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# Knee arthrodesis with the Sheffield external ring fixator

## Fusion in 6 of 10 consecutive patients

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**Background** Knee arthrodesis with external fixation (XF) is a possible salvage procedure for infected total knee arthroplasties (TKA). We report the outcome in 10 patients who underwent arthrodesis with the Sheffield Ring Fixator.

**Patients and methods** The patients had primary arthrosis in 8 cases; 2 cases were due to rheumatoid arthritis and sclerodermia. The mean time between the primary TKA and arthrodesis was 6 (0.5–14) years. The average age at arthrodesis was 69 years. The average follow-up period was 10 months.

**Results** Stable fusion was obtained in 6 patients after a mean XF time of 3.6 (2–4) months. 1 patient was referred to another hospital because of nonunion. This patient showed fusion with intramedullary nailing after 7 months. 3 nonunion patients required permanent bracing, 7 patients had pin tract infections. Infections healed in all patients.

**Interpretation** The Sheffield Ring Fixator gives an acceptable fusion rate for arthrodesis in the infected TKA, with limited complications.

Patients with a chronic or virulent deep knee infection that is resistant to antibiotic therapy, with extensive bone loss or severe systemic morbidities, can be unsuitable for revision arthroplasty. Knee fusion may be the only means of avoiding amputation (Conway et al. 2004, Leone and Hanssen 2005).

External fixation (XF), intramedullary nailing (IM) and dual plating have been used to achieve arthrodesis. IM is the commonest method used for non-septic cases (Wiedel 2002). IM in patients with deep joint infection carries the risk of dissemination, reactivation, or maintenance of a latent joint infection. XF minimizes this danger (Damron and McBeath 1995, Wiedel 2002). There have been no reports published on knee fusion patients with the Sheffield Ring Fixator after infected TKA. We therefore report the results of our first 10 patients to be operated with this technique.

### Patients and methods

10 patients (5 men) with infected TKAs underwent knee arthrodesis with the Sheffield fixator in our department from 2001 to 2005 (Table 1). The patients were studied retrospectively. In 8 cases the reason for the TKA was primary arthrosis; 2 cases were due to rheumatoid arthritis and sclerodermia. Prior to arthrodesis, patients had been treated with oral or intravenous antibiotics (all 10), revision arthroplasty (1 patient), synovectomy (4 patients), or debridement (10 patients). 1 patient (case 3) was operated on for a traumatic patella fracture after insertion of the original TKA, which led to infection through a cicatricial defect and ultimately to destruction of the extensor apparatus.

Table 1. Patients

Case no.	Age	Sex	Primary diagnosis	No. of years from primary TKA to arthrodesis	Significant systemic diseases
1	55	F	OA <sup>a</sup>	3	Breast cancer, hypertension, sclerodermia
2	68	M	OA	8	Bronchitis
3	66	F	OA <sup>b</sup>	0.6	
4	81	M	OA	4	Heart insufficiency, pulmonary embolism
5	70	F	OA	10	Addisons disease, asthma, pacemaker due to bradycardia
6	61	M	OA	13	Liver-transplanted, immunosuppressive drugs
7	66	M	OA	10	Prostate cancer, bronchitis
8	71	M	OA	0.6	
9	78	F	RA	0.6	
10	76	F	OA	14	Diabetes mellitus, osteoporosis, aorta stenosis

<sup>a</sup> secondary to sclerodermia  
<sup>b</sup> after fracture

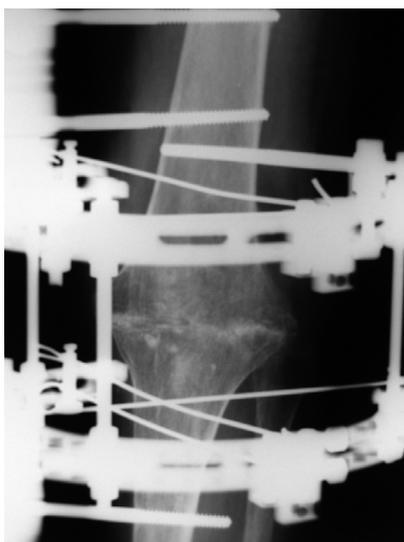


Figure 1. Anteroposterior radiograph showing trabecular fusion across the entire length of the arthrodesis.

