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The Role of the Ilizarov Ring External Fixator in the Management of Tibial Fractures with Impending/Incomplete Compartment Syndrome*

Função do fixador externo circular de Ilizarov no tratamento de fraturas tibiais com síndrome compartimental iminente/incompleta

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Abstract

Objective The management of tibia fractures complicated by compartment syndrome affects the treatment and functional outcome of patients due to the complications associated with fasciotomy. The purpose of the present study is to differentiate impending/incomplete compartment syndrome (ICS) from established acute compartment syndrome (ACS) in tibial fractures, and to assess the outcome of the fixation of the Ilizarov apparatus in patients with these fractures presenting with ICS, who were not submitted to fasciotomy.

Methods After the establishment of the inclusion and exclusion criteria, 19 patients were included in the study from January 2007 to December 2017. All patients were male, with an average age of 42.3 ± 11.38 years. All of these patients were managed with Ilizarov ring fixation as per the medical and surgical protocol established in the present study.

Results The average follow-up obtained for our 18 patients was of 47 ± 41.5 months, with one patient being lost to follow-up. The average time for ring application was of 3.7 ± 1.7 days. In total, 3 (16.7%) of these patients had nonunion. There were no soft-tissue or neurovascular complications in the immediate postoperative period. All of the patients eventually united and were independently mobile without any sequelae of compartment syndrome.

Keywords
- Ilizarov technique
- tibial fractures
- compartment syndromes

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Conclusion The Ilizarov ring external fixator can be used in the management of tibial fractures with ICS, avoiding fasciotomy with its various complications of infection and nonunion, resulting in fewer surgeries and faster rehabilitation. Surgeons should carefully differentiate ACS and ICS in these patients, as the clinical and functional results vary significantly. Unnecessary fasciotomies should be avoided.

Resumo

Objetivo O tratamento das fraturas da tíbia complicadas por síndrome compartimental afeta o tratamento e o resultado funcional dos pacientes devido às complicações associadas à fasciotomia. O objetivo deste estudo é diferenciar a síndrome compartimental iminente/incompleta (SCI) da síndrome compartimental aguda (SCA) estabelecida nas fraturas tibiais, para avaliar o resultado da fixação do aparelho de Ilizarov nos pacientes fraturados e com SCI, que não foram submetidos à fasciotomia.

Métodos Após o estabelecimento dos critérios de inclusão e exclusão, 19 pacientes foram incluídos no estudo de janeiro de 2007 a dezembro de 2017. Todos eram do sexo masculino, com média de idade de 42,3 ± 11,38 anos. Todos esses pacientes foram tratados com a fixação do aparelho de Ilizarov, de acordo com o protocolo médico e cirúrgico estabelecido neste estudo.

Resultados O acompanhamento médio dos nossos 19 pacientes foi de 47 ± 41,5 meses. O tempo médio de aplicação do fixador circular foi de 3,7 ± 1,7 dias. No total, 3 (16,7%) desses pacientes não apresentaram consolidação. Não houve complicações nas partes moles ou neurovasculares no pós-operatório imediato. A consolidação ocorreu finalmente em todos os pacientes, sem prejuízo da mobilidade e sem sequela de síndrome compartimental.

Conclusão O fixador circular de Ilizarov pode ser utilizado no tratamento dos pacientes com fraturas tibiais com SCI, e evita a fasciotomia, com suas várias complicações de infecção e não consolidação. O resultado é um número menor de procedimentos cirúrgicos e uma reabilitação mais rápida. Os cirurgiões devem diferenciar cuidadosamente a SCA e a SCI, pois, nesses pacientes, os resultados clínicos e funcionais variam significativamente. Fasciotomias desnecessárias devem ser evitadas.

