki et al. [12]</td>
<td>2 diaphyseal femoral fractures</td>
<td>77</td>
<td>woman</td>
<td>27</td>
<td>12</td>
<td>Femoral nailing</td>
</tr>
<tr>
<td>Jung et al. [8]</td>
<td>1 diaphyseal femoral fractures</td>
<td>70</td>
<td>woman</td>
<td>-</td>
<td>6</td>
<td>ORIF (plate)</td>
</tr>
<tr>
<td>Our series</td>
<td>5 diaphyseal femoral fractures</td>
<td>73</td>
<td>4 W/ 1 M</td>
<td>32.5</td>
<td>14.2</td>
<td>Femoral nailing in 3 cases, ORIF in 2 cases</td>
</tr>
</tbody>
</table>

Figure 6  a: long leg radiograph at union; b: osteosynthesis by endomedullary nailing; c: axis of the limb 178° at union.

Conclusion

Navigation tracker pin site fractures are a potential complication in computer-assisted knee arthroplasty. These fractures usually occur in the femur and are favored by incorrect positioning of the pins, especially if they are placed in the lower diaphysis of the femur and implanted transcortically, or if multiple drill holes must be made creating a ‘‘postage stamp’’ pattern. The diameter of the pins should be as small as possible with bicortical implantation in the metaphysis.

These fractures are usually preceded by pain after a pain-free period, and when at least one of the pin sites is transcortical. Pain of this type should suggest the diagno-
sis and weight-bearing should be totally avoided until pain subsides.

If the fracture is diagnosed, the prognosis in our series and in the literature is good after stable osteosynthesis with no bone graft. At the last follow-up in our series, fractures had not affected the functional results of the prosthesis.

Conflict of interest statement

P. Beaufils. Clinical trials: co-investigator, non-principal experimenter, for Zimmer Company, Warsaw, USA.

J. Beldame and P. Boisrenoult have no affiliation, financial interests or other interests in the company Zimmer.

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