European Journal of Orthopaedic Surgery & Traumatology (2023) 33:2625–2632
https://doi.org/10.1007/s00590-023-03493-2

ORIGINAL ARTICLE

# Circular external fixation for knee fusion in complex indications

**Yousef Marwan[2] · Ross Muir[1] · Elizabeth Barron[1] · Yvonne Hadland[1] · Elizabeth Moulder[1] · Hemant Sharma[1]**

Received: 7 January 2023 / Accepted: 5 February 2023 / Published online: 11 February 2023


## Abstract

**Purpose** Reconstructive surgery for complex knee problems is limited and challenging. The aim of this study is to report the technique, outcomes and complications of circular external fixation for knee fusion in complex indications.

**Methods** Retrospective review of a prospectively collected database of a complex limb reconstruction unit was done during December 2022. Patients with complex knee problems who underwent knee fusion with circular external fixator were included.

**Results** Fourteen patients met the inclusion criteria. The mean age of the patients was 63 ± 16.8 years. Deep infection was the indication for surgery in 11 patients (78.5%), of which 10 cases were related to previously failed revision arthroplasty. The mean duration of treatment in frame was 13 ± 4.1 months, while the mean follow-up duration following frame removal was 7.1 ± 4.2 years. Fusion was achieved in 13 patients (92.9%). The most common complication was pin site infection (6; 42.9%), of which three (21.4%) required pin/wire revision. One (7.1%) patient had fracture at the fusion site following frame removal that was treated with reapplication of the frame.

**Conclusion** Knee fusion using circular external fixation is a reliable surgical option for complex knee problems especially in infected failed revision total knee replacements.

**Keywords** Knee · Fusion · Arthrodesis · Ilizarov · External fixation · Hexapod external fixator

## Introduction

Arthrodesis, or fusion of the knee, is a reliable primary or salvage option for several complex problems. The first described knee arthrodesis is attributed to Albert, in 1878, for a paralytic flail knee in a patient with poliomyelitis [1]. Later, Hibbs performed fusion for a tuberculous knee in 1911 [2]. Key described the technique of knee arthrodesis using external fixation in 1932 [3], while Charnley reported his series of patients who underwent knee fusion using uniplanar external fixators in 1960 [4].

There are now numerous internal and external fixation methods available to achieve knee fusion. The choice of surgical technique and implant depends on several factors, including the underlying diagnosis, the condition of the bone and soft tissues, the patient's general medical status and history of ongoing or previous infection. To avoid serious complications, the advantages and limitations of the available options should be understood [5, 6]. For example, in a grossly infected knee, the application of a surface implant (i.e. dual plating) is not advised, unless two-stage surgery is planned to eradicate the infection [7, 8]. An intramedullary nail offers the advantage of early weight bearing and fast rehabilitation; however, in the presence of pre-existing infection, there is a high risk of spread and further morbidity [6, 8, 9]. Intramedullary nailing also has limited value when there is significant malalignment or limb shortening.

In complicated cases, circular external fixators provide the advantages of gradual correction of length or alignment and superior mechanical stability [5, 10–12]. In addition, the risk of biofilm formation and persistence of infection is minimized as contact of the implant with the infected site is avoided.

In this study, we aim to report the technique, outcomes and complications of circular external fixation for knee fusion in complex indications.

✉ Yousef Marwan
yousefmarwan@hotmail.com

[1] Limb Reconstruction Unit, Department of Trauma and Orthopaedic Surgery, Hull University Teaching Hospitals, Hull HU3 2JZ, UK

[2] Department of Surgery, Faculty of Medicine, Health Sciences Center, Kuwait University, Kuwait City, Kuwait

## Materials and methods

### Study setting

The study was undertaken at Hull University Teaching Hospitals, a level 1 major trauma centre hospital in the UK. The study protocol was reviewed and approved by our institutional governance board (protocol number: 2022.178). Patients were identified from a prospective database. Inclusion criteria were all patients with complex knee problems who underwent knee fusion with a circular external fixator, regardless of the surgical indication, between 2007 and 2020. Patients with a duration of follow-up of less than 24 months were excluded.

A retrospective chart review of eligible patients was performed by the primary investigator (YM) during December 2022. Data collection included patient demographics, details/indications of the surgery, duration of frame use, additional procedures required, mechanical alignment, complications and duration of follow-up. A successful outcome was defined as limb salvage with complete radiological joint fusion, the ability to bear weight and walk without pain, as well as clinical resolution of infection where relevant. Regarding alignment, coronal and sagittal mechanical alignment within 10° of neutral was considered acceptable.