Arthrodesis was indicated because of ongoing virulent infection that was not responsive to antibiotic treatment and revision surgery, severely eroded paraarticular bone, destroyed extensor apparatus, unsuitability for or unwillingness to undergo repeated major surgery for anesthesiological and psychological reasons. The average age at the time of arthrodesis was 69 (61–81) years. All arthrodeses were performed by the same surgeon.

In 9/10 patients the arthrodesis with XF was performed in two stages. After debridement, the prosthesis was removed and replaced with a gentamicin

spacer. Intravenous antibiotics were administered for 6–8 weeks. Biopsies for bacterial cultures were obtained and signs of infection observed. When the infection was quiescent, arthrodesis was performed.

Radiographic fusion was defined as trabecular bridging along the whole fusion area in both the anteroposterior (Figure 1) and lateral planes (Klinger et al. 2006). A clinically stable arthrodesis was the criterion for successful fusion. Clinical stability was evaluated after about 3 months by loosening the fixator bars, followed by weight bearing. If (1) the knee was stable and painless, if (2) radiographs showed no signs of callus formation or trabecularization, or if (3) infected pins caused loosening of the apparatus, the fixator was removed under anesthesia and stability was tested again. All patients underwent bandaging with a ROM splint (DonJoy, Vista, CA) or a custom-made stiff leather bandage for at least 4–6 weeks after removal. Pain was treated and pin tracts were inspected and cleaned daily. Pin tract infections (in 7 patients) were treated with dicloxacillin. Systemic antibiotics were administered 1 day after surgery, but cases 2, 3, and 9 were given intravenous antibiotics for a longer period (3, 7, and 19 days, respectively) due to elevated and initially sharply rising serum parameters indicating infection.

#### *Operative second-stage procedure*

Access to the joint was through the former incision. The gentamicin spacer and eroded bone were removed. Debridement was performed. The bone

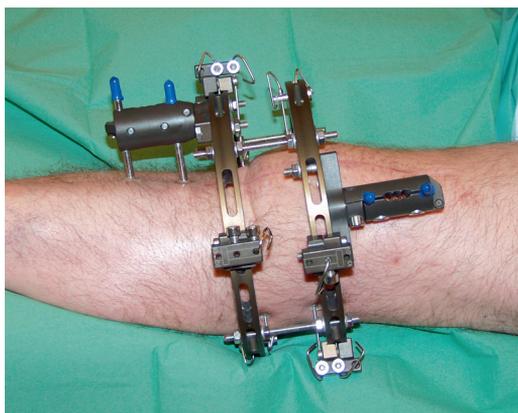


Figure 2. The assembled Sheffield Ring Fixator.

ends were temporarily held with Steinmann pins. The fixator rings were connected by bars. Clamps were fixed to the centers of the diaphyseal femur and tibia with 2 hydroxyapatite-coated screws and bolted to a semicircular ring. Three 2-mm transosseous tensioned K-wires were fixed in the metaphyses and 1 additional cortical hydroxyapatite-coated screw connected the femoral bone with the proximal ring. The pins were removed. The arthrodesis was compressed with good bone contact and firmly stabilized at 5–10 degrees flexion and 5–10 degrees valgus (Figure 2). No bone graft was used. Full weight bearing was allowed as soon as possible. Further compression was applied after 6 weeks, when the fixator components were tightened.

## Results

The average XF period was 3.2 (2–4) months. Fusion was achieved clinically at an average time of 3.6 (3–4) months and radiographically at mean 5.7 (3.5–10) months in 6 patients. All 10 patients started full weight bearing within 2 weeks. The average length of hospitalization was 2.9 (1–5) weeks. Of the 4 non-fusion patients, 2 had reduced knee compression due to loose femoral fixator pins in infected tracts (cases 2 and 8). The other 2 cases (cases 6 and 10) had the apparatus removed because of no signs of clinical and radiographic fusion, both after 3.5 months. 3 non-fused knees required permanent bracing, while 1 (case 2) was referred to another hospital for further treatment where IM

was performed with fusion after 7 months. Case 8 was manodepressive and was unwilling to endure an extended period of fixation or further surgical treatment. Because of lacking signs of healing combined with severe systemic disease, fusion was thought to be unlikely to occur with the fixator in cases 6 and 10. Instead, it was hoped they might fuse with a brace. All patients had leg-length shortening; for the 7 legs measured it was mean 6 (1.5–7.5) cm. All patients were available for monthly follow-up for an average of 9.9 (5.5–18) months, with additional radiographs at least 3 times postoperatively (Table 2).

