Management of simple (types A and B) closed tibial shaft fractures using percutaneous lag-screw fixation and Ilizarov external fixation in adults

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Abstract

Purpose Although intramedullary fixation of closed simple (type A or B) diaphyseal tibial fractures in adults is well tolerated by patients, providing lower morbidity rates and better mobility, it is associated with some complications. This study evaluated the results of managing these fractures using percutaneous minimal internal fixation using one or more lag screws, and Ilizarov external fixation.

Methods This method was tested to evaluate its efficacy in immediate weight bearing, fracture healing and prevention of any post-immobilisation stiffness of the ankle and knee joints. This randomised blinded study was performed at a referral, academically supervised, level III trauma centre. Three hundred and twenty-four of the initial 351 patients completed this study and were followed up for a minimum of 12 (12–88) months. Patient ages ranged from 20 to 51 years, with a mean of 39 years. Ankle and knee movements and full weight bearing were encouraged immediately postoperatively. Solid union was assessed clinically and radiographically. Active and passive ankle and knee ranges of motion were measured and compared with the normal side using the Wilcoxon signed rank test for matched pairs. Subjective Olerud and Molander Ankle Score was used to detect any ankle joint symptoms at the final follow-up.

Results No patient showed delayed or nonunion. All fractures healed within 95–129 days.

Conclusions Based on final clinical and radiographic outcomes, this technique proves to be adequate for managing simple diaphyseal tibial fractures. On the other hand, it is relatively expensive, technically demanding, necessitates exposure to radiation and patients are expected to be frame friendly.

Introduction

The tibial diaphysis is the most frequently fractured long bone and is the most susceptible to delayed union and nonunion because of its precarious blood supply. In these patients, immediate weight bearing is limited or not possible. Patients are a liability to themselves and their community as they are incapacitated by this type of fracture [1]. Most authors agree that the standard treatment for closed fractures of the tibial shaft is intramedullary fixation and subsequent early weight bearing. It is generally agreed that after closed reduction alignment should be maintained such that there is less than one centimetre of shortening, angulation is limited to under 5° and rotational deformity is limited to 5° or less [2–4].

These low-energy shaft fractures are rarely severely displaced or comminuted and may be treated conservatively by closed reduction and plaster fixation. The majority of such fractures heal in months and virtually all heal by months, and this time period was considered the standard for normal healing time in fractures of this type [5]. However, due to the prolonged period of immobilisation and its subsequent complications—associated soft tissue injury, possibility of loss of initial reduction, malunion, delayed and/or nonunion in some cases—surgical treatment was considered an unavoidable necessity in certain cases [6–8].

There is an increasingly marked interest in early ambulation and weight bearing in these fractures, not only for the patient, but also for the family, work, and community. Furthermore, post-immobilisation stiffness was always a concern for conservatively treated patients. This study discusses the role of percutaneous minimal internal fixation aided by Ilizarov external fixation in early patient ambulation, weight bearing, fracture healing, and ipsilateral ankle and knee movements.

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Patients and methods

Between October 2004 and January 2011, 351 adult patients suffering from low-energy, simple and closed, types A or B fractures of the tibial shaft (Fig. 1a, b) were managed by closed reduction, percutaneous lag screw to provide compression, and Ilizarov external fixation were assessed. Eligible, skeletally mature men or women with a closed fracture of the tibial shaft that was amenable to closed reduction and minimal internal fixation using one or more interfragmentary screws and supplemented by an Ilizarov external fixator were included (Fig. 2). Inclusion required informed consent. We excluded patients with fractures that were not amenable to closed reduction or minimal internal fixation, such as those with poor skin condition, comminuted and open fractures. Pathological fractures and fractures in skeletally immature patients were also excluded. A minimum of 12 months of follow-up was an inclusion criterion (12–88 months with a mean of 38 months). Twenty-seven patients were lost during the follow-up period, leaving only 324 patients (92.3 %) who completed the study. There were 280 men and 44 women, with age range between 20 and 51 (mean 36) years. The right lower limb was affected in 175 patients and the left leg in 151. Two hundred and nine patients had a type A and 115 type B fracture. Trauma to surgery time ranged from six to 72 hours. Perioperative care was standardised, a single preoperative antibiotic (broad-spectrum third-generation cephalosporin) was given six to 24 hours prior to surgery and was discontinued after surgery. In cases of pin-tract infection, antibiotics were given according to the severity of the condition and on culture and sensitivity tests performed if needed. All patients were treated by closed reduction and manipulation under fluoroscopic guidance (C-arm). Percutaneous, minimal internal fixation to