The data was analysed using the IBM SPSS Statistics 27.0 software (SPSS Inc., Chicago, Illinois, USA). Descriptive analysis was carried out for all variables to measure frequencies, percentages, means and standard deviation (SD).

### Surgical technique

All surgeries were done in a single-stage manner. The previous incision, if present, was used to approach the knee joint; otherwise, midline incision with medial parapatellar arthrotomy was done. If present, the knee prosthesis or other metal implants were removed. If infection was suspected, thorough debridement was performed, including excision of the sinus tract and reaming of the intramedullary canal if indicated, and a minimum of five multiple deep tissue samples were obtained. To avoid the spread of infection, reaming was limited to a few centimetres beyond the stem of any previous prosthesis. Thorough washout was performed with re-debridement if required. After debridement, surgical tools are exchanged, and clean drapes applied. Patella excision was performed in cases with poor soft tissue status to facilitate wound closure.

The distal femur and proximal tibia surfaces were prepared with total knee arthroplasty cutting guides to achieve transverse cuts in the correct axis of the bone. If lengthening was intended, a distal corticotomy was performed with the multiple drill holes and osteotome technique.

Peri-operative antibiotic prophylaxis was given immediately prior to surgery, or immediately after debridement in infection cases. If indicated, local antibiotics were delivered into the bone and soft tissues using Stimulan (Biocomposites Ltd, Staffordshire, England). Earlier in the case series, the post-operative protocol for deep infection was for two weeks of intravenous antibiotics followed by four weeks of oral antibiotics. More recently, this protocol was changed to one week of intravenous and then five weeks of oral antibiotics. In non-infected cases, 24 h of post-operative prophylactic antibiotics was administered.

### Post-operative protocol

Post-operative pain was managed with a nerve block catheter or intravenous patient-controlled analgesia for the first 48–72 h. The first pin site dressing change was done during the second post-operative day, and the patients were advised to perform weekly pin site care after discharge.

All patients were allowed to bear full weight on their leg immediately after surgery. Physiotherapy sessions were provided once or twice weekly, as required, until frame removal. The patients then continue physiotherapy to optimize gait and function as needed following frame removal.

## Results

We identified fifteen patients who underwent knee fusion using circular external fixation from our database. There was one exclusion due to insufficient follow-up. This patient had a successful fusion; however, died two months following removal of frame due to complications of COVID-19 infection.

Table 1 demonstrates the background characteristics of the patients. The mean age of the patients was $63 \pm 16.8$ (range = 20–83) years. Eight (57.1%) patients were males, and eight (57.1%) knees were right sided. The most common comorbidities among the patients were diabetes mellitus type 2 (4; 28.6%) and hypertension (4; 28.6%). Deep infection was the indication for surgery in 11 patients (78.5%), of which 10 cases were related to previously failed revision arthroplasty. A case example of knee fusion for infected revision arthroplasty is shown in Fig. 1, while Fig. 2 demonstrates knee fusion for a chronic knee dislocation.

The outcomes and complications are shown in Table 2. Twelve (85.7%) patients had a hexapod frame, while only two (14.3%) had an Ilizarov frame. The mean duration of treatment in frame was $13 \pm 4.1$ (range = 5–22) months,

**Table 1** Background characteristics of the patients. ($N = 14$)

| Characteristics | Result |
|---|---|
| Age (years) | |
| Mean ± SD* | 63 ± 16.8 |
| Range | 20–83 |
| Sex (*N*; %) | |
| Female | 6 (42.9) |
| Male | 8 (57.1) |
| Side (*N*; %) | |
| Right | 8 (57.1) |
| Left | 6 (42.9) |
| Significant comorbidities (*N*; %) | |
| Arrhythmia | 2 (14.3) |
| Chronic obstructive pulmonary disease | 1 (7.1) |
| Deep vein thrombosis | 1 (7.1) |
| Diabetes mellitus type 2 | 4 (28.6) |
| End stage renal disease | 1 (7.1) |
| Hypertension | 4 (28.6) |
| Hypothyroidism | 1 (7.1) |
| Ischaemic heart disease | 3 (21.4) |
| Indication for fusion (*N*; %) | |
| Infected revision knee arthroplasty | 7 (50.0) |
| Infected revision knee arthroplasty with failed extensor mechanism | 2 (14.3) |
| Chronic knee dislocation | 1 (7.1) |
| Chronic septic arthritis + osteomyelitis of the patella & distal femur | 1 (7.1) |
| Failed previous internal knee fusion following infected arthroplasty | 1 (7.1) |
| Spontaneous distal femur osteonecrosis | 1 (7.1) |
| Tibial plateau malunion with 25° flexion contracture & ligament instability | 1 (7.1) |

**SD* standard deviation

while the mean follow-up duration following frame removal was 7.1 ± 4.2 (range = 2–15) years.

