ORIGINAL ARTICLE

An original knee arthrodesis technique combining external fixator with Steinman pins direct fixation

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Summary
Introduction: Knee arthrodesis may be the last possible option for infected total knee arthroplasty (TKA) patients and in revision cases involving severe bone loss and/or extensor mechanism damages. Success in these situations depends on achieving good fixation assembly stability. We report bone fusion results using a fixation technique combining cross-pinning by two Steinman pins with a single-frame external fixator. Remission of infection at long-term follow-up was an additional criteria assessed for those cases initially treated for sepsis.

Hypothesis: This fixation modality improves fusion rates.

Patients and methods: In six of this series of eight patients (mean age: 59 years), surgery was performed in a context of infection: five cases of infected TKA, and one case of septic arthritis. In the other two cases, arthrodesis was respectively indicated for a severe post-traumatic stiffness compounded by extensor system rupture and for a fracture combined to a complete mechanical implant loosening. In three of the six infection cases, arthrodesis was performed as a single-stage procedure. All patients were operated on using the same technique: primary arthrodesis site stabilization by frontal cross-pinning with two Steinman pins, followed by installation of a sagittal external fixator frame. Results were assessed at a mean 8-year follow-up.

Results: All the arthrodeses showed fusion at a mean 3.5 months (range: 2.5 to 6 months) post-operative delay without reintervention. Weight-bearing was resumed at 2 to 3 months. The external fixator was removed at a mean 5.2 months. No recurrence of infection was observed over a mean follow-up of 8.2 years (range: 1 to 15 years). Three complications occurred: one hematoma, managed surgically; one supracondylar fracture treated orthopedically; and one osteitis, managed by surgical curettage.

Discussion: This knee arthrodesis technique proved effective, with no failures in this short series, especially in cases of primary infection. It is a reproducible means of osteosynthesis, with little subsequent morbidity. Fixation in two orthogonal planes seemed to provide the...
Introduction

Knee arthrodesis may be the only alternative to amputation in certain indications [1,2], infected knee prosthesis being the most frequent. Noninfectious causes may also lead to arthrodesis, such as severe bone lesions involving major bone-loss or extensor system rupture and knee laxity. Success requires stable assembly ensuring optimal arthrodesis site compression onto as large a bone surface as possible, as well as eradication of the infection when the indication involved sepsis [1,3—5]. Several types of instrumentation are employed for arthrodesis: internal fixation by intramedullary nailing or osteosynthesis plating, and single or biplane or circular (Ilizarov) external fixation. Only external fixation and intramedullary nailing, however, are recommended where arthrodesis is indicated for total knee arthroplasty (TKA) infection. The choice then is between the classically more rigid internal fixation, with a risk of recurrence of infection [1,2], and external fixation. We chose a sagittal single-plane external fixator associated to frontal cross-pinning using two Steinman pins. The hypothesis was that fixation in two orthogonal planes would ensure the stability required for satisfactory bone fusion [5—7].

The present study assesses the degree of bone fusion achieved with this technique and recurrence of infection at long-term follow-up in patients operated on for TKA infection.

Patients and methods

A series of eight patients (mean age: 59.1 years; range: 18 to 84 years) underwent knee arthrodesis using the same technique associating an external fixator and cross-pinning with two Steinman pins.

Indications were TKA infection in five cases, fistula osteoarthritis in one paraplegic patient, posttraumatic stiffness with associated extensor system rupture in one case, and fracture associated with TKA implant loosening in one case.

Five of the six cases of infection involved methicillin-resistant Staphylococcus aureus (MRSA), one being polymicrobial, associating MRSA and Mycobacterium xenopi. The other case was an implant infection involving methicillin-sensitive S. aureus. Three of the five cases where arthrodesis was indicated for implant infection were managed in two stages: primary implant removal and replacement by a cement spacer (Fig. 1), with a covering flap in two cases; and secondary arthrodesis due to unfavorable septic and cutaneous evolution (fistula). In the other two cases of TKA infection, arthrodesis was performed in the same step as implant removal, being indicated for associated extensor system rupture, with substantial loss of cutaneous substance in one case. In the paraplegic patient suffering from fistular right-knee osteoarthritis, arthrodesis was indicated for posterior dislocation with irreducible flexion deformity.

Patient 7 was a road-accident victim with an open grade-3 fracture on Cauchoux’s classification at the union of the mid and distal thirds of the femur, with associated ipsilateral extensor impairment. Arthrodesis was indicated after failure of extensor repair, with severe associated knee stiffness. In the remaining case, involving fracture associated with implant loosening in a bedridden severely obese diabetic, arthrodesis was indicated due to comorbidity.