compress bone ends was done with one or more screws (one screw in 199, two in 123 and three in two patients) (Fig. 2). An Ilizarov external fixator was applied in all cases. A simple four-ring construction was used to stabilise the fracture. Pre-assembly of the frame was done for almost all the cases, and the construction was available at the Emergency Department. Full assisted weight bearing was immediately encouraged. Plain X-rays in the traditional anteroposterior (AP) and lateral views were done preoperatively, postoperatively and on a monthly basis until solid union was confirmed. Solid union was defined as union of three of four cortices on AP and lateral radiographs. Check X-rays were taken every three months and at the final follow-up visit. Operative time ranged from 25 to 75 (mean 55) min. Variation in surgery time depended on the availability of the pre-assembled frame in the operation room and the learning curve of the surgeons performing the technique. Dynamisation of the frame was performed after radiographic healing, and then the frame was removed (seven to 22 days after dynamisation) (Fig. 3). Again, full, unprotected weight bearing was encouraged immediately after frame removal. For subjective evaluation of any ankle symptoms, patients completed the Oleurd and Molander Ankle Score [9] at the final follow-up visit (Table 1). This score was of special value because it contains items such as stair climbing, squatting and running, which also puts the ipsilateral knee joint under examination. For objective evaluation, and as the clinical determination of a single range of movement of the ankle is not reliable, combined movements of dorsiflexion, plantar flexion and inversion and eversion, as well as knee flexion and extension were measured by a goniometer by two independent (Figs. 4 and 5) consultant trauma orthopaedic surgeons who were blinded to patient treatment protocol, were not authors of this

Fig. 1 **a** Preoperative anteroposterior (AP) and **b** lateral plain X-ray films of a 27-year-old man with a simple, closed, type A junction in the middle lower third of the tibia

Fig. 2 Immediate post-X-ray anteroposterior (AP) and lateral view of management by one interfragmentary percutaneous screw and an Ilizarov frame

article and had over five years of orthopaedic experience. Interobserver agreement was expressed using the kappa statistic. Clinical evaluation was performed four weeks after frame removal and at the final follow-up visit. The participating authors did not offer stimulation modalities to promote bone growth (such as pulsed electro-magnetic-field stimulation) during the follow-up period.

Fig. 3 Anteroposterior and lateral plain X-rays, after frame removal

Table 1 Scoring system devised by Olerud and Molander (maximum 100 points)

Parameter	Degree	Score
1. Pain	None	25
	While walking on uneven surface	20
	While walking on uneven surface outdoors	10
	While walking indoors constant and severe	5
2. Stiffness	None	10
	stiffness	0
3. Swelling	None	10
	Only in evening	5
	constant	0
4. Stair-climbing	No problems	10
	Impaired	5
	Impossible	0
5. Running	Possible	5
	Impossible	0
6. Jumping	Possible	5
	Impossible	0
7. Squatting	No problems	5
	Impossible	0
8. Supports	None	10
	Taping, wrapping	5
	Stick or crutch	0
9. Work, activities of daily living	Same as before injury	20
	Loss of tempo	15
	Change to simpler job	15
	Severely impaired work capacity	0

Differences between groups were compared using a two-tailed Student's *t* test for normally distributed values. For comparison of categorical variables, a chi-squared test was performed; otherwise, the Wilcoxon signed rank test was used to compare variables to the healthy side.