Additional procedures during the period in frame were common, to manage obstacles or complications (Table 2). Drilling and bone marrow aspirate concentrate injection for delayed union or nonunion of part of the fusion site (e.g. lateral quarter of the joint) was done for four (28.6%) cases. Only three (21.4%) cases of infected pin site required revision of the pins in addition to antibiotics treatment.

At the end of treatment, 11 (78.6%) patients had varus coronal mechanical alignment of the lower extremity, and 11 (78.6%) patients had procurvatum/flexion sagittal mechanical alignment of the lower extremity (Table 2). Out of the 14 patients, 13 (92.9%) had coronal alignment within 10° from neutral, and 11 (78.6%) had sagittal alignment within 10° from neutral.

All patients undergoing knee fusion are offered distal extension of the frame and tibial corticotomy to compensate for the leg length discrepancy (LLD) secondary to the knee fusion. Six patients (42.9%) opted for this as a synchronous operative intervention (Table 2). Out of the 14 patients included in this series, residual LLD was noted in 13 (92.9%) cases regardless of undergoing lengthening or not. The mean LLD was 26.2 ± 18.1 (range = 5–60) mm, which was managed with an insole or shoe lift, with or without walking aid.

Complications of knee fusion are also demonstrated in Table 2. The most common complications observed in this case series were pin site infection (6; 42.9%) and pin periprosthetic fracture of the femur (2; 14.3%) (Fig. 3). One (7.1%) patient had failed fusion; this was a fibrous pain-free nonunion with a dynamic flexion deformity resting at 35°, and the patient did not wish to have any further intervention to address this complication. In addition, one (7.1%) patient had fracture at the fusion site following frame removal (Fig. 4).

## Discussion

In the current study of 14 patients with complex knee problems indicated for joint arthrodesis, favourable outcomes were attained in all patients using circular external fixation.

