ORIGINAL ARTICLE

The Incidence of Deep Infection Following Lower Leg Circular Frame Fixation with Minimum of 1-year Follow-up from Frame Removal

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Abstract

Aim: Superficial pin site infection is a common problem associated with external fixation, which has been extensively reported. However, the incidence and risk factors with regard to deep infection are rarely reported in the literature. In this study, we investigate and explore the incidence and risk factors of deep infection following circular frame surgery. For the purpose of this study, deep infection was defined as persistent discharge or collection for which surgical intervention was recommended.

Materials and methods: This study is retrospective review of all patients who underwent frame surgery between April 1, 2015 and April 1, 2019 in our unit with a minimum of 1 year follow-up following frame removal. We recorded patient demographics, patient risk factors, trauma or elective procedure, number of days the frame was *in situ*, location of infection and fracture pattern.

Results: Three-hundred and four patients were identified. Twenty-seven patients were excluded as they were lost to follow-up or had their primary frame surgery as a treatment for infection. This provided us with 277 patients for analysis. The mean age was 47 years (range: 9–89 years), the male to female ratio was 1.5:1, and 80% were trauma frames. Thirteen patients (4.69%) developed deep infection, and all occurred in trauma patients. Of the 13 patients who developed deep infection, 4 had infection before frame removal, and infection occurred in 9 after frame removal. Deep infections occurred in 8 patients within a year of frame removal and in one patient between 1 and 2 years of frame removal.

Within the 13 frame procedures for trauma, 12 were periarticular multi-fragmentary fractures, 3 of which were open, and the remaining were an open diaphyseal fracture. The periarticular fractures were more likely to develop deep infection than diaphyseal fractures ($p = 0.033$). Twelve patients (out of 13) also had concurrent minimally invasive internal fixation with screws in very close proximity of the wires.

Conclusion: The rate of deep infection following circular frame surgery appears to be low. Pooled, multi-centre data would be required to analyse risk factors; however, multi-fragmentary, periarticular fracture and the requirement for additional internal fixation appear to be an associated factor.

Keywords: Deep infection, Frame surgery, Incidence, Periarticular fractures.

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Introduction

The circular frame is a key tool in reconstructive trauma and orthopaedic surgery. However, pin site infection is a common complication in circular frame surgery, with incidence ranging from 1 to 100% in the current literature.[1–5]

One of the difficulties in reporting incidence is that there is no consensus on the definition of pin site infection. Lee-Smith et al. have attempted to differentiate between pin site reaction, colonisation and infection.[6] The reaction was defined as the normal or physiological changes that occur after pin insertion including changes in the normal skin colour, skin warmth and drainage at the pin site; these are expected to subside after 72 hours. Colonisation was defined as warmth and red skin colour around the pin site, increased drainage, possible pain and the presence of microbes on culture. Infection includes all the changes with reaction and colonisation, with the addition of possible pus, pin loosening and/or increased microbial growth.

There are several classifications for pin site infections, and the most commonly used systems are Chekett's and Otterburn's classification.[7,8] None of the classifications differentiate between superficial and deep infection but do describe a graded system incorporating deep infection.

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Many of the studies look at superficial pin site infection and rarely report deep infection rates. We, therefore, conducted a study to investigate the incidence of deep infections in circular frame surgery. The primary aim of this study was to investigate the incidence of deep infection following circular frame surgery. The secondary aim was to explore the risk factors associated with the development of deep infection. In this study, we have defined deep infection as a persistent discharge or collection for which surgical intervention was recommended.

Materials and Methods

A retrospective study was undertaken of all patients who underwent circular frame surgery in our unit between April 1, 2015 and April 1, 2019. Inclusion criteria were all elective and trauma procedures in patients of all ages. Patients were identified from our prospective database.

We excluded any patient who did not have a minimum 1-year follow-up following frame removal. This included those who were transferred out of area, lost to follow-up or died. We also excluded patients who underwent circular frame surgery for the purpose of treating an infection, including infected non-union and chronic osteomyelitis.

In our analysis, we recorded patient demographics, patient risk factors for infection, the number of days the frame was *in situ* and the fracture pattern. In trauma patients, the first author (JT) reviewed the initial radiographs and CT scans of all patients, and the AO Fracture and Dislocation Classification was used to classify the fracture pattern.[9] Multi-fragmentary and periarticular fractures were defined as 41C2, 41C3, 43C2 and 43C3.