No patients suffered skin or wound necrosis, neurovascular damage, or pin site fractures. All infections resolved. There were no subsequent femoral amputations. 7 patients had pin tract infection that was treated with oral dicloxacillin. The microorganisms present in the cultures from the first-stage operation are listed in Table 3.

## Discussion

External fixators offer the advantage of frame adjustment, thereby minimizing rotational forces and maximizing compression and stability at the arthrodesis—which allows early weight bearing, usually within a few days after surgery. Disadvantages are frame maintenance and encumbrance, later device removal, less predictable fusion rates, pin tract infections, pin loosening, risk of neurovascular damage during pin and wire insertion, and pin site stress fracture. Advantages of IM include high fusion rates, early weight bearing, and rapid mobilization. Disadvantages are long operation time, large perioperative blood loss, nail telescoping and breakage, potential rotational instability, perioperative fracture, bone marrow infection, and the fact that IM is technically challenging. Unless a short fusion nail is used, IM is hindered by an ipsilateral hip prosthesis while XF permits insertion of a hip prosthesis later on (Damron and McBeath 1995, Wiedel 2002, Conway et al. 2004, Domingo et al. 2004).

The external fixators were removed after approximately 3 months. We might have obtained more than 6 fused knees out of 10 attempts had the fixation period of the 4 nonunion patients been of a

Table 2. Results

A	B	C	D	E	F	G	H	I
1	1 DG	3	4	4	7.5	+	6	7
2	1 DG	2	Loose (11 mo)	No fusion (11 mo)	3	+	7	11
3 <sup>a</sup>	1 SR	3	4.5	10	2	–	1	10
4	2 D, 1 DG	3.5	3.5	3.5	Yes	+	10	7
5	1 D, 1 DG	4	4	4	1.5	+	1	15.5
6	3 re-TKAs, 2S, 1DG	3.5	Loose (10 mo)	No fusion (9 mo)	6	–	1	8
7	1 DG	3	3	7	5	+	8	7
8	1 S, 1 DG	3.5	Loose (13 mo)	No fusion (13 mo)	?	+	1	10
9	1 SR, 1 DG	3	3	6	5	+	2	6
10	1 DG	3.5	Loose (18 mo)	No fusion (18 mo)	?	–	12	18

<sup>a</sup> Case 3: removal of TKA and XF in one stage.

A Case no.

B Revisions prior to arthrodesis

D – debridement

DG – debridement with removal of TKA and instillation of gentamicin spacer

S – synovectomy

SR – synovectomy with removal of liner

C External fixation time (months)

D Time to clinical fusion (months)

E Time to radiographical fusion (months)

F Leg shortening measured by wedge height in the erect position with a horizontal plane through the superior iliac anterior spines.

G Pin tract infection

H Postoperative time to full weight bearing (days)

I Follow-up period (months)

Table 3. Results from perioperative biopsies during the first-stage operation

Case no.	Gram-positive bacteria	Gram-negative bacteria	PCR <sup>a</sup>	Scintigraphy <sup>b</sup>	Suspected route of infection
1 <sup>c</sup>	No growth	No growth	–	+	Hematogenous
2 <sup>c</sup>	No growth	No growth	–	–	Hematogenous
3	Coagulase-negative staphylococci, <i>Finnegoldia magna</i>	No growth	–	–	Cicatrical defect after patella fracture
4	<i>Streptococcus mutans</i>	No growth	–	–	Hematogenous
5	No growth	<i>Enterococcus faecalis</i> Proteus sp.	–	–	Hematogenous
6	Hemolytic streptococcus group G	No growth	–	–	Hematogenous
7	<i>Staphylococcus aureus</i>	No growth	–	–	Hematogenous
8	<i>Staphylococcus aureus</i>	No growth	–	–	Hematogenous
9 <sup>c</sup>	No growth	No growth	–	+	Hematogenous
10	<i>Staphylococcus aureus</i>	No growth	–	–	Hematogenous

<sup>a</sup> PCR: polymerase chain reaction with broad-range bacterial primers and DNA sequencing.