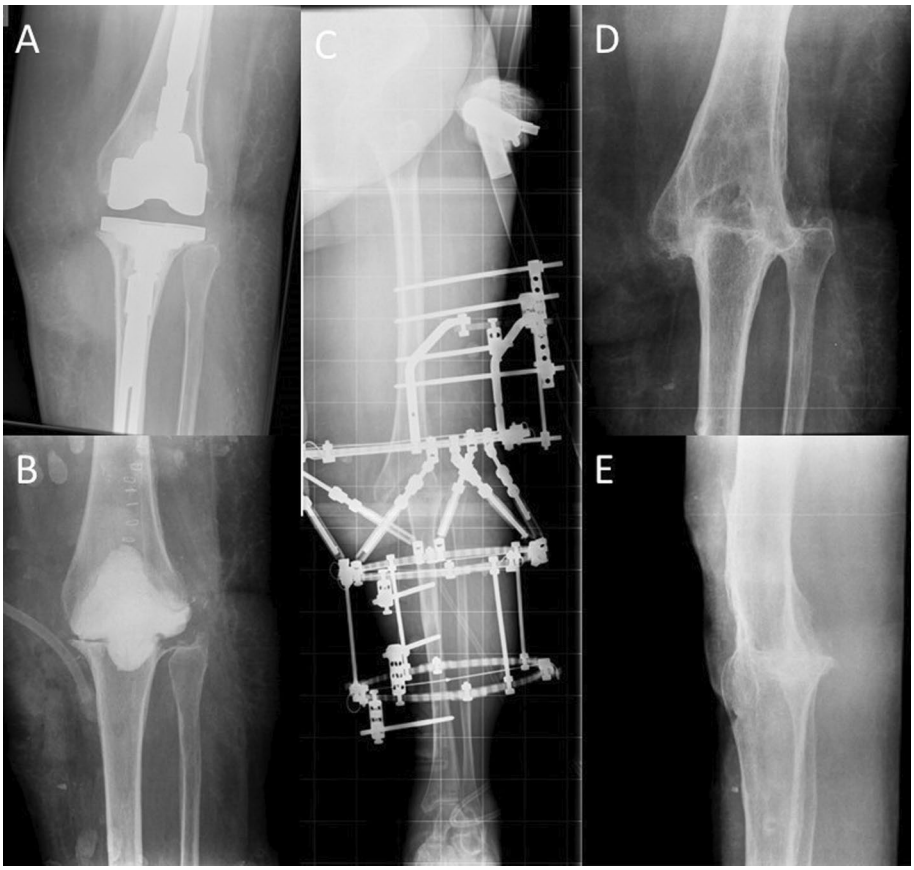


**Fig. 1** X-rays of knee fusion done for infected left total knee arthroplasty after multiple failed revision surgeries. **A** Infected revision knee arthroplasty; **B** Post implant removal and application of antibiotic cement spacer before referral to our team; **C** Circular external fixation hexapod frame for fusion; **D** and **E** Anteroposterior and lateral knee X-rays obtained 4 years following frame removal

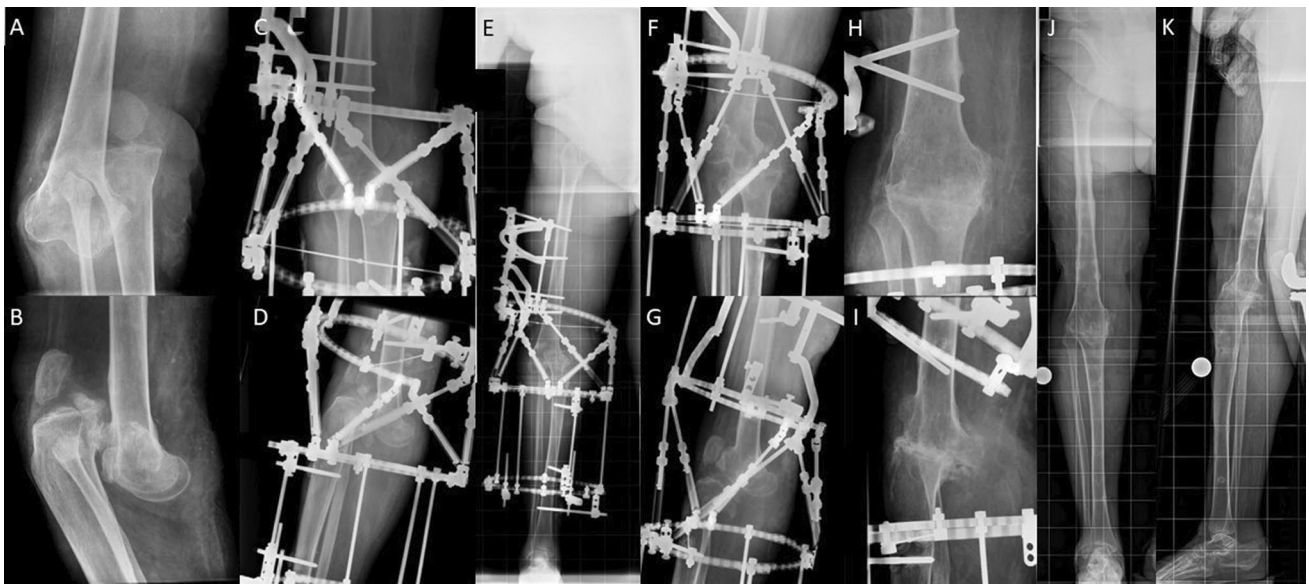


**Fig. 2** X-rays of knee fusion done for chronic right knee dislocation. **A** and **B** Anteroposterior and lateral knee views of the chronically dislocated knee; **C**, **D** and **E** Anteroposterior, lateral and full length lower extremity views 5 days after application of circular external fixation hexapod frame; **F** and **G** Anteroposterior and lateral knee views obtained 3 months following distraction to regain the soft tissue length; **H** and **I** Anteroposterior and lateral knee views at the end of circular external fixation frame treatment; **J** and **K** Anteroposterior and lateral full length lower extremity views obtained 14 months following frame removal