Surgical technique

The same knee arthrodesis technique was used in all the present series. Surgery was performed under pneumatic tourniquet. Skin incision was guided by the anterior scars. The patellar tendon was first sectioned, so as to fold back the extensor system and expose the joint line. Gradual release restored enough knee mobility for satisfactory exposure. Implant components (or spacers) were removed, and the proximal extremity of the tibia and distal extremity of the femur were painstakingly cleaned before minimal bone resection, guided by four criteria:

- optimal conservation of bone stock;
- sufficient contact surface to enable bone fusion;
- correction of any frontal deviation or rotational impairment;
- sagittal adjustment of the arthrodesis position following the preoperative plan, usually 5° flexion.

After preparing the tibial and femoral extremities, internal fixation was achieved with two 5 mm-diameter Steinman cross-pins. One was introduced via the cutaneous side of the medial femoral condyle, 5 to 7 cm above the joint line, pointing distally and laterally, exiting 5 to 7 cm below the joint line on the anterolateral side of the tibia. The second was introduced via the medial side of the medial tibial metaphysis, 5 to 7 cm below the joint line, pointing proximally and laterally, exiting 5 to 7 cm above the joint line on the lateral side of the lateral femoral condyle. These entry points optimized guidance, to avoid damage to the arteriovenous popliteal axis. The assembly thus largely neutralized forces operating in the frontal plane. When necessary, the posterior surface of the patella was stripped and fixed across the joint line by one tibial and one femoral screw. The single-plane femorotibial Hoffmann external fixator was then installed in the sagittal plane. The femoral set of three or four 5 mm pins was positioned anteriorly, as close to the joint line as possible. The three or four 4 mm tibial pins were positioned sagittally, just outside...
of the tibial epiphysis, as close to the joint line as possible, usually under the anterior tibial tuberosity. Bone resection pieces were used to fill the arthrodesis site (Fig. 2).

The tourniquet was released at end of surgery. After hemostasis and lavage, closure was performed over two suction drains.

The arthrodesis was adjusted in complete extension in one case, 5° flexion in three, 10°–15° flexion in three, and 45° flexion in one (the paraplegic patient).

Weight-bearing was forbidden for 2 to 3 months. Postoperative follow-up comprised clinical, X-ray and biological assessment at regular intervals.

**Follow-up procedure**

Results were assessed on several criteria.

Time to bone fusion was assessed from the series of control X-rays. Weight-bearing was resumed once femorotibial trabecular bridges appeared on two perpendicular views. Consolidation was considered to have been achieved at resumption of weight-bearing when this proved pain-free. The external fixator was removed 1.5 to 2 months after resumption of weight-bearing.

Pain was assessed subjectively according to the pain-score items of the International Knee Society (IKS) functional grading system.
Infection was considered to be in remission when no local or general clinical or biological signs were observed at last follow-up. Leukocyte and CRP levels were the two biological criteria, monitored up to a minimum of 12 months’ FU.

Results

Mean follow-up was 8.2 years (range: 12 months to 15 years).

Complications

Three patients experienced early complications. Two were minor: one anteromedial fistula hematoma, and one osteitis on a fixator pin, which responded to surgical curettage. The third case was of supracondylar fracture at 4 months postoperatively with migration of a Steinman pin; as the arthrodesis had fused, the fracture was successfully managed by ablation of the material and 2 months’ cast immobilization.

Consolidation rate and time

Fusion was consistently achieved, at a mean 3.5 months (range: 2.5 to 6 months). Material was removed at a mean 5.2 months (range: 4–8 months: at 4 months in three, at 6 months in one, 5.5 months in the obese patient, at 6 months in two cases and at 8 months in the remaining case) (Fig. 3).

Functional result

At the end of follow-up, three patients were pain free, four had mild or occasional pain, and one had moderate occasional pain.

Clinical and biological remission of infection was consistently achieved at a minimum 12 months’ follow-up, with cicatrisation free of any local inflammatory signs, and recovery of biological criteria (leukocyte and CRP levels) where these had shown abnormality.

Discussion

This retrospective study sought, firstly, to assess bone fusion in knee arthrodeses managed by cross-pin fixation associated to a single-plane external fixator and, secondly, to compare the control of infection obtained with this technique to other techniques classically applied to knee implant infection as reported in the literature.

Three main knee arthrodesis techniques are described in the literature [1,2]:

- 1-bar external fixator in one or two planes [6,7] or Ilizarov external fixator [8,9];
- intramedullary nailing [3,4,10–12];
- osteosynthesis by screwed plating [13].

