Total knee arthroplasty for osteoarthritis secondary to extra-articular malunions


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KEYWORDS
Extra-articular malunion; Total knee prosthesis; Traumatic knee arthritis

Summary
Introduction: Post-traumatic total knee arthroplasty for extra-articular malunion requires correction of the deformity, either through asymmetrical bone resection (possibly inducing ligaments imbalance) or osteotomy at the time of arthroplasty. We report the results of a continuous multicenter, retrospective series of 78 patients (18 implants with osteotomy) with a mean 4 years of follow-up. The hypothesis is that the selected procedure requires to be based on the deformity's location and severity.

Patients: With a mean age of 63 years (younger in the osteotomy group), 38 patients had femoral malunion, 36 had tibial malunion, and four had a combined malunion. There were 70 frontal deformities (48 varus and 22 valgus) and 10 rotational deformities, often diaphyseal, four of which more than 20°. Twelve patients had a history of infection; eight had frontal laxity greater than 10°, and 15 a limited range of motion in flexion. In 70 cases, semi- or nonconstrained implants were used, and in eight cases more constrained implants, including four hinge prostheses.

Results: We observed two deep infections, one case of avulsion of the extensor mechanism, and two cases of aseptic loosening with femoral malunion and varus deformity. There were 70 frontal deformities (48 varus and 22 valgus) and 10 rotational deformities, often diaphyseal, four of which more than 20°. Twelve patients had a history of infection; eight had frontal laxity greater than 10°, and 15 a limited range of motion in flexion. In 70 cases, semi- or nonconstrained implants were used, and in eight cases more constrained implants, including four hinge prostheses.

Results: We observed two deep infections, one case of avulsion of the extensor mechanism, and two cases of aseptic loosening with femoral malunion and varus deformity. Two osteotomies resulted in nonunion, one with internal fixation devices mobilization requiring revision using extension rods. The function and pain scores were significantly improved. The mobility improvements were moderate but did not compromise the surgical procedure main objective. The preoperative hip-knee angle was corrected with both techniques. Only the function score gain was greater for the isolated arthroplasty procedures.
Introduction

Knee osteoarthritis with extra-articular malunion by definition includes fracture sequelae for which the initial continuity solution does not involve the cartilaginous surfaces. When the femoral or tibial fracture extends beyond the knee’s capsuloligamentous envelope, healing in a poor position induces extra-articular deformity, which can have repercussions on the joint’s mechanics. When post-traumatic gonarthrosis has developed, implanting a knee prosthesis involves realigning the lower limb to ensure that the fixation of the implant components remains stable and to minimize long-term insert wear.

Several possibilities exist for correcting extra-articular deformities. The first is to recover frontal deformities within the bone cuts, i.e., with asymmetrical resection within the capsuloligamentous envelope on the corresponding bone, which induces resection laxity, varying in degree in proportion to the degree of bone deformity [1]. This laxity can be tolerated if it is moderate. If it is greater, it should be compensated by release of the opposite collateral ligament. At worst, it requires increasing the prosthesis constraint. More logically, the deformity can be corrected with associated extraligament osteotomy, sometimes performed before prosthesis implantation, which requires the two procedures to be either simultaneous [2] or successive [3—4].

The literature on isolated knee arthroplasties with extra-articular malunion is scarce. Most authors report small series, whose main limitation is the absence of precise localization of the malunion in relation to the knee’s capsuloligamentous envelope. Roffi et al. [5] discuss fractures neighboring the knee. In the series reported by Lonner et al. [6] on 31 knees, osteotomy was associated with the prosthesis in four cases, suggesting substantial extra-articular deformity, with no other details on the remainder of the population studied. In another publication, these authors seem to prefer associated prosthesis and osteotomy to correct femoral varus deformities [7]. Papadopoulos et al. [8] performed six associated osteotomies in the treatment of 21 cases of secondary gonarthrosis to distal femoral fractures. Wu et al. provide a general discussion on the problem of post-traumatic osteoarthritis of the knee without specifying the corrective techniques for extra-articular malunion [9]. Wang et Wang [10] provide a precise description of the technique consisting of recovering a varus deformity in the bone cuts with specific ligament balancing. However, the respective indications and the limitations of each technique remain ill defined.

Discussion and conclusion: The indications for arthroplasty alone were extended to 20° varus and 15° valgus, with no major residual laxity. Beyond 10°, hinge prosthesis should be available. Associated osteotomy can correct rotational deformities that cannot be compensated with bone cuts. In deformities that are close to the joint, osteotomy facilitates implantation of moderately constrained prosthesis. This indication is based on CAT scan rotational deformities measurements because rotational deformities require an osteotomy, and/or the presence of extraligamentous deformity that cannot be reduced with collateral ligaments surgical release.