This study was undertaken following institutional approval; Reference ID 2020.078.

The Student's *t* test was used to analyse and compare continuous variables whilst the Fisher's exact test was applied for categorical variables. $p < 0.05$ was taken to denote statistical significance.

Results

Patient Cohort

Three-hundred and four consecutive patients were identified from the database. Twenty-seven patients were excluded, as they were lost to follow-up, moved out of area or had their primary frame surgery as a treatment for infection. This left 277 patients for analysis. All patients had lower leg frames with 80% trauma frames. The mean age was 47 years (range: 9–89), and the male to female ratio was 1.5:1.

There were no statistically significant differences found for factors such as age, gender, smoking or diabetes when comparing those who had a deep infection and those who did not (Table 1).

Table 1: Demographics and risk factors in developing deep infection

	Deep infection		
Variable	*Yes*	*No*	*p-value*
Mean age, years	50.3	46.9	0.51*
Gender, male/female	8/5	162/102	1.00†
Smoker, no/yes	12/1	224/40	0.70†
Diabetes, no/yes	12/1	246/18	1.00†

*t test; †Fisher's exact test

In the 222 patients who underwent frame surgery for acute trauma, 78 were diaphyseal fractures, and 144 were periarticular fractures (Table 2). Amongst the periarticular fractures, 85 were fractures of the ankle, and 59 were fractures of the knee. Of the 144 periarticular fractures, 108 were multi-fragmentary according to the AO classification.

Table 2: AO classification of fracture pattern in trauma frames

AO classification	*Number of patients*	*Further breakdown*
41 – Proximal tibial (knee)		
A (Extra-articular)	1	A1 – 0 A2 – 1 A3 – 0
B (Partial articular)	0	B1 – 0 B2 – 0 B3 – 0
C (Complex articular)	58	C1 – 1 C2 – 5 C3 – 52
42 – Diaphyseal		
A (Simple)	25	A1 – 7 A2 – 4 A3 – 14
B (Wedge)	28	B1 – 9 B2 – 6 B3 – 13
C (Complex)	25	C1 – 6 C2 – 7 C3 – 12
43 – Distal tibial (ankle)		
A (Extra-articular)	16	A1 – 9 A2 – 1 A3 – 6
B (Partial articular)	1	B1 – 1 B2 – 0 B3 – 0
C (Complex articular)	68	C1 – 16 C2 – 36 C3 – 16

The remaining 55 patients had frame surgery on an elective basis. There were 15 foot and ankle frames and 40 tibial and knee frames. Amongst the 55 patients, 31 had frames for deformity correction, 4 for joint distraction, 7 for frame-assisted high tibial osteotomy, 11 for non-union or malunion of previous fracture and 2 for fusion.

Deep Infection Incidence

A total of 13 patients (4.69%) developed deep infection. All were trauma patients. In the 13 patients who developed deep infection, 4 had infection before frame removal, and 9 instances of infection occurred after frame removal. Eight instances of deep infections occurred within a year of frame removal and one patient developed deep infection between 1 and 2 years after frame removal. Details of these 13 patients can be seen in Table 3.

Within the 13 frame procedures for trauma, 12 were periarticular and multi-fragmentary fractures, 3 of which were open, and the remaining was an open diaphyseal fracture.

The deep infection rate in the frame management of periarticular fractures was 8.33% (12/144) and 1.28% (1/78) in diaphyseal fractures. This would suggest an increased risk of infection following the frame management of periarticular fractures vs diaphyseal fractures ($p = 0.036$). It should be noted that the majority of periarticular fractures in this series were complex articular fractures, 58/59 proximal tibial fractures and 68/85 distal tibial fractures.

Amongst the 12 patients who developed periarticular infection, all had had concurrent internal fixation. Four were distal tibia periarticular fractures, and eight were proximal tibial periarticular fractures. The only patient who developed infection without concurrent internal fixation had an open diaphyseal fracture.