Results

Early ambulation and complete weight bearing was encouraged immediately after surgery and took place within a mean of two (one to six) days in all patients. Solid union occurred after a mean of 104 (95–129) days. Time in frame (application to removal) ranged between 99 and 149 (mean 110) days. Full, unprotected, unaided weight bearing took place after solid union in all cases, even before frame removal (dynamisation period). No delayed union (defined in this work as no signs of union for more than four months and accompanied by clinical symptoms of delayed union

Fig. 4 Lateral photo for the patient, showing good knee flexion and ankle dorsiflexion

Fig. 5 Lateral photo showing good knee flexion and maximal ankle plantar flexion

such as pain and difficulty in weight-bearing) or nonunion (over six months with no evidence of union) were reported. Ninety of the 324 patients needed physiotherapy to rapidly improve their ankle and knee range of motion (Figs. 4 and 5). No more than four weeks of physiotherapy sessions was reported by any patient. Measurements of ankle and knee movements one month after frame removal are recorded in Table 2. This was repeated at the final follow-up visit, and no statistical difference was observed. There was no statistically significant difference (Wilcoxon signed rank test, $p=0.07$) between ankle, subtalar and knee joints of the ipsilateral and healthy contralateral side. At the final follow-up visit, mean range of movement of all examined joints did not significantly differ between sides (Table 3). Mean total Olerud-Molander ankle score was completed by the 324 patients month after frame removal was 89 (70–100) points (Table 3). This was markedly improved to 95 points at the final follow-up visit.

There were minor complications recorded in this study, including pin-tract infection in 81 patients (25 %). This relatively high incidence may be attributed to inadequate or poor frame care in some noncompliant patients. Pin-tract infection was thoroughly evaluated, staged (grade I or II in the majority of cases) and properly treated by attentive pin care, adequate local debridement, local

antiseptics and antibiotics, systemic antibiotics as recommended by cultures and skin swabs and pin removal in severe resistant cases not responding to all of the above. Pin breakage and removal took place in only 14 cases (0.04 %). No pin-induced neurovascular injuries were recorded. Complications such as shortening, angulation, rotation, compartment syndrome, malunion, delayed and/or nonunion were not recorded. No patient reported anterior knee pain or needed secondary surgery related to the original fracture during the follow-up period, such as revision or bone grafting.

Table 2 Comparison between mean range of movement of ankle and knee joints in the ipsilateral side and the healthy contralateral limb in 324 patients

Joint	Movement	Ipsilateral	Contralateral	Difference
Ankle & Subtalar	Inversion	38 (20–60)	40 (15–60)	2
	Eversion	10 (0–25)	10 (0–25)	0
	Dorsiflexion	13 (7–35)	18 (5–50)	5
	Plantar flexion	56 (20–90)	60 (20–90)	4
Knee	Flexion	132 (90–165)	140 (100–165)	8

Table 3 Mean Olerud-Molander ankle score for the 324 patients

Parameter	Score	Maximum score
Pain	24.0	25
Stiffness	7.8	10
Swelling	8.5	10
Stair climbing	10	10
Running	4.5	5
Jumping	4.2	5
Squatting	4.0	5
Supports	9.5	10
Work, activities of daily life	16.5	20
Total	89	100

Discussion

Evidence favours the use of intramedullary nails to stabilise diaphyseal tibial fractures [10–12]. In a meta-analysis of open tibial-shaft fractures, union-related reoperation rates ranged from 4 % to 48 % [10]. Similarly, high rates have been reported for closed fractures [13, 14]. In the literature, many articles report the use of the Ilizarov frame for managing tibial fractures. This technique was of special value for managing comminuted, open fractures with bone loss, infected, intra-articular, delayed union and/or nonunited fractures [15–18].