<sup>b</sup> Scintigraphy: technetium-99m leukocyte scintigraphy.

<sup>c</sup> Blood tests and clinical findings indicated deep infection in cases 1, 2 and 9.

similar time range as in other XF studies, and if pin tract infections—with subsequent risk of pin loosening—had been avoided (Rand 1993) perhaps by administering peroral antibiotics for a relatively long period postoperatively. For the reasons stated,

3 of these patients were treated permanently with bracing. In infected TKAs, fusion rates with uni- or biplanar apparatuses and the multi-ring Ilizarov fixator spanned from one-third to nine-tenths and from two-thirds to all, respectively, in series with

4–29 patients and 2–19 patients (with considerable fixation periods varying from 2–10 months and 2–6 months) (Rothacker and Cabanela 1983, Knutson et al. 1985, Rand et al. 1987, Vlasak et al. 1995, Garberina et al. 2001, Manzotti et al. 2001, Vanryn and Verebelyi 2002, Conway et al. 2004, Klinger et al. 2006).

A meta-analysis of techniques used for knee arthrodesis after failed TKA, most of which were infected, reported overall fusion rates of 95% in patients treated with IM, compared with 64% for patients treated with XF (Damron and McBeath 1995). The authors recommended IM except for when the infection cannot be eradicated, in which case two-stage XF would be more appropriate. They stated that XF has been used more frequently in cases with Gram-negative or multimicrobial infections, but noted a significant increase in XF fusion rates where infections were caused by Gram-positive organisms.

Rand (1993) reported 89 fusions out of 98 knee arthrodeses after failed TKAs with IM. It was stated that IM was the procedure of choice for non-septic failure of TKAs, or management of nonunion of an arthrodesis where there was remission of the infection. It was suggested that IM should be avoided in the presence of active infection due to the risk of introducing the infection into the bone marrow. This very serious complication was an important consideration in our choice of XF rather than IM.

Whether there is a significant difference in fusion rates for one- or two-stage XF is unclear because the selection criteria for knee arthrodesis vary between studies. Some authors suggest that staged XF should always be used in an attempt to eradicate multimicrobial or virulent infection where there is also extensive bone loss, and favor XF over IM and dual plating. Others advocate that a one-stage procedure is acceptable in the presence of Gram-positive infection without purulence. 7 of our 10 patients had pin tract infections, which is about the same as in other studies (Rand et al. 1986, 1987, Bengtson and Knutson 1991, Wiedel 2002, Conway et al. 2004, Leone and Hanssen 2005).

The femoral screws loosened in two non-fused knees, which may be explained by lower stability of the femoral ring relative to that of the tibial ring. The reason may be the narrower angles between

the three K-wires compared to the tibia. Also, reduced bone quality in the femur compared to the tibia could possibly have delayed fusion in the 2 non-fusion patients with no infected tracts. Inferior femoral stability might be overcome and improved by applying an extra fixation bar, more femoral ring screws, or an additional proximal ring (Farrar et al. 2001). Also, secondary bone grafting, a prolonged fixation period, and further compression or callus distraction can be considered when signs of clinical and radiological fusion are not present (Knutson et al. 1985, Rand 1993).

Except for 1 case, we used a two-stage procedure. Other studies on treatment of deep infections in TKAs recommend opting for a one-stage procedure after adequate debridement (Bengtson and Knutson 1991, Conway et al. 2004, Leone and Hanssen 2005). We have found that the two-stage procedure is advisable when there is active virulent infection and severe bone loss.

#### *Contributions of authors*

AU: wrote the article. AU and KF: acquired and interpreted all relevant data. AU, KF, and LB: each contributed substantially to the conception and design of the study. LB: performed the surgery.

No competing interests declared.

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