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ORIGINAL PAPER

Clinical outcomes with the corticotomy-first technique associated with the Ilizarov method for the management of the septic long bones non-union

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Abstract

Purpose Corticotomy is an integral part of the Ilizarov method on management of infected nonunited fractures that are challenging orthopaedic surgeons. However, the presence of active draining sinuses may contaminate the operative field with the potential of developing corticotomy site infection. The authors present a surgical technique aiming at minimizing or avoiding the risk of surgical site infection (SSI) in the corticotomy zone.

Patients and methods A total of 144 cases of draining infected nonunions were treated by Ilizarov fixator using the corticotomy-first technique. The study included humeral (18 cases), femoral (52 cases), and tibial (74 cases) nonunions. The mean age was 44.48 years with 87 males and 57 females. The mean duration of nonunion was 28.69 months. After debridement, the combined shortening and nonunion gap averaged 5.98 (range 3–10) cm. Evaluation of bone and functional results was done according to Association for the Study and Application of the Method of Ilizarov (ASAMI) criteria.

Results The follow-up period averaged 51.05 (range 36–72) months. None of the cases developed corticotomy site or distraction gap infection. Union was successfully achieved in 141 cases (97.92%). Nonunion persisted in three cases (2.08%) in the distal tibia. Infection was eventually controlled in 138 cases (95.83%). Bone grafting was not needed in any case.

Conclusions The Ilizarov fixator with the corticotomy-first technique was effective in the management of draining infected non-united fractures of long bones while avoiding the SSI in the corticotomy site in all cases.

Keywords Surgical site infection · Infected nonunion · Corticotomy · External fixator · Ilizarov · Infection

Introduction

Infection has been a major nemesis confronting orthopaedic surgeons with a debilitating impact on the patient's quality of life [1, 2]. Infection of nonunited fractures is a complicating factor causing delay of fracture healing, loosening of the fixation devices, and chronic osteomyelitis. Variable treatment modalities have been used successfully in the treatment of infected nonunions, including bone grafting, free tissue transfer and antibiotic cement. However, these methods have obvious limitations, such as donor site morbidity, stress fracture, and restriction of the size of bone defects. In addition, none of these approaches provide a solution to treat infected nonunion associated with deformity and leg-length discrepancy (LLD) simultaneously [3].

The Ilizarov method is a versatile solution for these complicated cases and can be considered as limb salvage operation [4]. Mechanically, the Ilizarov fixator offers stability and allows early weight bearing and functional limb use. Biologically, corticotomy promotes vascularity to the entire bone and surrounding soft tissues as well as being a key factor for bone transports to close bone gaps and/or restore limb length inequality [3, 5]. Infection at the distraction zone is a potential surgical site infection (SSI) complication of bone transport especially with active draining infected nonunited fractures.

The development of SSI is affected by several factors related to the patient, the surgical environment, staff involvement, and the surgical technique. The presence of local contamination is a known risk factor for spreading infection with

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the risk increasing proportionately to the contamination degree [6, 7].

The aim of this study was to present the corticotomy-first surgical technique for the management of draining infected nonunited long bone fractures and to report its effectiveness in prophylaxis of corticotomy SSI.

Patients and methods

This retrospective study was conducted after approval of the Ethical Committee of the University. The inclusion criteria were nonunited fractures of long bones with active draining infection treated by Ilizarov fixator using the corticotomy-first technique. Cases that had corticotomy for aseptic nonunions, bone defects, and deformities were excluded from the study. After exclusion of five cases missed follow-up, the study included 144 cases with humeral (18 cases; 12.5%), femoral (52 cases; 36.11%), and tibial (74 cases; 51.39%) nonunions. The mean age was 44.48 (range 28–65; SD 9.63) years with 87 males (60.42%) and 57 females (39.58%).

Patients were thoroughly evaluated clinically and with radiographs in at least two planes, CT scans for better identification of sequestra, doppler ultrasound examination of lower limb veins, sinogram for resection planning of the septic zone, and arteriography in cases with previous vascular injury.