To our knowledge, no articles have been published in the literature reporting application of the Ilizarov frame in simple diaphyseal tibial fractures. The rationale for this technique was immediate weight bearing, better knee and ankle motion and high union success rates [19]. Furthermore, the reported average time to union was approximately 20 weeks for simple fractures that had been caused by a low-energy mechanism and over 30 weeks for comminuted fractures that had been caused by a high-energy mechanism. Different authors also reported that fractures of the middle third of the tibia usually healed in an average of 12 weeks, and little variation in healing time relative to the type of fracture was noted [20–30].

The Ilizarov frame application after initial closed reduction and minimal percutaneous fixation by lag screws is described in the literature, especially in high-energy intra-articular fractures [31, 32]. Following the original principles of the Ilizarov technique, we used closed indirect reduction techniques under image guidance, first using olive wires to compress fracture ends. There were some cases in which it was difficult to obtain perfect reduction and absolute compression of the fracture ends, although these were simple closed fractures. Fracture healing was by secondary intention and callus formation. We were also confronted in some cases with wire cut through, especially in the presence of

pin-tract infection, and wire breakage, although negligible. Failures with the Ilizarov system, as mentioned above, were observed in patients treated by inexperienced surgeons (our residents). We started to apply the basic Arbeitsgemeinschaft für Osteosynthesefragen (AO) principles to allow for compression of the fracture ends using the lag-screw effect to achieve and maintain perfect reduction. Other authors reported the value of interfragmentary screws [33]. Moreover, they noticed a tendency of faster fracture healing in patients with interfragmentary lag screws compared with those with sole bridge-plating screws [34]. To our knowledge, minimal internal fixation after closed reduction using the percutaneous lag-screw technique for managing closed simple tibial fractures has not been reported in the literature. This technique provided adequate stability, and healing of the majority of cases was by primary intention. In addition, there was no fear of pin-tract infection or wire failure, loss of reduction and/or need to change the olive wire.

Similar results were reported using conservative measures for managing such simple fractures [23–25]. However, there were reports of loss of the initial reduction; the need for remanipulation, casting or bracing; delayed union or nonunion; and complications of prolonged recumbency and delayed weight bearing. Furthermore, cases managed by intramedullary nailing reported anterior knee pain; major complications such as death from thromboembolism; deep vein thrombosis; deep infections and the need for a secondary surgery (intramedullary nail dynamisation, revision of fixation, implant failure, nail breakage and/or bone grafting) at different rates [10–12]. The rate of healing in our study was higher than the reported studies; plus, there were no cases of delayed union or nonunion in this study. The lower morbidity rate in this study might be attributed to the initial closed reduction and percutaneous internal fixation performed, and it is believed that early ambulation and immediate weight bearing improves limb circulation and enhances the healing process, based on the fact that the speed of fracture healing is usually proportionate to the amount of available circulation to and between the fragments.

One of the most important advantages of using this technique is the excellent recorded knee and ankle range of motion within a short time of frame removal. Active and passive movements of both joints were allowed and encouraged along the entire course of treatment, immediately after application of the frame, and few cases needed physiotherapy sessions to regain normal full activities. The main disadvantages of this procedure are that it is technically demanding, the need for imaging, its relatively high expense, depression may occur in some patients and adequate care of the frame is a must. From our point of view, immediate weight bearing and the fact that the patient could be back to work justify these factors. Also, reduced hospital stay and time needed for physiotherapy is a consideration.

The number of participants was not large but provided satisfactory evidence that this procedure is successful for managing such diaphyseal fractures. To conclude, although Intramedullary fixation is better tolerated by patients with lower morbidity and better (although delayed) mobility, it is associated with some complication rates, such as delayed weight bearing, anterior knee pain, thromboembolism, sepsis, implant failure, need for further surgery, less mobility in the knee and ankle and reoperation with nailing due to bone grafting and implant exchanges (5–13.2 %) [10]. On the other hand, although technically demanding, the procedure reported here is a reliable and efficient method of treating simple tibial shaft fractures in adults, as it provided adequate healing time, immediate ambulation and weight bearing, excellent ankle and knee motion and a very low complication rate. Based on the final clinical and radiographic outcomes, this technique proves to be adequate for managing simple diaphyseal tibial fractures.

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