



## Grade 3 open tibial shaft fractures treated with a circular frame, functional outcome and systematic review of literature



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### ABSTRACT

We report on the surgical and functional outcome of 22 patients with Grade 3 open tibial fractures treated with circular frame. All cases united and there were no re-fractures or amputations. All patients were assessed at a minimum of 1-year post frame removal. Assessment included clinical examination, IOWA ankle and knee scores, Olerud and Molander ankle score and EuroQoL EQ-5D. Clinical scores were either good or excellent in over half of the patients in all knee and ankle scores. There was a significant positive correlation between functional outcomes and the EQ-5D score.

The EQ-5D mean health state visual analogue score was comparable to the general UK population despite patients scoring less than the average UK population in three of the five domains. 36% reported some difficulties in walking and 41% had problems with pain. 14% had difficulties with self-care and 46% had difficulties with their usual activities. 14% had problems with anxiety or depression.

Systematic review of the literature suggests, in the management of open tibial fractures, circular frames provide equivalent or superior surgical outcomes in comparison with other techniques.

Our study finds the application of a circular frame also results in a good functional outcome in the majority of cases.

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### Introduction

Grade 3 open tibia fractures usually present following high energy trauma [1]. They are associated with significant damage to the soft tissue envelope and the bony architecture of the tibia. Court-Brown and McBirnie reported that over 40% of all open fractures involve the tibia [1]. In the UK there is an agreement on the initial management of these injuries following the introduction of national guidelines [2].

The high incidence of complications (infection and non union) that has been reported after Grade 3 open tibial fractures has been attributed to the severity of the original injury sustained, the tenuous blood supply of the tibia (particularly anterior medially) and the subsequent additional damage to both the hard and soft tissues as a result of the reconstruction procedure(s) [3–5]. Soft tissue coverage is now commonly achieved by microvascular flaps, which improve local blood supply, increase union rates and reduce infection and amputation rates [6,7].

Although different methods of fixation have been used over the years with satisfactory results, lately intramedullary nailing (IM) and external fixation devices have prevailed as they minimize secondary insult to the soft tissues and the bone vascularity [3–5]. A recent study however, revealed non-union rates of 30.8% for intramedullary nailing and 40% for mono-lateral external fixation with infections rates of 15.4% and 40% respectively [8].

Circular frames represent a special form of external fixation devices. They utilize indirect reduction techniques with fine wires and small incisions, which ensure minimal soft-tissue damage and soft tissue footprint. The wires are tensioned and supported circumferentially creating a ‘trampoline’ effect, resulting in superior mechanical performance [9] to monolateral external fixators enabling the commencement of both early range of motion and weight bearing [10–12].

While there are some studies reporting on the surgical treatment of open tibial fractures with circular frames [10–12], the literature referring to both surgical and functional outcomes remains obscure. The purpose of the herein study therefore is to present our institutional experience on the surgical management and functional outcome of Grade 3 open tibial fractures treated with a circular frame.

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## Patients and methods

Between November 2005 and November 2011 all patients that presented in our institution with an isolated Grade 3 open tibial fractures were eligible to participate. Inclusion criteria were adult patients with a tibial fracture amenable to intramedullary nail fixation, who were managed with a circular frame and completed their course of treatment with at least 1 year follow up following frame removal. Exclusion criteria were children and patients having a delayed presentation to our unit as a result of original failed surgery carried out elsewhere and patients who had sustained polytrauma. Institutional board review approval was obtained for this study.

All patients were prescribed prophylactic antibiotics (co-amoxiclav) from presentation at the hospital until wound coverage was achieved. All patients were administered low molecular heparin as a means of thromboprophylaxis for 28 days from admission.

The fractures were classified using the AO system and consisted of five B2, six B3, one C1, three C2 and seven C3 [13]. The soft tissue element of the fractures were classified according to the Gustilo classification [14,15]. The management of the soft-tissue injury was carried out with combined ortho-plastic input. Where appropriate split-thickness skin grafting and/or flaps were used as necessary or acute deformation of the limb (shortening) to close the soft tissue defect.

The circular frame was designed and constructed according to the nature of the fracture. Bone defects were managed by acute shortening and distraction osteogenesis from a remote corticotomy site. Corticotomy was performed with a Gigli saw and a percutaneous periosteum preserving technique. A three to four ring frame was constructed with a minimum of two wires or half pins per ring. Wires were tensioned to 130 kg. The fixation was supplemented with titanium half pins or hydroxyapatite coated pins in osteoporotic bone or frames with an expected long duration. All drilling was pulsed and cooled with chlorhexidine soaked gauze and half pins were predrilled.

