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Original Article

Circular External Fixation as an Alternative Method of Stabilization for Extra-articular Tibia Fractures in the Elderly

Abstract

Background: Recent epidemiologic reports from national fracture registries demonstrate an increase in the incidence of tibia fractures in the elderlies. Objectives: the objective of this retrospective study is to evaluate Circular External Fixation (CEF) for primary and definitive fixation of tibia extra-articular fractures (TEF) in the elderly treated at a level I trauma center. **Materials and Methods:** we evaluated a subset of 31 elderly patients (over 70 years) with 31 TEF (mean age 76 years, range 70-89) of which six (19.4%) were open treated with CEF between 2010 and 2017. 29 (93.5%) fractures underwent definitive fixation with traditional Ilizarov, 2 were treated with Sheffield and Taylor Spatial frames and evaluated clinically and radiologically accordingly to ASAMI bone and functional scores. **Results:** All fractures consolidated without additional procedures at an average of 21.3 weeks (range 9-42). No deep infections were observed. Four malunions within 8° occurred. ASAMI bone results were excellent in 93.6% of patients and revealed an excellent result in 21 (67.7%) of patients, eight patients (25.8%) had a good result, and 2 (6.5%) a fair result. **Conclusions:** CEF gave excellent results in the treatment of a variety of tibial shaft fractures in an elderly population, in terms of early return to ambulation, with average time to union, rate of delayed union, and misalignment rate comparable or superior to intramedullary nail and plate osteosynthesis, that represent the options more frequently proposed in clinical practice and literature. Advantages of circular external fixation in osteosynthesis of extra-articular tibia fractures in these patients are the minimal impact on soft tissues and the stability of the construct, that allows immediate weight bearing and early return to ambulation.

Keywords: *Circular fixation, elderly population, geriatric trauma, Ilizarov technique, tibial fractures*

Giovanni Lovisetti, Ettore Vulcano[1], Lorenzo Bettella, Ralph Cook[2], Francesco Sala[3], John D. Muelle[4], Tazio Talamonti[3]

Department of Orthopaedics and Traumatology, Menaggio Hospital, ASST Lariana, Como, [3]Department of Orthopaedics and Traumatology, ASST Grande Ospedale Metropolitano Niguarda, Level 1 Trauma Center, Milano, Italy, [1]Department of Orthopedics, Columbia University, Chairman of Orthopedic Surgery, Mount Sinai Medical Center, Miami Beach, FL, [2]Department of Orthopedic Foot and Ankle Surgery, Limb Lengthening and Reconstruction, Mount Sinai West, [4]Department of Orthopaedic Surgery, New York Presbyterian Hospital, Columbia University Irving Medical Center, New York, USA

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Address for correspondence:
Dr. Tazio Talamonti, Department of Orthopaedics and Traumatology, ASST Grande Ospedale Metropolitano Niguarda, Level 1 Trauma Center, Piazza Ospedale Maggiore, 3, 20162 Milan, Italy. E-mail: taziotalamonti@hotmail.com

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Introduction

Fractures of the tibia are not typically considered among fragility fractures such as those occurring in the proximal femur, proximal humerus, distal radius, pelvis, and spine; however, recent epidemiologic reports from national fracture registries[1,2] demonstrate an increase in the incidence of tibia fractures with increasing age in female patients, reaching a peak value after 80 years of age. Osteoporosis is a systemic condition[3] and reduces the biomechanical strength of the tibia among other bones. Reduced collagen content in aging skin decreases its resistance to shearing forces[4] and compromises elasticity, accounting for the increased risk of open fractures after minor trauma in older women.[5] Atrophic skin changes along with medical comorbidities such as diabetes and vascular insufficiency can increase the risk of secondary exposure and deep infection after treatment of these injuries through plates and screws.[6,7] In addition, plate osteosynthesis often prohibits immediate weight-bearing, delaying a return to ambulation – a major limitation when dealing with older patients. Meanwhile, intramedullary nailing encounters different problems in this population with frequent voluminous intramedullary canals, given the limited utility of blocking screws in osteoporotic bone and the frequent association of distal fibular fractures. All these factors predispose for an increased risk of loss of reduction and resultant malunion.

Circular external fixation (CEF) can be considered a "biologically friendly" treatment method and allows for immediate weight-bearing following fixation.[8] It represents an alternative strategy that

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can afford an anatomic reduction without a significant disruption of soft tissues. The ability to obtain an excellent reduction and predictably maintain alignment throughout the duration of fracture treatment has led many surgeons to extend the indications to include extra-articular tibial fractures.