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Patients and methods

Study population

Seventy-eight TKA files (78 patients) on extra-articular malunion were selected. The malunions were extra-articular because the initial fracture extended beyond the knee’s capsuloligamentous envelope (whose joint surfaces were also involved in three cases because of associated patellar fracture, in one case from femoral intercondylar extension, and in two other cases by extension into the tibial plateaux originating in a tibial metaphyseal fracture).

The study population included 33 males and 45 females, mean age, 63 years (range, 34—90 years), operated between 2000 and 2008 in eight specialized centers in France. Thirty-eight of these patients had femoral malunion, 36 had tibial malunion, and four had both femoral and tibial malunion. The femoral malunions were more often diaphyseal (Table 1). The majority of the malunions included frontal deformity (70 cases), varus in 48 cases (hip-knee-ankle alignment [HKA] angle, 169 ± 6°; range, 144—179°) and valgus in 22 cases (HKA angle, 186 ± 4°; range, 181—195°). The knees were aligned in the eight remaining cases. The sagittal and rotational deformations were for the most part found in diaphyseal malunions (Table 2). There were 10 rotational deformities (seven femoral and three tibial), with four of them 20° or greater in lateral rotation (20, 20, 20, and 30°).

The initial fractures were treated surgically in 57 cases (two femoral screw fixations, 13 femoral and 16 tibial plates, 17 femoral intramedullary nail fixations and nine tibial). Twenty-one patients had nonsurgical treatment (traction for 13 leg fractures and eight femoral fractures). Finally, eight knees had never undergone surgery; all the others had been operated at least once (range, one to nine times).
mean time between injury and implantation was 31 years, ranging from 1 to 64 years. The more malunion was juxta-articular, the shorter the time between the initial injury and implantation (mean, 14 years for metaphyseal malunion versus 35 years for diaphyseal malunion; \(p < 0.001\)). Finally, 12 patients had a history of infection, eight frontal laxity greater than 10°, and 15 stiffness upon flexion, which did not extend beyond 90°.

### Surgical technique

Sixty isolated procedures and 18 prosthesis implantations associated with osteotomy were performed.

In three cases of moderate tibial varus malunion, medial unicompartmental prostheses were implanted. In 67 cases, conventional semi-constrained prostheses were used. Revision prostheses with greater constraint were necessary in eight cases (four hinges and four augmented postcams). Extension tibial rods were deemed necessary in 23 cases, including nine long rods to bridge the associated osteotomy. Nineteen osteotomies of the anterior tibial tuberosity were performed, notably in the stiffness cases. Of the other associated procedures, there were four cases of Judet quadriceps release, five cases of posterior capsular release, and one medial capsular tightening.

With isolated TKA, the bone deformity was corrected in the cut of the corresponding bone, necessarily asymmetrical. The resulting resection laxity was located in the frontal deformity convexity and was balanced by release of the convexity collateral ligament. Only two deformities could not be corrected with satisfactory balancing and were therefore treated with a hinge prosthesis (one case of femoral malunion with 20° varus and one case of tibial malunion with 15° valgus and preoperative convexity laxity). Six rotational deformities measured at 10° were not corrected: four cases of malunion in external rotation (three femoral and one tibial) and two cases of femoral malunion in internal rotation.

In 18 cases, an osteotomy was associated with the TKA to correct the extra-articular deformity. In this group, the patients were younger than the groups of isolated arthroplasties (56 versus 65 years), but the angular range and the location of the frontal deformities were similar (Table 3). The arthroplasty and osteotomy procedures were simultaneous in 16 cases, with 11 single approaches for the osteotomy and the arthroplasty, whereas in five cases, a specific approach was necessary for the osteotomy. In the last two cases, the osteotomy preceded the arthroplasty by 8 and 12 months, consisting in proximal frontal metaphyseal correction of a valgus tibia in one case and supramalleolar tibial derotation osteotomy in the other case.

Eight tibial osteotomies were performed in the metaphyseal region (despite the diaphyseal location of the malunion in three cases): seven in the upper metaphysis and one supramalleolar derotation osteotomy. Eight femoral osteotomies were performed, with seven located in the diaphysis (four frontal corrections, three derotations, including one oblique plane) and one in the distal femoral metaphysis (derotation) (Fig. 1). In two cases, a double tibial and femoral osteotomy was required to correct mixed tibial/femoral deformities, for one patient in the metaphyses adjacent to the knee and for another patient the proximal tibial metaphysis in association with a diaphyseal femoral osteotomy. The tibial deformity was constitutional in one case, and in the other, it was induced by a previous osteotomy.