Only external fixation or intramedullary nailing, however, are to be recommended in case of infected TKA. In the eight largest and most recent series managed by intramedullary nailing, bone consolidation ranged from 80.9 to 100%. McQueen et al. [3] and Vlasak et al. [5] reported 100% fusion in series of 13 and 44 patients, respectively, whereas Incavo et al. [12] obtained 80.9% primary fusion, with four of their 21 arthrodeses requiring revision. Damron and McBeath [1], in a literature review, reported a mean bone fusion rate of 94.6% and Wiedel [2], in a more recent review, a range of 83 to 100%. Results using external fixation vary even more, from 36 to 93% fusion [5,9], Damron and McBeath [1] reporting a mean rate of 63.6% in a review of the literature, with a range of 43 to 71% for Wiedel [2]. The present series showed 100% fusion at a mean 3.5 months (range: 2.5 to 6 months), comparable to the best series using intramedullary nailing and thus...
better in terms of bone fusion than other external fixation techniques. These results, however, are to be interpreted with caution. Firstly, most of the series in the literature are too small to enable comparative statistical analysis, the longest being that of Mabry et al. [10], with 24 cases managed by intramedullary nailing and 61 by external fixation. Moreover, they are very heterogeneous, mixing septic and nonseptic etiologies, precluding comparison between the different methods. The external fixation results are more variable than those for intramedullary nailing, probably because there are a variety of techniques for the former whereas intramedullary nailing techniques are more similar. Wiedel [2], Bargiotas et al. [4] and Oostenbroek and van Roermund [9] consider the rigidity of the assembly to be essential to arthrodesis fusion, which could account for the difference in fusion rates between intramedullary nailing and external fixation, the former being more rigid. Certain authors also report large variations in fusion rate according to the type of external fixator: Vlasak et al. [5] and Hak et al. [6], comparing single versus biplane fixators, obtained better results with the latter (38% vs 42% respectively for Vlasak et al. [5] and 50% vs 57% respectively for Hak et al. [6]). Parrate et al.'s [7] recently reported good results (89% bone fusion) in a series of arthrodeses using two perpendicular fixators. The technique we report here is intended to increase rigidity while limiting the size of the external fixator and the number of pin channels and hence the risk of infection and pin-related fracture. There were no failures of fusion in the present series.

The result for knee arthrodesis in a context of sepsis also depends on remission of infection at last follow-up. TKA infection represents 58 to 89% of indications for knee arthrodesis according to Wiedel [2]. Damron and McBeath [1] reported between 0 and 22% recurrence of infection after arthrodesis by intramedullary nailing and between 5 and 8% with external fixation. The three recent series of arthrodesis by intramedullary nailing (McQueen et al. [3], Bargiotas et al. [4] and Mabry et al. [10]) showed infection recurrence rates of between 6.8 and 8.3%. Two series of arthrodesis by external fixation involved no recurrence of infection: in Parrate et al.’s [7] series, 78% of the arthrodeses were indicated for TKA infection, as were 15 in Oostenbroek and van Roermund’s [9] series. In contrast, Vlasak et al. [5] reported 18% recurrence of infection in a series of 13 arthrodeses by external fixation. Results are thus very variable, mixing septic and nonseptic etiologies. The percentage of indications involving infection tends to be greater in series managed by external fixation. Moreover, for certain authors the type of bacterium affects results. Damron and McBeath [1] reported lower fusion rates in case of polymicrobial, Gram negative or S. aureus infection; although these were no more than trends, the authors recommend a two-step procedure in these cases. Given all of the factors which influence results, the various techniques are hard to compare, but external fixation nevertheless seems to be more effective than intramedullary nailing in terms of remission of infection. In the present series, six of the eight arthrodeses were performed in a context of sepsis, with no recurrence of infection at a mean 8.2 years’ follow-up.

Arthrodesis is unanimously agreed to be a good solution to resort to in difficult cases of implant infection. The different types of osteosynthesis, however, have their advantages and drawbacks. Intramedullary nailing for TKA infection always requires a two-step procedure [4,11,12], and is thus indicated only for patients whose general status enables them to face two heavy operations. According to Mabry et al. [10], nailing takes one and a half times as long as fitting an external fixator and entails twice as much blood loss. Moreover, if sepsis recurs, an intramedullary nail can be difficult to remove: Incavo et al. [12] reported three cases where anterior tibial corticotomy followed by wiring and graft were required in order to ablate the material. Intramedullary nails, moreover, are usually customized [12,14]), which is costly in both money and time. The complications most frequently encountered with external fixation are pin-related infection (discharge, or osteolysis around the pin) and pin-site fracture [6,9]: Mabry et al. [10] reported a 21% rate of pin-related infection and 8% of pin-site fracture. Parrate et al. [7] found that hydroxyapatite-coated pins reduced the incidence of discharge.

Conclusion

External fixators play a large role in arthrodesis indications for TKA infection. They are available without delay, and installation is straightforward and reproducible, enabling good adjustment of frontal and sagittal alignments. Associated morbidity is low and a one-step procedure is possible where the infection allows it. The assembly is less stable than with intramedullary nailing, but this is made up for in the present technique by the two frontal Steinman cross-pins. The stability of this osteosynthesis assembly ensured consistent bone consolidation, and remission of infection was achieved in all cases involving sepsis.

Conflicts of interest

No financial support was received. None of the investigators have a conflict of interest related to the topic of the publication.

References