Palavras-chave
- técnica de Ilizarov
- fraturas da tíbia
- síndromes compartimentais

Introduction

The management of tibial fractures complicated by compartment syndrome can result in poor clinical and functional outcomes.[1] Even the timely intervention with fasciotomy causes surgical-site infection and delayed fracture healing in patients treated with internal fixation.[2] Studies[1,3] have shown that the pressure measurements are incorrect in up to 30% of the patients diagnosed with compartment syndrome. This is why making an uncontestable decision to perform a fasciotomy is difficult in these patients, even when the tendency is to gravitate towards fasciotomy due to medico-legal implications.

There is one subset of patients in whom none of the clinical features of compartment syndrome are manifested upon examination; they are diagnosed with impending/incomplete compartment syndrome (ICS). The criteria to establish this diagnosis are: mild to moderate increase in leg circumference; firm swelling on palpation; the appearance of multiple fluid-filled blisters; mild pain on stretching the tendons of the muscles passing through the involved compartment; absence of rest pain; and no vascular, sensory or motor deficits.[4,5]

The present study aimed to assess the outcome of Ilizarov ring fixation in patients with tibial fractures presenting with ICS, who were not submitted to a fasciotomy.

Patients and Methods

The present retrospective study was approved by our institutional review board. From January 2007 to December 2017, 19 patients were identified in our hospital records and included in the study after consent was obtained. All the patients were male (n = 19) involved in high-energy trauma, with a mean age of 42.30 ± 11.38 years. Out of the 19 patients, 15 had closed, and 4 had open fractures. There was one patient with hypertension, and two were smokers.

The inclusion criteria were:

1. Acute closed/open tibial fractures with or without intra-articular extension, with signs of ICS, as described by Sood et al.[4]
2. Normal mentation.[5]

We excluded patients with:

1. Altered sensorium/Glasgow Coma Scale (GCS) < 15;
2. Vascular injury; and
3. Established acute compartment syndrome (ACS).

Patient and Fracture Characteristics

The fracture patterns and soft-tissue injuries were graded according to the Arbeitsgemeinschaft für Osteosynthesefragen (Working Group for Bone-Fusion Issues)/ Orthopedic Trauma Association (AO/OTA) classification.[6] Out of the 19 patients, 16 (84.2%) had comminuted intra-articular fractures, 2 (10.5%) patients had extra-articular fractures of the proximal tibia, and 1 (5.2%) patient had a segmental fracture of the tibial shaft. Preoperative radiographs were taken in two planes for every patient. A computed tomography (CT) scan was performed for 2 patients (Patients 2 and 16), as they had significant articular depression and comminution on the radiographs. Patient demographics and fracture details are shown in ►**Table 1**.

Medical Management

For every patient, we followed our medical management protocol, which consists of the administration of 100 ml of intravenous (IV) 20% Mannitol for a period of 24 to 72 hours, the application of magnesium sulfate paste, limb elevation, and application of a plaster of Paris (POP) slab loose above knee to reduce the limb swelling.[7,8] Continuous musculoskeletal and neurovascular monitoring was performed to identify the signs of progression to compartment syndrome. The presence of hemorrhagic blisters indicated the severity of the soft-tissue injury and internal degloving. None of the 19 patients had any preoperative neurovascular injury. All of the patients underwent Ilizarov ring fixation within 3.7 ± 1.7 days of the injury (►**Fig. 1**).

Operative Technique

In patients with intra-articular fractures, congruity of the articular surface of the proximal tibia was achieved by applying traction and making minimal incisions to elevate the depressed fragments with the aid of an osteotome or bone punch. The reduction was then held temporarily with Kirschner wires and finally with interfragmentary screws. The length and alignment of the limb were maintained by continuous traction and visualization under an image intensifier (II). The proximal ring of the Ilizarov apparatus was fixed to the proximal tibia at the level of the fibular head, with six points of purchase to the bone (three wires); two rings were then fixed to the mid and lower thirds of the tibia with at least four points of purchase on the bone. The stability of the apparatus was further enhanced by adding Schanz pins to the rings and, sometimes, a distal femur ring, which was removed at six weeks in every case.