The purpose of this study was to retrospectively analyze the results of treatment with circumferential external fixation in a cohort of 31 patients 70 years of age and older who sustained extra-articular tibia fractures and to compare these results to different osteosynthesis techniques proposed in the literature.

Materials and Methods

This retrospective study was approved by our hospital's ethical review board; the procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation of our institution and with the Helsinki Declaration of 1975, as revised in 2000.

We retrospectively reviewed 31 patients (13 males and 18 females) aged 70 years and older (mean age: 76 years, range: 70–89 years) who had sustained displaced extra-articular tibia fractures and were treated with a CEF between 2010 and 2017 in two trauma centers [Table 1]. All the surgeries in our cohort were performed by two surgeons (GL and FS).

Table 1: Descriptive statistics

Parameter	Result, *n* (%)
Age (years), mean (range)	76 (70-89)
Sex (male/female)	13 (41.9)/18 (58.1)
AO classification	
41C	1 (3.2)
42A	6 (19.4)
42B	9 (29.0)
42C	7 (22.6)
43A	8 (25.8)
Open fracture	6 (19.4)
Gustilo type	
I	1 (3.2)
II	2 (6.5)
IIIA	2 (6.5)
IIIB	1 (3.2)
Closed fracture	25 (80.6)
Periprosthetic fracture	2 (6.5)
Type of frame	
Traditional ilizarov	29 (93.5)
Sheffield	1 (3.2)
Taylor spatial frame	1 (3.2)
Preoperative functional status	
Ambulates independently	24 (77.4)
Ambulates with assistive device	7 (22.6)
No distance limitation	23 (74.2)
Distance limitation ≤3 blocks	8 (25.8)

Inclusion criteria have been age more than 70 years, closed fractures with tenuous soft tissue envelopes, open fractures, metaphyseal fractures, in which intramedullary nailing may had resulted in malalignment, associated unstable distal fibula fractures, and the presence of an ipsilateral total knee arthroplasty.

We deliberately excluded patients younger than 70 years because cutaneous fragility which is more relevant in patients older than 70[9] years affected by dermatoporosis, is likely responsible for the increased incidence of open fractures in the elderly, in whom 60% of open fractures occurred following a low energy fall.[10]

Exclusion criteria were considered the presence of dementia or serious cognitive disabilities, as there is potential harm associated with the hardware in those incapable of complying with a surgeon's care instructions, intra-articular extension of the fracture, and associated fractures in the lower legs.

For patients meeting the abovementioned criteria, CEF was considered as routine treatment.

Fractures were classified according to the AO and Gustilo classifications.[11,12] According to the AO classification, there was one proximal metaphyseal fracture (41: C2), 22 diaphyseal fractures (42: A1: four, A2: one, A3: one, B1: two, B2: six, B3: one, C1: two, C2: four, and C3: one), and eight distal metaphyseal fractures (43: A1: five, A2: one, and A3: two patients). Interestingly, 16 of the 22 diaphyseal fractures belonged to the distal diaphysis, in proximity with the distal metadiaphyseal junction of the tibia, with a pattern not well categorized by the AO/OTA classification but described in the literature.[8] There were 25 closed and six open fractures, with one Gustilo I, two Gustilo II, two Gustilo IIIA [Figure 1], and one Gustilo IIIB. Two of the fractures were periprosthetic, occurring distal to the tibial component of a total knee replacement [Figure 2]. The type of circular external fixator used varied between cases, with a traditional Ilizarov utilized for 29 patients, a Sheffield frame used for one patient, and a Taylor spatial frame utilized for one patient.

Medical comorbidities included diabetes, depression, mild cognitive impairment, and cerebrovascular accident [Table 2]. Before injury, 23 patients (74.1%) ambulated without the use of an assistive device with no distance limitation, one patient ambulated without an assistive device but had a distance limitation secondary to cardiopulmonary comorbidities, and seven patients (22.6%) required the use of a cane or walker for ambulation.

Operative technique

All fractures were first aligned on a traction table and then Ilizarov frame was applied and the fractures reduced utilizing a one-wire method that corrects minor malalignment with an olive traction wire placed in the plane of the deformity, allowing uniform healing, proper alignment, and adequate reduction of fracture gaps.[13] This operative technique was employed in 30/31 patients, with the sole outlier having been reduced using a hexapod external fixator (TSF; Smith and Nephew, Memphis, Tennessee).