The pin sites were cleaned weekly with chlorhexidine but otherwise kept covered [16]. Patients were mobilized fully weight bearing with range of motion exercises under the direction of a dedicated physiotherapist unless prevented by other injuries. Ilizarov frames were applied if on table reduction was near anatomical, TSF was applied to those which warranted further deformity correction, facilitated by software [17]. The TSF varies from the Ilizarov frame in that between the ring either side of the fracture are placed six telescopic struts that can be independently lengthened or shortened to achieve further correction in all planes.

Following discharge from the hospital all patients were followed up in the outpatient department in dedicated circular frame clinics, initially on a weekly basis until pinsites, wound and flaps were deemed sound. Subsequently, patients were seen on a 6 weekly period for both clinical and radiological assessment. Such details were documented prospectively as incidence of local and systemic complications, re-admissions, and re-operations.

Radiological union was defined as the presence of bridging callous in at least three out of the four cortices [18]. Clinical union was defined as a full painless weight bearing with the circular frame having been dynamised. The frame was removed when there was evidence of union across a minimum of three cortices and a painless full weight bearing.

At a minimum of 1 year post frame removal, all patients underwent a formal clinical assessment along with outcome scores. The overall health related quality of life was assessed using the EuroQol EQ-5D [19]. Functional scores were assessed by the Olerud and Molander Ankle [20] and the Iowa knee and ankle

scores [21]. Evidence of malunion was measured and recorded from the final radiographs.

The EQ-5D is a validated questionnaire that is simple to use and has good response rates [22]. Normal values for the EuroQol have been obtained from the UK population allowing comparison to be made with our study cohort [23].

The Iowa knee and ankle scores combine self-assessment of pain and function with clinical assessment of range of motion and deformity. A separate score out of 100 is obtained for each joint [21]. An excellent score is deemed as 90 or above; good as 80–89; fair as 70–79 and poor as a score below 70.

The Olerud and Molander ankle score evaluates the symptoms from the ankle to give a score out of 100 [20]. The scores are then rated as excellent for 91 or above; good for 61–90; fair for 31–60 and poor for below 30.

The mean time of follow up was 19 months (range 12–42 months).

Statistical analysis of the results was undertaken using the Mann–Whitney *U*, Chi-squared and Student *t*-tests and Spearman Rank coefficient as appropriate. A *p*-value of <0.05 was considered to be statistically significant.

In order to compare the results of our patient cohort with the available published studies, we also undertook a systematic analysis of the most significant English language publications on the treatment of open tibial fractures from the last four decades. A literature search was undertaken of the Medline, Embase and Cochrane databases. The search terms used included open tibia, tibia fracture, open fracture, limb salvage, amputation, quality of life, EQ-5D, SF-36 and SIP with the Boolean terms 'AND', 'OR' and 'NOT' used as appropriate. The first author DD reviewed all abstracts. The full article was obtained in all potentially suitable abstracts. We focused on surgical outcomes, complications and functional outcome. The criteria for inclusion of studies were as follows:

1. Open fracture of the tibial diaphysis. If the study population also contained closed fractures the paper had to provide sufficient information to allow sub-group analysis.
2. Management was by external fixator, plates and screws, intramedullary nailing or circular frame.
3. Data provided on union rate, infection, amputation and for further surgery. Secondary data on time to union and malunion was retrieved when available.
4. Data on functional outcome in terms of quality of life questionnaires and functional scores was recorded. Implied functional outcome such as the ability to return to work was taken as secondary data.
5. Minimum study population size of 10 patients.

We excluded review articles and those including fractures extending into the knee or ankle joints. In total 57 papers were included within the review of surgical outcome [3,5,7,8,10–12,24–73] and 24 papers were included in the review of functional outcome [3,10,11,29,30,32,33,48,51,54,55,57,59,60,75–85].

## Results

Out of 38 patients treated in our institution, 25 met the inclusion criteria. Thirteen patients treated with a frame were excluded as the fracture was not deemed to be manageable by an intramedullary nail due to proximity to either the knee or ankle joints. Two patients were lost to follow up and one patient died from unrelated causes, leaving 22 patients (19 males) to form the study group with a mean age of 35.5 years (median 27, range 17–64).

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