In patients with metadiaphyseal fractures of the tibia, the limb was stabilized with one or two rings depending on the distance of the fracture from the line of the knee joint on either side, maintaining the length and alignment of the limb. The rings closest to the fracture in the Ilizarov apparatus were fixed at least 1 inch from the fracture line, both proximally and distally.

In the postoperative period, all the patients were mobilized with partial weight-bearing, which was then increased to full weight-bearing at 6 weeks. The Ilizarov apparatus was removed when the patients were able to walk comfortably without pain, with a normal gait pattern, and the radiographs showed union. After the removal, the patients were put on a patellar tendon bearing (PTB) cast for a period of six weeks.

Analysis of Outcomes

Bony union was defined radiologically as the union of at least three cortices in anteroposterior (AP) and lateral views during the follow-up period.[9] The clinical outcomes were measured by the Knee Society Score (KSS),[10] and the Knee Injury and Osteoarthritis Outcome Score (KOOS),[11] whereas the radiological outcome was measured by the Rasmussen Functional Score.[12] All the complications of nonunion, soft-tissue injury, and pin-tract infection[13] were also noted.

Results

Out of the 19 patients, 1 (Patient1) died of natural causes after bony union, and another one (Patient 6) was lost to follow-up. We have presented the results of the 18 available patients (including Patient 1). The median duration of the follow up was of 47 ± 41.5 months. All of the patients underwent Ilizarov ring fixation within 3.7 ± 1.7 days of the injury. All of the 18 patients had united and were independently mobile, including the patient who later died (►**Figs. 2–5**). None of the patients had postoperative neurovascular complications.

Clinical and Functional Outcomes

The clinical and functional outcomes were measured by the KSS and KOOS in all of the 17 patients (excluding the deceased patient). The clinical and functional components of the KSS were excellent in 13 patients, good in 3 patients,

Table 1 Patient demographics and details of the fracture treatment

Serial number	Diagnosis	Associated injuries	Tscherne grading	NV status	Time to surgery (days)	Postoperative complications	Sequalae	Time until ring removal (months)	Clinical and functional scores	Rasmussen Functional Score	Follow-up (months)
1	AO 41 C2	None	2	Intact	4	None	None	7	NA	NA	Expired
2	AO 41 C3	Left intertrochanteric#	2	Intact	6	None	Pin-tract infection	6	KSS CLIN: 87; KSS FUNC: 90; KOOS: 89.1	14	36
3	AO 41 C1	None	2	Intact	2	None	None	6	KSS CLIN: 89; KSS FUNC: 90; KOOS: 90.5	16	16
4	AO 41 C2	None	2	Intact	3	None	None	7	KSS CLIN: 81; KSS FUNC: 80; KOOS: 80.5	16	12
5	AO 41 C2	None	2	Intact	6	None	None	4	KSS CLIN: 86; KSS FUNC: 80; KOOS: 85.4	16	18
6	AO 41 C2	None	2	Intact	4	None	None		NA	NA	LFU
7	AO 42C2	None	2	Intact	3	None	None	8	KSS CLIN: 88; KSS FUNC: 90; KOOS: 85.1	NA	22
8	AO 41C2	None	2	Intact	4	None	None	8	KSS CLIN: 80; KSS FUNC: 80; KOOS; 76.8	18	40
9	AO 41C1	None	2	Intact	5	None	Knee stiffness- treated with MUA for 3 months after 1st surgery	3	KSS CLIN: 85; KSS FUNC: 80; KOOS: 78.6	16	12
10	AO 41C2	DISTAL 1/3 FIBULA #	1	INTACT	4	None	1. Delayed union - treated with BMI 3 months after 1st surgery; 2. Chronic osteomyelitis for which debridement was performed 20 and 26 months after 1st surgery	8	KSS CLIN: 71; KSS FUNC: 70; KOOS: 70.8	16	36
11	AO 41C2	None	2	Intact	6	None	None	4	KSS CLIN: 85; KSS FUNC: 80; KOOS: 78	14	12
12	AO 41 C1	None	2	Intact	5	None	None	3	KSS CLIN: 92; KSS FUNC: 90; KOOS: 91.7	16	30
13	AO 41 C1	None	2	Intact	2	None	None	5	KSS CLIN: 86; KSS FUNC: 80; KOOS: 78.6	14	60
14	AO 41 A3	None	2	Intact	5	None	1. Pin-track infection; 2. nonunion - treated with a rail fixator, removed after 4 months	NA	KSS CLIN: 86; KSS FUNC: 80; KOOS: 77.4	NA	44
15	AO 41 A3	Pelvic,# right subtrochanteric#	2	Intact	1	None	Nonunion - submitted again to Ilizarov ring fixation 5 months after the 1st surgery; the second ring was removed 6 months later, after fracture union	11	KSS CLIN: 93; KSS FUNC: 90; KOOS: 93.9	NA	100
16	AO 41C3	Left distal fibula#	2	Intact	5	None	None	6	KSS CLIN: 89; KSS FUNC: 80; KOOS: 78	14	124
17	AO 41C2	None	2	Intact	4		Delayed union- underwent with BMI	7	KSS CLIN: 55; KSS FUNC: 60; KOOS: 57.1	12	156