**Table 2** Outcomes and complications of circular external frame for knee fusion. ($N=14$)

| Outcomes and complications | Results |
|---|---|
| Frame type (*N*; %) | |
| Ilizarov | 2 (14.3) |
| Hexapod | 12 (85.7) |
| Duration of frame treatment (months) | |
| Mean ± SD* | 13 ± 4.1 |
| Range | 5–22 |
| Follow-up duration (years) | |
| Mean ± SD* | 7.1 ± 4.2 |
| Range | 2–15 |
| Additional procedures during frame treatment (*N*; %) | |
| Drilling and bone marrow aspirate concentrate injection for delayed union | 4 (28.6) |
| Wires/pins revision for pin site complications | 3 (21.4) |
| Proximal extension of frame for pin site fracture | 2 (14.3) |
| Common peroneal nerve decompression | 1 (7.1) |
| Fusion alignment—Coronal (°) | |
| Varus (*N*; %) | 11 (78.6) |
| Mean ± SD* | 3.5 ± 2.3 |
| Range | 1–7.8 |
| Valgus (*N*; %) | 1 (7.1) |
| Value (1 patient only) | 15 |
| Range | NA |
| Neutral (*N*; %) | 2 (14.3) |
| Fusion alignment—Sagittal (°) | |
| Procurvatum^ (*N*; %) | 11 (78.6) |
| Mean ± SD* | 8.7 ± 9.3 |
| Range | 1.5–35 |
| Recurvatum (*N*; %) | 1 (7.1) |
| Value (1 patient only) | 4 |
| Range | NA |
| Neutral (*N*; %) | 2 (14.3) |
| LLD* (mm) (*N*; %) | 13 (92.9) |
| Mean ± SD* | 26.2 ± 18.1 |
| Range | 5–60 |
| Patients desired limb lengthening (*N*; %) | |
| No | 8 (57.1) |
| Yes | 6 (42.9) |
| Complications (*N*; %) | |
| Pin site infection | 6 (42.9) |
| Periprosthetic fracture | 2 (14.3) |
| Arthrodesis site fracture | 1 (7.1) |
| Nonunion (i.e. failed fusion)^ | 1 (7.1) |
| Osteomyelitis | 1 (7.1) |
| Pin breakage | 1 (7.1) |
| Proximal femur fracture post frame removal | 1 (7.1) |

**LLD* leg length discrepancy, *SD* standard deviation

^One patient had fibrous nonunion and ended up with a dynamic flexion deformity resting at 35°

Regardless of the expected number of complications and additional procedures, desired outcomes were achievable with this surgery. Complications were manageable; however, some might have extended the period of frame treatment.

With the current advancement and success of knee arthroplasty, knee fusion is an infrequent primary or revision surgery. Based on patient registries from Denmark, the cumulative incidence of knee arthrodesis within 15 years after primary arthroplasty was 0.26% [13]. The same study demonstrates that the five-year cumulative incidence has dropped significantly over time between the periods of 1997 to 2002 and 2008 to 2013; from 0.32 to 0.09% [13]. Periprosthetic infection was the most common indication for arthrodesis following primary knee arthroplasty in the Danish databases, compromising more than 90% of the cases [13]. In our series, failed infected arthroplasty was also the most common indication for fusion. This indicates that infection remains a significant problem in joint arthroplasty surgery, and highlights the importance of improvement in preventive measures to lower the rate of this complication.

The use of circular external fixation frames for knee fusion was reported in a few studies in the literature. When used as a salvage procedure following failed arthroplasty, circular external fixators have a very high success rate and can prevent above-knee amputation [12, 14–17]. Nevertheless, the complication rate with this surgery is relatively high [12, 14–17]. This could be due to the complex nature of the indications for surgery. Most of the complications reported were minor and did not affect the final outcome, such as pin/wire site infection or loosening; however, some major complications affecting the course and result of frame treatment were also reported, including pin periprosthetic femoral fracture and nonunion of the arthrodesis site [12, 14–17]. These findings are similar to our observations. The high complication rate is likely due to the complex nature of the surgery, advanced age of the patients, poor bone quality and multiple previous surgeries with often compromised soft tissue. This highlights that the surgeon and patient should be aware of the possible complications and should be prepared to manage them before undertaking knee fusion using circular external fixation. It is also critical to understand the potential need for additional procedures to optimize the treatment outcomes (e.g. leg lengthening).