Postoperative care

Patients were permitted to bear weight on the affected extremity immediately following surgery without restrictions [Figures 3-5], except in those patients with a distal fibula fracture within 10 cm from the tip, in which partial weight-bearing was instituted with a limit of 15 kg. Active knee and ankle range of motion exercises were instituted on postoperative day 1, with a focus on preventing equinus contracture of the ankle. Pin site care was initiated on postoperative day 2 and consisted of application of 50% saline-50% peroxide solution daily. Pin site infections were treated with a 10-day course of oral antibiotics (doxycycline or cephalexin), with all cases responding to treatment. Every local intolerance to wires and half pins was addressed, and the presence of infection was recorded. Pin site infection was diagnosed according to the criteria proposed by Davies *et al*.[14]

All patients were assessed clinically every 2 weeks and radiographically every 4 weeks. Healing was assessed radiographically with serial plain films focused at the fracture level with union defined as dense bridging callus present in three anatomic cortices of the tibia as assessed on anteroposterior, lateral, and oblique plain radiographs.[15] Clinical healing was defined by the absence of pain or instability during stress of the affected extremity at the fracture level according to a stress procedure (full open 3 mm test) that we have described previously[13] and was confirmed by the absence of pain or instability after a trial of ambulation for 3 min with the connecting bars fully opened at the level of the fracture. After consolidation was confirmed both clinically and radiographically, frame removal was performed within 2 weeks. Removal was achieved using conscious sedation administered by an anesthesiologist.

Table 2: Comorbid conditions

Comorbid condition	Number of patients
Blindness	1
Cardiomyopathy	2
Cerebrovascular accident	3
Chronic obstructive pulmonary disease	3
Congestive heart failure	2
Coronary artery disease	2
Mild cognitive impairment	3
Depression	5
Diabetes mellitus	7
Epilepsy	1
Hypertension	3
Obesity	2
Polytrauma	2
Polymyalgia rheumatica	1
Rheumatoid arthritis	1

Outcome measures

Outcomes were assessed at 6 months following frame removal by the senior authors (GL and SF). No patient was lost to follow-up. The main outcome measures assessed were time in frame, delayed union, nonunion, malunion, deep infections, and clinical outcome. In addition, the presence or absence of anatomical reduction was recorded immediately following surgery according to the criteria that we described previously.[13] Malunion was defined as >5° angulation in the coronal or sagittal plane, >1 cm of shortening, or >5 mm of translation. Deep infection was defined as purulent drainage or osteomyelitis presenting after definitive wound healing, with the diagnosis made by the treating surgeon based on clinical suspicion and subsequent positive tissue cultures.

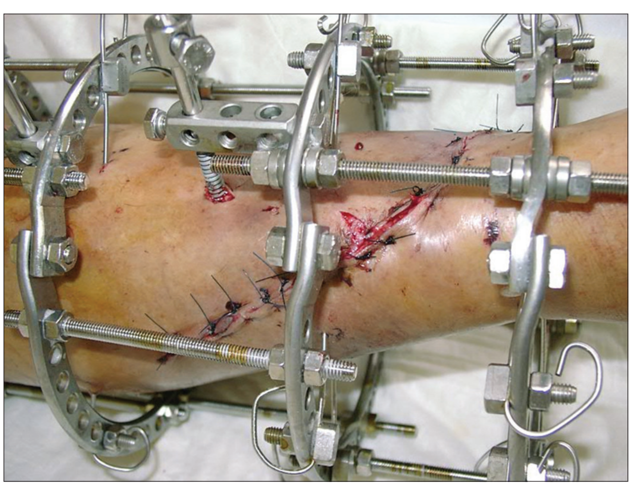

Figure 1: Typical Gustilo III A pattern of open tibia fracture of the elderly

Figure 2: Tibial diaphyseal fracture beneath TKR: Immediate postoperative weight-bearing