Table 1 (*Continued*)

Serial number	Diagnosis	Associated injuries	Tscherne grading	NV status	Time to surgery (days)	Postoperative complications	Sequalae	Time until ring removal (months)	Clinical and functional scores	Rasmussen Functional Score	Follow-up (months)
18	AO 41C2	None	2	Intact	1	None	Nonunion -rail fixator applied, removed after 6 months	NA	KSS CLIN: 72; KSS FUNC: 75; KOOS: 78	16	36
19	AO 41C2	Right patella#	1	Intact	1	None	None	5	KSS CLIN: 70; KSS FUNC: 75; KOOS: 76.8	14	44

Abbreviations: AO, Arbeitsgemeinschaft für Osteosynthesefragen (Working Group for Bone-Fusion Issues); BMI, bone-marrow injection; CLIN, clinical; FUNC, functional; KSS, Knee Society Score; KOOS, Knee Injury and Osteoarthritic Outcome Score; LFU, lost to follow-up; MUA, mobilization under anesthesia; NA, not applicable; NV, Neuro-vascular.
Note: #Fracture.

and fair in 1 patient (Patient 17). The KOOS was also acceptable in all but 1 patient (Patient 17), as shown in ►**Table 1**.

Radiological Outcomes

The radiological outcome was assessed by the Rasmussen Functional Score, which consists of three components: articular depression, condylar widening, and angulation, and are graded from excellent to poor. The average Rasmussen Functional Score was of 15 ± 6.9 among the patients with intra-articular fractures (►**Figs. 6–9**).

Complications

Bone

In total, 3 patients (16.7%; Patients 14, 15 and 18) did not unite after the ring fixation; 2 of these patients (Patients 14 and 18) underwent the application of a rail fixator, and 1 (Patient 15) was treated with an Ilizarov ring fixator again. All three patients had united at the last follow-up.

Delayed union was diagnosed in 2 patients (11.1%; Patients 10 and 17), who were treated with local bone marrow injection (BMI).

Osteomyelitis was diagnosed in 1 patient (5.2%; Patient 17), who underwent debridement twice after fracture union.

Soft Tissue

One patient developed knee stiffness (Patient 9) and was submitted to mobilization under anesthesia (MUA) at the time of ring removal.

In total, 2 patients (11.1%; Patients 2 and 14) developed pin-track infection, which healed with local dressings and antibiotics.