### Evaluation method

The analysis was based on the simplified 2009 Société orthopédique de l’Ouest (SOO) score [11], because all of the parameters necessary for calculating the IKS score were not always available for this retrospective review. This functional score was calculated out of 100 (stair score + walking distance score – walking aids score), with four categories: a total score greater than 89 corresponded to an excellent

### Table 1 Location of malunions. The distribution between diaphyseal malunions and malunions with metaphyseal participation did not differ for isolated TKAs and implants associated with osteotomy (\(p = 3.24\) and 3.28, respectively).

<table>
<thead>
<tr>
<th></th>
<th>Diaphyseal</th>
<th>Isolated TKA</th>
<th>TKA and osteotomy</th>
<th>Metaphyseal</th>
<th>Isolated TKA</th>
<th>TKA and osteotomy</th>
<th>Metaphyso-epiphyseal Isolated TKA</th>
<th>TKA and osteotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Femur</td>
<td>20</td>
<td>6</td>
<td>6</td>
<td>4</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibia</td>
<td>17</td>
<td>3</td>
<td>12</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed: femur and tibia</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Table 2 Malunions spatial orientation (a malunion can have several components).

<table>
<thead>
<tr>
<th></th>
<th>Diaphyseal</th>
<th>Isolated TKA</th>
<th>TKA and osteotomy</th>
<th>Metaphyseal</th>
<th>Isolated TKA</th>
<th>TKA and osteotomy</th>
<th>Metaphyso-epiphyseal Isolated TKA</th>
<th>TKA and osteotomy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frontal</td>
<td>36</td>
<td>8</td>
<td>19</td>
<td>6</td>
<td>3</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sagittal</td>
<td>12</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rotational</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 3 Preoperative data versus the two techniques.

<table>
<thead>
<tr>
<th></th>
<th>Isolated TKA</th>
<th>TKA and osteotomy</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age</td>
<td>65 ± 12</td>
<td>56 ± 12</td>
<td>0.006</td>
</tr>
<tr>
<td>Sex ratio</td>
<td>24F/36H</td>
<td>9F/9H</td>
<td>0.56</td>
</tr>
<tr>
<td>Preoperative HKA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Varus</td>
<td>170 ± 4°</td>
<td>167 ± 11°</td>
<td>0.18</td>
</tr>
<tr>
<td>(n = 41)</td>
<td></td>
<td>(n = 7)</td>
<td></td>
</tr>
<tr>
<td>Valgus</td>
<td>187 ± 4°</td>
<td>190 ± 11°</td>
<td>0.37</td>
</tr>
<tr>
<td>(n = 13)</td>
<td></td>
<td>(n = 9)</td>
<td></td>
</tr>
<tr>
<td>Preoperative mobility</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flexion</td>
<td>106 ± 22°</td>
<td>94 ± 34°</td>
<td>0.08</td>
</tr>
<tr>
<td>Extension</td>
<td>5 ± 7°</td>
<td>2 ± 3°</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Figure 1 (a) A 65-year-old patient with diaphyseal malunion of the femur with 20° external rotation and 8° varus (HKA, 172°). (b) The osteotomy was performed in the distal metaphyseal zone and was bridged with a rod from a posterior stabilized TKA. A plate stabilized the rotation. At 62 months of follow-up and after mobilization under general anesthesia, the functional result was good and flexion was 125°. The postoperative HKA angle was 178°.

The characteristics of the series were described in means and standard deviations for the continuous variables and in percentages for the categorical variables. The clinical assessment described by the knee and function scores was analyzed using the Student t-test with correction for the small numbers of subjects. The proportions of metaphyseal and diaphyseal malunions in the two techniques were compared with the Chi² test (with Yates correction for the small groups). The significance threshold was set at p < 0.05.

Results

Complications

Overall, the mean follow-up was 4 ± 2.5 years (range, 6 months to 8 years). Sixty-eight patients were seen in the last 2 years before the symposium. Ten patients were lost to follow-up with a mean follow-up of 2.5 years (1–7).

Two intraoperative complications occurred: one femoral perforation and rupture of the extensor apparatus. The femoral perforation occurred during placement of the extension rod for a metaphyseal femoral malunion without osteotomy. Intraoperative radioscopic verification informed the operator so that the situation could be redressed extraperitoneally with a longer rod and cerclage. The extensor apparatus ruptured on a stiff knee (preoperative flexion, 60°). It was repaired by direct suturing with a 20° extension lag and 90° final flexion.