Single-stage surgery for infected cases is standard practice in our unit. Single-stage surgery for chronic osteomyelitis has shown excellent results with the introduction of calcium sulphate based local antibiotics [18–20]. This approach requires detailed pre-operative planning and thorough surgical debridement to ensure infection eradication. Our patients had the benefit of evaluation and management within a well-established bone infection multidisciplinary team that is composed of specialists in infectious diseases, musculoskeletal radiology, plastic surgery and orthopaedic

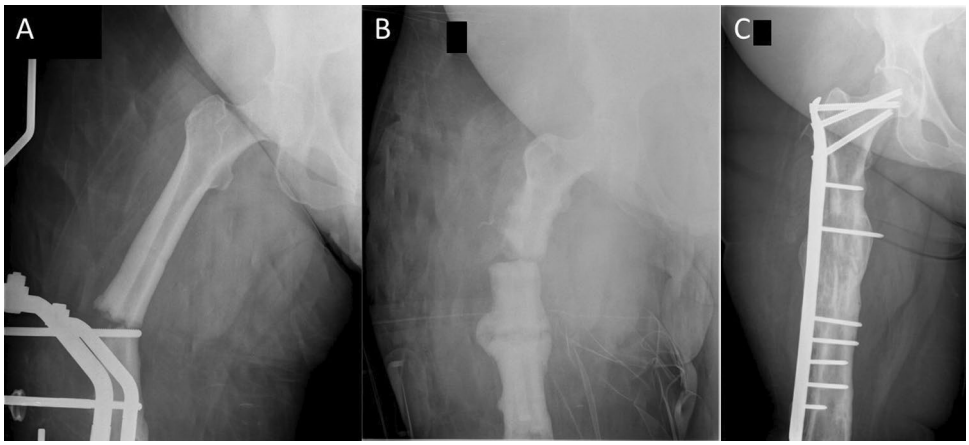


**Fig. 3** X-rays of pin site periprosthetic fracture in a knee fusion case. **A** Anteroposterior view of the proximal femur showing fracture at the proximal halfpin site that occurred 6 months post-operatively and was managed by pin removal and proximal extension of the circular external fixation frame; **B** Anteroposterior view of the proximal femur obtained 3 weeks after frame removal showing healing of the previous fracture site and new subtrochanteric pin site fracture; **C** Anteroposterior view of the proximal femur obtained 5 years after treatment of the complications with pin site debridement and open reduction and internal fixation

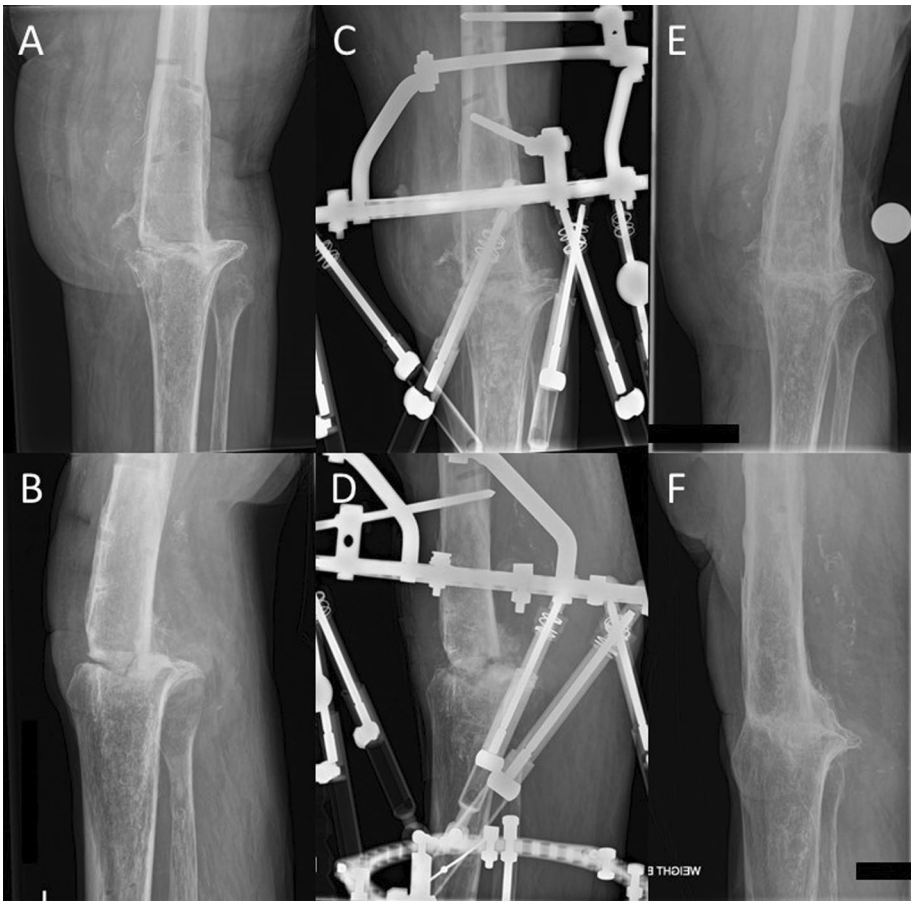


**Fig. 4** X-rays of knee fusion site fracture. **A** and **B** Anteroposterior and lateral knee views showing fracture at the arthrodesis site 3 weeks post removal of the circular external fixation frame; **C** and **D** Anteroposterior and lateral knee views obtained 1 week following frame reapplication; **E** and **F** Anteroposterior and lateral knee views obtained 3 years following treatment of the fracture and frame removal

surgery. Additionally, the use of circular external fixation avoids bone surface contact of the fusion hardware, which reduces the risk of biofilm formation and facilitates eradication of infection.