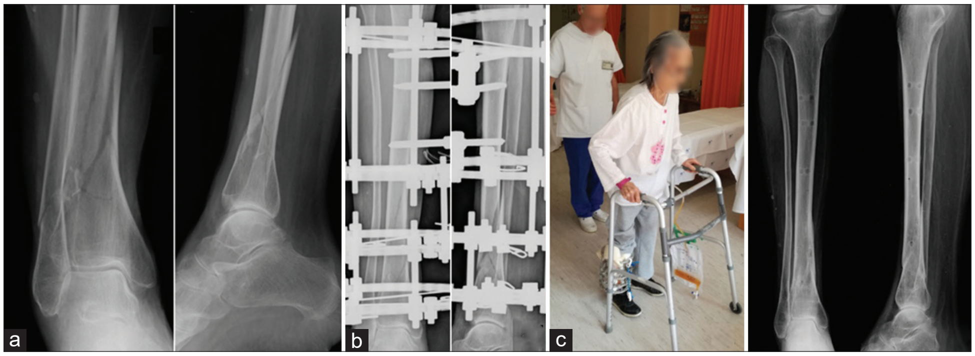

Figure 3: Patient: 78-year-old, female. (a) Preoperative anteroposterior and lateral tibia and fibula radiographs of a comminuted, distal third tibia and fibula fracture without evidence of intra-articular extension. (b) Postoperative anteroposterior and lateral tibia and fibula radiographs of the same patient illustrated in Figure 3 after application of the circular external fixator frame. There is noticeable improvement in the varus alignment of the fracture postoperatively. (c) Anteroposterior and lateral tibia and fibula radiographs, 7 months after trauma, of the same patient illustrated in figure 3A and 3B, demonstrating consolidation and bridging callus present in all four cortices, with near anatomic healing of the fracture.

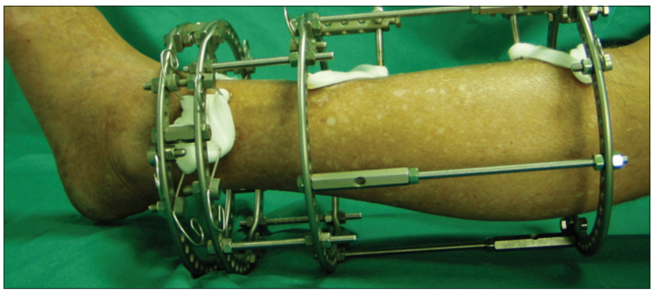

Figure 4: Skin pseudoscars indicate a dermatoporotic skin with potential delayed healing problems

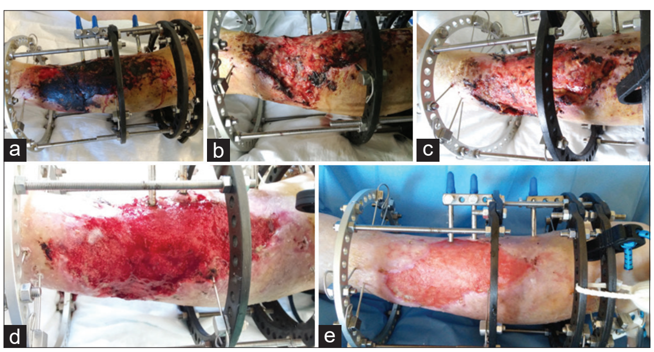

Figure 5: (a-e) Progressive dermoepidermal regeneration in extensive skin necrosis

Final assessment for bone results and functional results were done using Association of the Study and Application of the Method of Ilizarov (ASAMI) score.[16] We decided not to utilize self-reported health status scores, because they have been shown of limited utility in an elderly population.[17]

Results

In the postoperative period, we observed a progressive improvement of soft-tissue conditions, and in no patient, soft-tissue coverage procedures were necessary [Figure 5a-e]. There were no cases of compartment syndrome, peroneal nerve palsy, deep venous thrombosis, mortality, or implant failure during the time that the patients were in the frame or in the 6th months following frame removal. There were no cases of pullout or breakage of the HA-coated half pins.

All fractures consolidated without the need for additional procedures, except for frame removal as previously described. The mean time to union was 21.3 weeks (range: 9–42 weeks). Closed fractures had a shorter mean time to union than open fractures (20.3 vs. 26.0 weeks, respectively). Delayed union occurred in two patients (6.6%) with consolidation occurring at 39 and 42 weeks postoperatively. The average time to union for the closed fractures was 20.3 weeks compared with the 26.0 weeks average time to union for open fractures with a $P = 0.0466$, making it a significant difference (IBM SPSS Statistics for Windows, version 23 - IBM Corp., Armonk, NY, USA).