Discussion

The use of the Ilizarov ring fixator is an accepted method of fixation for tibial fractures. In high-energy proximal tibial injuries, it has a lower rate of complications, but similar functional outcomes when compared to internal fixation.[14,15] The incidence of ACS in tibial fractures is around 4% to 11%.[16,17] Discerning the signs of ICS from established ACS is the key to good clinical and functional outcomes in the management of these injuries. The clinical criteria laid down by Sood et al.[4] help differentiate ICS from ACS, as fasciotomy has to be performed urgently for the latter.

In our series of 19 patients, the diagnosis of ICS was made early, at the time of presentation to our emergency department, and confirmed by 3 experienced consultants. One of the methods we use to identify the severity of the soft-tissue damage is by the presence of hemorrhagic blisters over the proximal tibia, which indicates internal degloving of the soft tissues. These patients were then promptly put on anti-edema measures, and fixation was performed with the Ilizarov ring fixator. Internal fixation is not advocated in these patients, as the soft-tissue envelope heals in

Fig. 1 Hemorrhagic blisters.

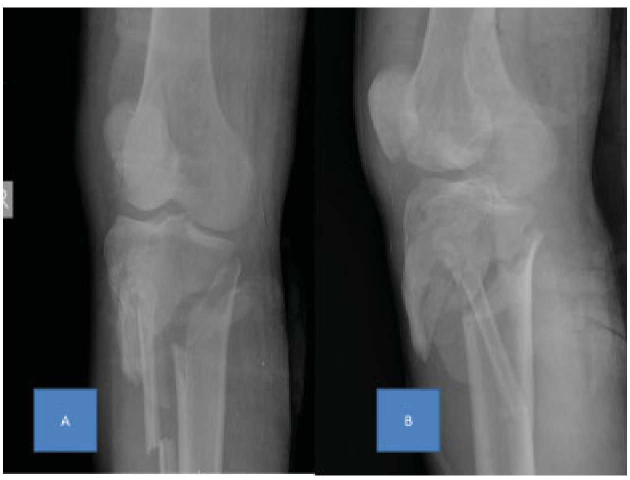

Fig. 2A and 2B Preoperative anteroposterior and lateral radiographs of Patient 9.

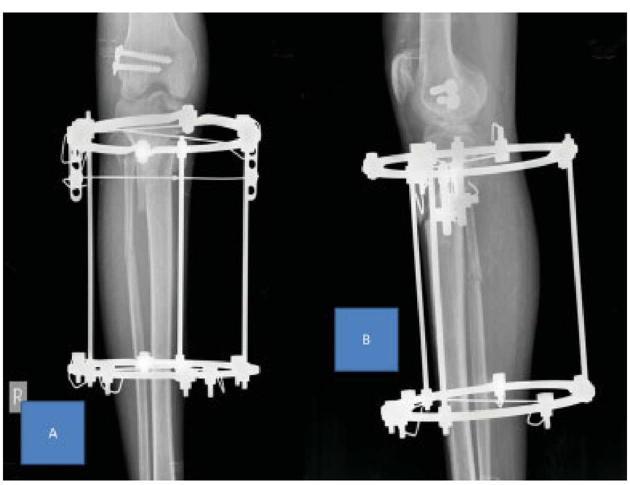

Fig. 3A and 3B Anteroposterior and lateral radiographs of Patient 9 in the immediate postoperative period with ring fixation.

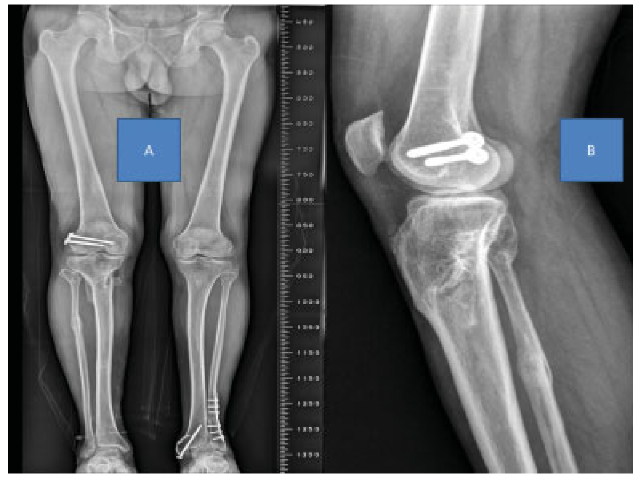

Fig. 4A and 4B Anteroposterior and lateral radiographs of Patient 9 with 12 months of follow-up.