In the current series, one of the patients had a chronic irreducible knee dislocation with significant shortening and soft tissue contracture. Such cases are rarely reported in the literature since knee dislocation is an emergency condition that is

managed promptly [21–25]. Since no consensus is available regarding the treatment of such a deformity, the management of these cases is challenging. The treatment plan should be based on the severity of the injury, soft tissue status and patient demands and expectations. In a patient with severe shortening and soft tissue contracture, it is not feasible to perform open reduction and ligament reconstruction or arthroplasty. Therefore, gradual soft tissue lengthening and joint reduction followed by joint fusion using circular external fixation frame may be the only option. Ferreira and Marais have described the use of a hexapod circular frame to successfully manage a chronically dislocated knee; however, their case had better soft tissue status leading to shorter period of frame treatment [25].

This study has limitations due to the retrospective nature, with an inherent risk of bias. In retrospective studies, the documented information in the patients' charts is limited. For example, functional outcomes were not detailed in our study because the clinical encounter did not include a validated assessment of functional parameters (e.g. pain scores, limitation of motion, quality of life). Furthermore, the number of cases is small, which limits comparison of outcomes with different patient groups or different circular fixation devices. Also, the study was done at a single institution which may limits application of the results across to patient populations. Finally, there was no control group to compare outcomes of different surgical options.

In conclusion, knee fusion using circular external fixation is a reliable surgical option for complex knee problems especially in infected failed revision total knee replacements.

**Authors contribution** YM contributed to all steps of the research. RM, EB, YH and EM contributed to data interpretation and manuscript preparation. HS was the senior author supervising and contributing to all steps of the research.

**Funding** The authors declare that no funds, grants or other support were received during the preparation of this manuscript.

**Availability of data and materials** Available upon request.

**Code availability** Not applicable.

## Declarations

**Conflict of interest** The authors have no relevant financial or non-financial interests to disclose.

**Ethical approval** The study protocol was reviewed and approved by our institutional governance board (protocol number: 2022.178).