At the end of treatment, misalignment occurred in four patients (12.9%); however, an angulation of more than 8° was never observed. There were no deep infections encountered in the study population, although we observed five wire-related superficial infections which all resolved with local antiseptics and oral antibiotics. There were no re-fractures or subsequent loss of radiographic alignment observed in the 6 months following frame removal.

ASAMI bone outcomes assessed 6 months following frame removal recorded 29/31 (93.6%) excellent results and 2/31 (6.6%) good results.

ASAMI clinical outcomes assessed 6 months following frame removal revealed that 21 patients (67.7%) experienced an excellent result, with subsequent return to their preoperative functional level, whereas eight patients (25.8%) reported a good result, and only two patients (6.5%) reported a fair result, with no poor results reported.

Discussion

This retrospective study highlights the efficacy of CEF techniques in treating extra-articular tibial fractures. CEF is considered an alternative fixation method for both proximal and distal tibia articular fractures[18-21] with encouraging results similar or superior to intramedullary nailing reported for both distal third and mid-shaft tibia fractures.[8,9,13,22-24]

There is a paucity of literature evaluating the influence of the aging processes on bone and soft tissues in extra-articular tibia fracture treatment, with the majority of these injuries occurring in young active individuals. In a Cochrane review, evaluating different methods and types of intramedullary nailing for treating tibial shaft fractures in adults, eleven randomized and quasi-randomized controlled clinical studies were included: in a total of 2093 participants with 2123 fractures, mean patient age has been reported as just 37.9 years.[25] Other authors intended to explore age as a potential source of heterogeneity using subgroup analysis and meta-regression; however, they were unable to complete the analysis because of insufficient data.[26] In contrast, recent studies[1,2] have shown that the epidemiology of tibia fractures may be changing given the increasingly active and rapidly aging population. In an interesting analysis conducted using the data from the Swedish Fracture Register, the mean age of women with tibia fractures was 58.4 years, significantly higher than the mean of 43.8 years of men.[2]

There exists a bimodal incidence pattern for tibial shaft fractures, with a peak in both young adults (16–30 years) and among elderly women (>80 years), whereas proximal and distal tibia fractures demonstrate an increasing incidence with increasing age. In a nationwide report from the Finnish National Hospital Discharge Register evaluating tibial shaft fractures between 1997 and 2014, the incidence in women increased with age and reached its peak after 80 years of age (26.5/100,000 person-years).[1] Meanwhile, in men, there appeared to be little impact of osteoporosis on the incidence of tibial shaft fractures.[2] These findings confirm the data of previous studies and suggested that tibial shaft fractures in women may be considered fragility fractures.[27,28] Although the mechanism of most of these injuries is a fall from standing height – often considered "low energy fractures" – local factors related to aging must be considered as they increase the potential risk of treatment complications.

In 2007, Kaya coined the term "dermatoporosis" to characterize the chronic cutaneous fragility of aging skin.[4] Key features of dermatoporosis are atrophic skin with solar purpura and white pseudoscars of the extremities [Figure 4]. The prevalence of dermatoporosis in elderly individuals was between 13.1% and 37.5%.[29,30] Skin lacerations, delayed healing, bleeding complications, and cutaneous infections are frequent sequela of dermatoporosis, and the thickness of the epidermis and dermis at the pretibial level can be reduced to 0.7–0.8 mm.[5] Cutaneous atrophy and aging are likely responsible for the increased incidence of open fractures in the elderly, in whom 60% of open fractures occurred following a low energy fall.[10] Besides, a correlation between dermatoporosis and osteoporosis has been demonstrated based on the principle of simultaneous aging of collagen present in the skin and collagen present in bone.[31] The overwhelming majority (88.8%) of Gustilo type III fractures were of the IIIA variety, likely secondary to violation of the integument connected to dermal atrophy.[4,5]

These data raise concerns regarding the treatment of tibial shaft and distal metaphyseal fractures with open reduction and internal fixation with plates and screws. The thinning, atrophic skin of the elderly can compromise hardware coverage – even with low profile plates – and may confer increased risk of delayed healing, hardware exposure, biofilm formation, and local sepsis. Recent studies have confirmed the previously reported high complication rates associated with minimally invasive plate fixation of distal tibia fractures.[6,7,32,33] In one study, 69% of patients experienced a postoperative complication, with 21.1% suffering a major complication (23.8% in the age group of 60–89 years).[7] Importantly, infection and nonunion of the tibia are difficult complications to manage in the elderly with bone resection and transport techniques due to the lower regenerative potential and a low tolerance to long-term treatments.