There were 12 postoperative complications. Apart from one case of regressive fibular paralysis and one case of patellar necrosis that remained asymptomatic, six patients were revised without changing the implant: one deep infection treated with joint lavage and adapted antibiotics, two periprosthetic fractures, one femoral and the other tibial, which both had had osteosynthesis, two cases of clunk syndrome treated by resecting the suprapatellar fibrous nodule, and one case of nonunion of a tibial osteotomy, successfully revised by bone grafting and changing the osteosynthesis material.

Four patients were revised and the prosthetic components changed. Two cases of aseptic loosening occurred at 2 and 8 years of follow-up. Early bipolar loosening was observed in a 55-year-old patient operated initially for femoral diaphyseal malunion with varus aggravated by constitutional tibial varus, who had undergone correction with a double tibial and femoral osteotomy. The second case of loosening, occurring late, was femoral, in a 75-year-old...
patient with femoral metaphyseal malunion with varus (HKA angle, 160°), who had been treated with a hinge implant without osteotomy.

One case of dismantling of an osteotomy cut with no loosening also required prosthesis revision. This was a 56-year-old patient treated for femoral diaphyseal malunion with varus (HKA angle, 165°), corrected with diaphyseal osteotomy associated with a standard implant. The osteotomy cut shifted secondarily and the prosthesis was changed for another equipped with an extension rod bridging the osteotomy site.

Finally, one case of septic loosening was treated by removing and replacing the prosthesis during the second postoperative year.

Functional and clinical results

The mean pain score of the overall series at the last follow-up had significantly improved, increasing from 8 ± 9 preoperatively to 42 ± 11 (p < 0.001). The mean function score of the overall series was also significantly improved, increasing from 44 ± 23 to 89 ± 15 (p < 0.001). The function scores were excellent in 52 cases, good in 14 cases, fair in seven, and poor in five patients. The mean flexion gain was 4 ± 24° (preoperative, 105 ± 26°; postoperative, 109 ± 21°). The mean gain in extension was 4 ± 6° (preoperative, 5 ± 6°; postoperative, 0.5 ± 3°). Six manipulations under general anesthesia were necessary in five diaphyseal malunions (three femoral and two tibial) and one femoral metaphyseal-diaphyseal malunion. Postoperatively, no patients had frontal laxity greater than 5°.

The preoperative HKA angle was 178 ± 4° (range, 172–184°) for the cases of varus and 181 ± 2° (range, 175–184°) for the cases of valgus, with no difference between the two techniques (Table 4).

The only significant difference between the two techniques involved the function scores, higher for the isolated arthroplasty procedures than for the osteotomies (Table 4) and the two cases of pseudarthrosis in the group undergoing arthroplasty associated with an osteotomy.

Discussion

These results show a significant improvement in the function and pain scores and effective correction of the frontal deformities for all of the techniques. We observed no consequential postoperative laxity, notably in the group of isolated TKAs. The complication rate is clearly high. However, many were related to injuries, notably the two infections in patients with a history of infection.

Associating osteotomy with TKA, most often simultaneously, does not compromise recuperation of mobility, but the gain in the functional result, as evaluated by the function score, seems less than in the group of isolated TKAs. This can be accounted for by two complications specifically concerning the osteotomy site: nonunion of the tibial metaphyseal osteotomy, which seems related to technical problems (sandwiched cement). The other dismantling of a femoral diaphyseal osteotomy was explained by a deficiency in the osteotomy fixation, which had not been bridged by an extension rod. In their series, Lonner et al. [7] also reported a case of nonunion in a femoral diaphyseal osteotomy, which nevertheless had been bridged by an extension rod. The nonunion of the osteotomy site is therefore a risk that can be minimized by practicing metaphyseal osteotomies, the region with the best potential for bone union. Osteosynthesis, which should stabilize the site in all planes, is reinforced by using an extension rod bridging the osteotomy site, which must be associated with direct osteosynthesis to block rotations (Fig. 1). Finally, there must be perfect contact between the bone extremities, with no interposing cement. This type of intervention therefore presents a certain technical challenge, which requires preoperative planning so that the best-adapted material is available. In particular, the decision to perform a femoral diaphyseal osteotomy requires calculating and acquiring the rod length necessary to bridge the osteotomy site adequately.