**Consent to participate** Consent to participate is obtained.

**Consent to publish** Consent to publish is obtained.

## References

1. Christian CA, Donley BG (1998) Arthrodesis of Ankle, Knee, and Hip. In: Canale ST (ed) Campbell's Operative Orthopaedics. 9th edn. St Louis, MO, Mosby, pp 145–187
2. Hibbs RA (1911) An operation for stiffening the knee joint with report of four cases from the service of the New York Orthopedic Hospital. Ann Surg 53:404–407
3. Key J (1932) Positive pressure in arthrodesis for tuberculosis of the knee joint. South Med J 25:909–915
4. Charnley J (1960) Arthrodesis of the knee. Clin Orthop Relat Res 18:37–42
5. Wood JH, Conway JD (2015) Advanced concepts in knee arthrodesis. World J Orthop 6(2):202–210. https://doi.org/10.5312/wjo.v6.i2.202
6. Balato G, Rizzo M, Ascione T, Smeraglia F, Mariconda M (2018) Re-infection rates and clinical outcomes following arthrodesis with intramedullary nail and external fixator for infected knee prosthesis: a systematic review and meta-analysis. BMC Musculoskelet Disord 19(1):361. https://doi.org/10.1186/s12891-018-2283-4
7. Nichols SJ, Landon GC, Tullos HS (1991) Arthrodesis with dual plates after failed total knee arthroplasty. J Bone Jt Surg Am 73:1020–1024
8. Chalmers BP, Matrka AK, Sems SA et al (2020) Two-stage arthrodesis for complex, failed, infected total knee arthroplasty. Bone Jt J 102-B(6_Supple_A):170–175. https://doi.org/10.1302/0301-620X.102B6.BJJ-2019-1554.R1
9. Luyet A, Steinmetz S, Gallusser N et al (2021) Fusion rate of 89% after knee arthrodesis using an intramedullary nail: a mono-centric retrospective review of 48 cases. Knee Surg Sports Traumatol Arthrosc. https://doi.org/10.1007/s00167-021-06693-7
10. Garberina MJ, Fitch RD, Hoffmann ED, Hardaker WT, Vail TP, Scully SP (2001) Knee arthrodesis with circular external fixation. Clin Orthop Relat Res 382:168–178. https://doi.org/10.1097/00003086-200101000-00023
11. Manzotti A, Pullen C, Guerreschi F, Catagni MA (2001) The Ilizarov method for failed knee arthrodesis following septic TKR. Knee 8:135–138. https://doi.org/10.1016/s0968-0160(01)00065-5
12. Bruno AA, Kirienko A, Peccati A et al (2017) Knee arthrodesis by the Ilizarov method in the treatment of total knee arthroplasty failure. Knee 24(1):91–99. https://doi.org/10.1016/j.knee.2016.11.002
13. Gottfriedsen TB, Schrøder HM, Odgaard A (2016) Knee arthrodesis after failure of knee arthroplasty: a nationwide register-based study. J Bone Jt Surg Am 98(16):1370–1377. https://doi.org/10.2106/JBJS.15.01363
14. David R, Shtarker H, Horesh Z, Tsur A, Soudry M (2001) Arthrodesis with the Ilizarov device after failed knee arthroplasty. Orthopedics 24(1):33–36. https://doi.org/10.3928/0147-7447-20010101-15
15. Gunes T, Sen C, Erdem M (2005) Knee arthrodesis using circular external fixator in the treatment of infected knee prosthesis: case report. Knee Surg Sports Traumatol Arthrosc 13(4):329–334. https://doi.org/10.1007/s00167-004-0528-2
16. Spina M, Gualdrini G, Fosco M, Giunti A (2010) Knee arthrodesis with the Ilizarov external fixator as treatment for septic failure of knee arthroplasty. J Orthop Traumatol 11(2):81–88. https://doi.org/10.1007/s10195-010-0089-8
17. Raskolnikov D, Slover JD, Egol KA (2013) The use of a multiplanar, multi-axis external fixator to achieve knee arthrodesis in a worst case scenario: a case series. Iowa Orthop J 33:19–24
18. McNally MA, Ferguson JY, Scarborough M, Ramsden A, Stubbs DA, Atkins BL (2022) Mid- to long-term results of single-stage surgery for patients with chronic osteomyelitis using a

bioabsorbable gentamicin-loaded ceramic carrier. Bone Jt J 104-B(9):1095–1100. https://doi.org/10.1302/0301-620X.104B9.BJJ-2022-0396.R1
19. Patel P, Iliadis AD, Vris A, Heidari N, Trompeter A (2022) Intramedullary application of local antibiotic bullets for the treatment of long bone fracture related infection. Eur J Orthop Surg Traumatol. https://doi.org/10.1007/s00590-022-03205-2.10.1007/s00590-022-03205-2
20. Thahir A, Lim JA, West C, Krkovic M (2022) The use of calcium sulphate beads in the management of osteomyelitis of femur and tibia: a systematic review. Arch Bone Jt Surg 10(4):320–327. https://doi.org/10.22038/ABJS.2021.53566.2661
21. Henshaw RM, Shapiro MS, Oppenheim WL (1996) Delayed reduction of traumatic knee dislocation: a case report and literature review. Clin Orthop 330:152. https://doi.org/10.1097/00003086-199609000-00018
22. Simonian PT, Wickiewicz TL, Hotchkiss RN et al (1998) Chronic knee dislocation: reduction, reconstruction, and application of a skeletally fixed knee hinge. A report of two cases. Am J Sports Med 26:591–596. https://doi.org/10.1177/03635465980260042201
23. Petrie RS, Trousdale RT, Cabanela ME (2000) Total knee arthroplasty for chronic posterior knee dislocation: report of 2 cases with technical considerations. J Arthroplast 15:380. https://doi.org/10.1016/s0883-5403(00)90854-4
24. Liporace FA, Hommen JP, Su ET, Jeong GK, Dayan AJ (2006) Semiconstrained knee arthroplasty in the setting of a chronic knee dislocation—a case report. J Orthop Trauma 20:286–288. https://doi.org/10.1097/00005131-200604000-00010
25. Ferreira N, Marais LC (2012) Chronic knee dislocation treated with a Taylor Spatial Frame. SA Orthop J 11(2):61–64