The progress of osteoporosis in the tibia and its relationships with other weight-bearing districts has been well documented with high-resolution peripheral quantitative computer tomography studies.[3] This experience showed that volumetric bone mineral density of the tibia correlates significantly with femoral and vertebral biomechanical strength, indicating that the microarchitecture of these weight-bearing bones is jointly affected by osteoporosis. The consequences of osteoporosis include thinning of cortical bone, enlargement of the intramedullary canal, reduced purchase of blocking screws, and an association with multifragmentary distal fibular fractures. All these factors can increase the risk of loss of reduction with intramedullary nailing, which would translate in the inability to go for an immediate full weight-bearing and early independent mobilization.

This study retrospectively evaluated the efficacy of CEF techniques in treating extra-articular tibial fractures occurring in 31 patients with a mean age of 76 years. Although this series includes a relatively small number of patients, to our knowledge, there exist no studies of tibial fractures in the literature evaluating treatment options in this specific patient population. Our series confirms the female predominance (18/31, 58%) noted in prior epidemiology studies of tibial fractures[1]. Consolidation occurred in all patients, in a relatively short period (mean: 21.3 weeks), with only two cases of delayed healing.

The open fracture patterns frequently encountered in the elderly population – Gustilo type IIIA low-energy fractures related to skin breakage, and large cutaneous lesions secondary to degloving mechanisms – responded favorably to the conservative approach offered by CEF. Progressive regeneration of the integument was observed in all patients with open fractures in our cohort and no plastic surgeries where performed, with no deep infections observed. Failure of fixation was prevented with the use of proximal HA-coated half pins and a distal metaphyseal wire cluster. We consider HA-coated half pins mandatory in external fixation of the elderly.

With a paucity of similar series in the literature, it is difficult to compare our results to those of internal osteosynthesis in the elderly. It is evident however that plate and screw fixation presents with certain disadvantages: particularly, the inability to allow for immediate full weight-bearing and the risk of soft-tissue complications and local sepsis. While intramedullary nailing affords immediate weight-bearing, there exist similar risks of soft-tissue complications about the distal interlocking screws in the setting of atrophic skin changes commonly observed in the elderly. In addition, the correlation of tibia fragility fractures (with patterns that extend distally, voluminous intramedullary canals, and the frequent association of unstable distal fibular fractures) with a potential increase in malalignment requires further investigation. Finally, the difference in treatment costs and surgical training must be considered. Internal osteosynthesis hardware is generally less expensive than CEF. However, the costs of treatment of complications may ultimately favor CEF. Meanwhile, surgical training and experience with CEF techniques are frequently less adequate than for internal osteosynthesis, limiting the indication of this technique.

While our study demonstrated promising results for the use of CEF for the treatment of tibial shaft fractures in the elderly, it was not without limitations. First, our study was retrospective in nature, with the lack of a control group, and had a small sample size of only 31 patients, which made detecting significance among subgroups challenging. Furthermore, the limited sample size could be underpowered to reliably detect complications which are usually low in closed tibial shaft fractures, irrespective of the method of treatment. Another limitation was the heterogeneity in fracture types assessed, with five different AO classification types accounted for, two periprosthetic fractures, and six open fractures which ranged in severity from Grade I to Grade III B. While this heterogeneous population has the potential to bias outcome results, it simultaneously demonstrates the broad utility of the CEF for the management of a variety of fracture patterns and clinical scenarios. Finally, a potential limitation to our study was the heterogeneity of frames used, with one Taylor spatial frame and one Sheffield frame utilized in addition to 29 traditional Ilizarov frames. This is a minor consideration, as all frames served the same purpose to provide minimally invasive circular fixation while allowing for immediate weight-bearing and likely had little potential to bias results.

Conclusion

We could demonstrate excellent results for the treatment of a variety of tibial shaft fractures with CEF in an elderly population. Our study attained a 0% nonunion, deep infection, and reoperation rate, which is superior to reported values for other treatment modalities. Furthermore, our average time to union, rate of delayed union, and misalignment rate were comparable to other fixation modalities. Finally, we described anatomical reduction as an important driver of functional and radiological outcome in this population. Future studies should focus on prospectively comparing modalities in this patient population.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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