In the group of isolated TKAs, the laxity of the resection was controlled since there were no cases of substantial residual laxity. In the cases of tibial deformity (29 cases; 22 varus and seven valgus), the laxity obtained has repercussions on the flexion and extension spaces. This laxity was compensated by increasing the thickness of the polyethylene insert, except for one valgus tibia with a 190° dislocation (laxity caused by tearing the medial collateral ligament), corrected with a hinge prosthesis. With femoral deformities, resection laxity is only expressed in the joint space in extension. The four cases of femoral deformity with valgus in our series were moderate and were corrected in the bone cuts, retaining a slight residual valgus. In the 21 varus femoral malunions, five also retained significant varus: 170–176°, but these were diaphyseal deformities farther from the knee (Fig. 2). The situation is more delicate in the
deformities close to the knee, including in the 75-year-old patient treated with a hinge prosthesis that finally loosened.

This isolated arthroplasty technique should be weighed against combined simultaneous arthroplasty and osteotomy, particularly if the femoral malunion is substantial and approaches the knee. In practice, it seems important to identify the nonreducible or extraligamentous part of the deformity, because, in absence of osteotomy, this will require asymmetric bone resection with ligament lengthening, a technique that has its limits, as we have seen. The stress X-rays are not always contributive, either for technical reasons or because of osteoarthritic stiffening. To locate the frontal deformity, we used an a posteriori method derived from Paley’s [12] diagrams, founded on the intersection of the epiphyseal and diaphyseal axes in relation to the capsuloligamentous envelope (Fig. 3). This method can also be problematic in that it is not always easy to specify the insertion of the ligament on plain X-rays, notably at the lower extremity of the medial collateral ligament. Moreover, during the intervention, additional reducibility can be obtained by resecting the femoral and tibial osteophytes located on the deep side of the collateral ligaments. Only after these have been released can one obtain true irreducible residual deformity, which can only be fully assessed intraoperatively, and therefore with a certain imprecision, unless a navigation system is available. The value of this angular deformity is the essential component, associated with other factors such as the patient’s age, in deciding on either an osteotomy associated with TKA or isolated prosthesis replacement. This study demonstrates that global deformities up to 22° varus (22° for the tibia and 20° for the femur) and 15° valgus (6° for the femur and 15° for the tibia) have been corrected without osteotomy. The maximum varus deformity (22°) as well as the maximum valgus deformity (15°) corrected in the bone cuts were located on proximal tibial metaphysis. On varus deformities, Wang and Wang [10] extend the technique up to 20° on femoral deformities and 30° on tibial deformities. It should be remembered, however, that all these measures involve overall deformities aggravated by wear and that they undoubtedly overestimate the true residual deformities that have been effectively corrected with bone cuts.

On the other hand, the isolated TKA technique leaves the rotational deformities in place, which seem difficult to compensate by the position of the prosthesis components, without disturbing the course of the collateral ligaments. Thus, moderate rotational deformities persisted in our series, as in Wang and Wang’s [10], with two cases of femoral rotational deformities, one with 10° of external rotation and the other with 20° internal rotation, apparently with no consequences on the functional result at follow-up. This was also true in our six patients in this case with a mean 2.5 years of follow-up (1–6), but the association of osteotomy has the advantage of exact correction of the deformity in all its components, including rotational. The three femoral rotational

![Figure 3](image_url)
osteotomies, whether diaphyseal or metaphyseal, were easily associated with the prosthesis, because the derotation was performed around the extension rod of the femoral component. However, for the tibia, derotation near the knee is not customary because it seems to expose the patient to a number of complications, notably compartment syndrome and/or sciatic paralysis [13]. Derotation in this series was therefore performed at the supramalleolar level 12 months before the arthroplasty.

In conclusion, in the elderly patient, particularly if the malunion is distant from the joint, the indications for isolated knee replacement can be extended to 20° global varus knee deformities and 15° valgus knee deformities, even if it means leaving a moderate residual deformity on a well-balanced knee. Beyond 10° of frontal deformity, and if there is already preoperative laxity of the convexity, caution would dictate having a hinge prosthesis available. This is particularly true of valgus deformity in which excessive lateral release can lead to complete sacrifice of the lateral plane, particularly in cases of disinsertion of the popliteal tendon, running the risk of serious instability in flexion [14]. For substantial metaphyseal misalignment, the alternative is the implant associated with corrective osteotomy. The results of this series show that simultaneous procedures are possible, as long as the technical aspects are well under control so that union defects stemming from the osteotomy are prevented. The indication should be based on a preoperative workup that can calculate the extraligamentous part of the deformity in an attempt to anticipate the nonreducible residual deformity that will persist after surgical release of the collateral ligaments. Finally, the patient should be screened for excessive large rotational deformities requiring specific osteotomy.

Conflict of interest statement

GD: financial interest in TORNIER.
PM, CC, CB: occasional guest consultants with TORNIER.
FD, YC: have not declared a conflict of interest.
PB: no conflict of interest.

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References