Fig. 5A and 5B Patient 9 with 12 months of follow-up.

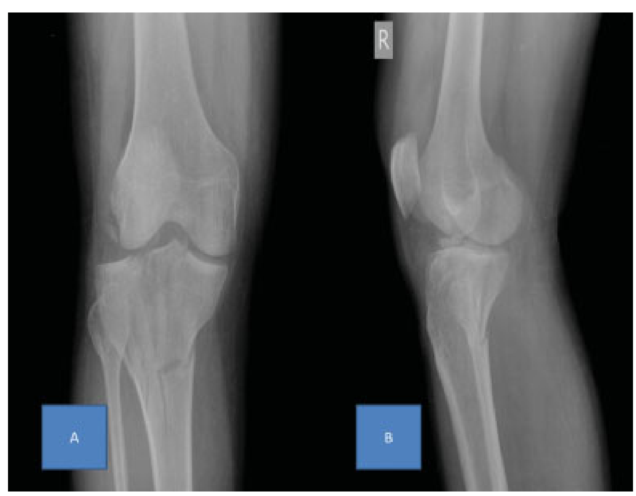

Fig. 6A and 6B Preoperative anteroposterior and lateral radiographs of Patient 13.

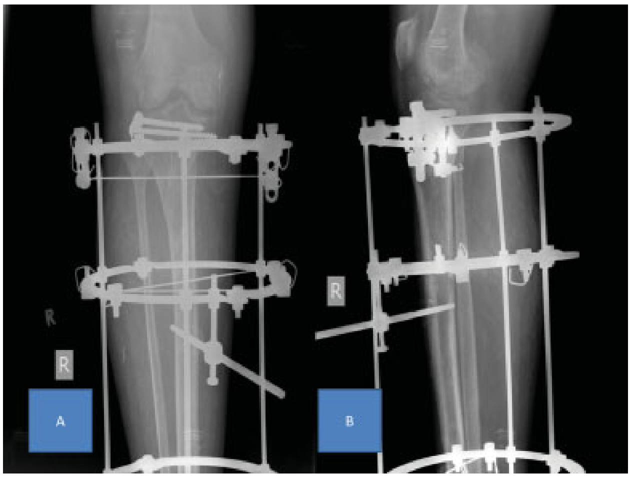

Fig. 7A and 7B Anteroposterior and lateral radiographs of Patient 13 in the immediate postoperative period, with ring fixation.

Fig. 8A and 8B Anteroposterior and lateral radiographs of Patient 13 with 60 months of follow-up.

varying degrees, and leads to skin breakdown when internal fixation is performed.

None of the patients in our series had developed neurovascular or any soft-tissue complications in the immediate postoperative period. The nonunion rate in our series was of 16.7% (3/18): 2 patients had extra-articular fractures, and 1 patient had an intra-articular fracture with diaphyseal extension. This was low when compared to the results of tibial fractures associated with fasciotomy in intra-articular as well as shaft fractures published in the literature (20% to 45%).[2]

Currently, there is a concern about infection after fasciotomy and open reduction and internal fixation.

Fig. 9A and 9B Patient 13 with 60 months of follow-up.