Table 3: Patients with trauma frame that develop deep infection

Patient No	*Sex*	*Age*	*Site of fracture*	*AO classification of fracture*	*Type of frame*	*Open fracture*	*Use of internal fixation*	*Use of bone augment*	*Duration of frame (days)*	*Date of diagnosis of deep infection from removal of frame (days)*
1	M	21	Ankle pilon	43 C3	Ilizarov	No	Yes	No	96	259
2	F	65	Ankle pilon	43 C3	TrueLok Hexapod	Yes	Yes	Yes	393	–286*
3	M	24	Tibial shaft	42 B2	TrueLok Hexapod	Yes	No	No	138	232
4	F	63	Tibial plateau	41 C3	Ilizarov	No	Yes	No	132	601
5	M	71	Tibial plateau	41 C3	Taylor Spatial Frame	No	Yes	Yes	146	6
6	F	54	Tibial plateau	41 C3	Ilizarov	No	Yes	Yes	118	63
7	M	45	Ankle pilon	43 C3	Ilizarov	No	Yes	Yes	262	65
8	M	38	Tibial plateau	41 C3	Taylor Spatial Frame	No	Yes	Yes	197	104
9	M	52	Tibial plateau	41 C3	TrueLok Hexapod	No	Yes	Yes	157	–129*
10	M	61	Tibial plateau	41 C3	Taylor Spatial Frame	Yes	Yes	No	119	208
11	F	53	Tibial plateau	41 C2	Ilizarov	No	Yes	Yes	87	–3*
12	M	35	Ankle pilon	43 C2	Taylor Spatial Frame	Yes	Yes	No	346	247
13	F	71	Tibial plateau	41 C3	TrueLok Hexapod	No	Yes	Yes	195	–42*

*Infection occurred before the frame was removed; hence, negative

Bone substitutes or augments, for example, calcium phosphate void fillers, were used in 8/13 of the patients who developed deep infections.

Discussion

In our study, the incidence of deep infection following frame surgery was 4.69% which is comparable to that in the limited reports in the current literature.[3,5] A recent study by Parameswaran et al. showed a 3.5% rate of deep infection, where the endpoint was pin removal or osteomyelitis.[3] Given the differences in the definition of deep infection, it is difficult to accurately compare the incidence of deep infection between studies.

Our study has demonstrated that patients with complex periarticular fractures were more likely to develop deep infection than those who had diaphyseal fractures ($p = 0.036$) which is supported by the work of Gordon et al., who found a greater infection rate in periarticular pin placement than in diaphyseal pin placement (4.5% vs 1.6%, $p < 0.01$).[10] This is likely due to the increased soft tissue movement around joints and decreased stability of the pin-bone interface which is in turn associated with infection.[3]

Twelve of the patients in our study who developed deep infection had periarticular fractures, underwent minimal open reduction internal fixation and circular frame fixation. Periarticular fracture segments are usually very small, and therefore, the fine wires and screws would be in close proximity and almost certainly in contact with each other. This may have influenced the deep infection rate in such patients. However, 96 other patients in our study had multi-fragmentary periarticular fractures and did not develop deep infection despite similar interventions.

The external fixator construct and stability is essential in the prevention of pin tract infection. Variables that affect stability include the geometrical and mechanical properties of the external fixators as well as the properties of the surrounding tissues and fracture pattern.[11] Therefore, patients with more complex fracture configurations such as multi-fragmentary periarticular fractures are potentially at a higher risk to develop infection.

Soft tissue integrity is essential in bone healing and the prevention of infection. The use of additional internal fixation and bone substitutes suggest a more severe injury than a simple fracture. This significant injury to the surrounding soft tissue may also contribute to the risk of infection. Our study found no deep infections in patients undergoing elective frame surgery, when the damage to the soft tissues and bone can be minimized compared to trauma.

Limitations include the retrospective nature of this study as well as relatively small patient numbers and heterogeneity in frame configurations and a wide variety of indications and methods with three consultant surgeons. However, it could be argued that this is a reflection of real-world clinical practice and certainly reflects the need for larger-scale studies, examination of wider practice and the establishment of standards and the standardization of surgical practice.

Conclusion

Incidence of the deep infection rate following circular frame surgery to the lower limb is low. The majority of deep infections occurred in patients with periarticular fractures which required minimal open reduction internal fixation. It is difficult to postulate whether infection is due to trauma, the surgery or the nature of the anatomical location of the injury. Strategies to separate internal fixation elements and fine wires may be helpful in the reduction of the rate of infection.

These results may guide clinicians in the consent process and provide pre-operative information to patients.

Clinical Significance

Complex periarticular fractures managed with minimal open reduction and internal fixation and circular frame are associated with an increased incidence of deep infection. Clinicians should consider a minimalistic approach to concurrent internal fixation.

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