Recent literature has shown an increased incidence of surgical site infection after internal fixation in tibial plateau fracture with compartment syndrome.[5,15,18] For each day of delay in fasciotomy wound closure, the risk of infection increases by 7%.[18] Sharma et al.[5] described the management of 15 patients with simple articular or metaphyseal proximal tibia fractures with ICS, treated with fasciotomy and internal fixation in a single stage, with 1 case of superficial infection and 2 cases of delayed union. In our series, none of the patients developed an infection or any soft-tissue complication in the immediate postoperative period. All our cases of ICS were managed according to our protocol of confirmation of diagnosis by three consultants, continuous and meticulous recording of all positive and negative clinical findings, use of 20% mannitol for the reduction of the compartmental pressures for 72 hours, and use of the Ilizarov apparatus for the fixation of the fracture.

Ertürk et al.[19] have shown a significant statistical difference in compartment pressure when internal fixation was compared with Ilizarov ring fixation in rabbit limbs, with reduced compartment pressure in the Ilizarov-fixation group. They have attributed the fall in pressure in the ring-fixation group to the serous drainage through the pin tracks, which act as a conduit for drainage from the various compartments. The reduction in limb swelling after the application of the Ilizarov ring is also attributed to the stability provided by the trampoline effect.[20] In the present study, we have used the ring fixator, as we believe that the wires and the frame create a state of dynamic stability in the limb, preventing a rise in compartment pressure despite alteration in the length of the bone and soft tissues.

Ulmer[21] has shown that the clinical signs associated with ACS have a high negative predictive value, indicating that they can be used best to rule out ACS. We have used the Sood et al.[4] criteria to exclude ACS and diagnose ICS in all of our patients. McQueen et al.[22] have reiterated the role of fasciotomy when the differential pressure (Δp) remains ≤ 30 mmHg over 2 continuous hours. However, compartment pressure and the measurement of the differential pressure in the diagnosis of ICS or ACS have a high inter-observer variability, with variability between measurement methods, high false-positive rates, and they are not universally available or used.[23,24] In spite of the advances in non-invasive methods such as the measurement of the levels of creatine kinase (CK) and of tissue elastance to increase the accuracy of the early diagnosis of compartment syndrome, there remains a lack of clarity regarding the clinical diagnosis.[25–27] Studies[21,28] have reiterated the primary importance of clinical judgment in the management of ICS. We feel that rigorous and repetitive clinical examination remains the most important tool in the diagnosis of ICS/ACS in the absence of a manometer in hospitals with limited resources or irregular usage. Currently, it is common practice to combine the patients of ICS with those with ACS and perform fasciotomy for all, thereby piling on the complications associated with the operative management of high-energy proximal tibia fractures with the sequelae of fasciotomy.[2]

The other options for the treatment of these injuries are applying an external fixator or POP slab until the skin is stable enough to perform internal fixation, which may take two to three weeks. The external fixator has been found to be an independent risk factor for infection, even in patients without compartment syndrome.[29] Staged internal fixation is not possible in open fractures and in the absence of skin in a pristine condition due to the deroofed healing blebs. We think that Ilizarov ring fixation has a definite role in the management of these injuries caused by ICS.

The advantages of the present study are that it follows established criteria to diagnose ICS, it uses an implant that is universally accepted in the management of tibia fractures, and has clear clinical, functional and radiological outcomes. The highlights of the present study are that we strongly discourage the use of fasciotomy as a tool in the management of patients with ICS, and we advocate the record of findings, medical measures to reduce compartment pressures, and circumferential external fixator in the management of these fractures. The disadvantages of the present study are its small sample size, he lack of a control group, and the bias regarding the recruitment of eligible patients. We hope that our experience helps increase awareness concerning the management of ICS and avoid unnecessary fasciotomies.

Conclusion

Surgeons should be able to differentiate between ICS and established ACS, as the former can be managed without fasciotomy. Fixation with the Ilizarov apparatus in tibia fractures with ICS results in improved outcomes, with rates of infection and soft tissue complications lower than those resulting after fasciotomy.

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Conflict of Interests
The authors have no conflict of interests to declare.

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