Initial mechanisms of trauma, type of primary fracture according to Gustilo and Anderson classification [8], associated injuries, initial treatment, smoking habit, and comorbidities are presented in Table 1. All patients had previous surgical procedures (mean 4.35; range 2–6; SD 1.21), e.g., ORIF, external fixation, repeated debridement, and implant removal. The mean duration of nonunion was 28.69 (range 16–58; SD 11.33) months. Joint stiffness was present in the knee (11 cases; 7.64%), and in the elbow (seven cases; 4.86%). Associated angulation deformity was present in 83 cases (57.64%).

Explanation of the procedure, meeting other patients with Ilizarov fixation, smoking cessation, and good blood sugar control were essential pre-operative preparatory steps. Informed consent was obtained from all patients.

Table 1 Characteristics of patients

		Number of cases	Percentage
Mechanism of trauma	Traffic accidents	89	61.81
	Falls from a height	26	18.06
	Work-related injuries	17	11.81
	Gunshot injuries	12	8.33
Type of primary fracture	Closed	24	16.67
	Open grade I	27	18.75
	Open grade II	43	29.86
	Open grade III	50	34.72
Associated injuries	Nerve injury		
	Radial nerve	3	2.08
	Sciatic nerve	1	0.69
	Common peroneal nerve	3	2.08
	Vascular injury		
	Femoral artery	1	0.69
	Posterior tibial artery	2	1.39
	Associated fractures	37	25.69
Initial treatment	Internal fixation	82	56.94
	External fixation	62	43.06
Smoking habit		56	38.89
Comorbidities	Diabetes mellitus	28	19.44
	Deep venous thrombosis	7	4.86
	Sympathetic dystrophy	5	3.47

Surgical technique

The surgical procedure included two sequential stages in the same operation. While isolating the area of active infection, the first stage aimed at performing a clean corticotomy following application of a limited Ilizarov frame to the intact longer bone segment. The second stage was debridement and completion of the frame.

After supine patient positioning on a radiolucent table and general or regional anesthesia, the whole limb was scrubbed and draped in the usual way. The infected nonunion focus was then isolated by an extra draping. The remaining parts were scrubbed again by alcohol (Fig. 1). Then, a pre-construct Ilizarov fixator was applied across the planned corticotomy site. The components of the pre-construct varied according to the corticotomy site, viz., upper versus lower tibia and upper versus lower femur. For proximal tibial corticotomy, the pre-construct was formed of a ring block of 5/8 ring connected to a full ring above the corticotomy and one full ring distal to the corticotomy site (Fig. 2a). The pre-construct was fixed by two or three wires in each ring tensioned to 120 to 130 kg. In short segments, two olive wires opposite each other were mounted to the frame to increase the stability. Drop wire was used to enforce the single ring of the transported segment. Drop wires and wires fixing the 5/8 ring were tensioned to 100 kg. The femoral and humeral constructs were also fixed by additional 5- or 6-mm half-pins. Arches were used for proximal femoral and humeral fixation. Wires and Schanz pins insertions were done according to the goniometric atlas of the Association for the Study and Application of the Method of Ilizarov (ASAMI) [9].

Thereafter, the corticotomy was performed through 1.5-cm incision with an osteotome after pre-drilling. The corticotomy was completed in the far cortex with osteoclasis. Following

Fig. 1 **a** Pre-operative photo of an infected nonunited fracture of the distal tibial shaft. **b** Intra-operative photo after isolation of the infected nonunion focus and additional scrubbing of the proximal leg by alcohol

periosteal and wound closure, that part of the limb was isolated by sterile draping (Fig. 2b).

The second part of the procedure involved tackling the nonunion site followed by completing the Ilizarov frame. The management of the infected nonunion focus was done by the management of the infected nonunion focus by debridement of necrotic and infected soft and bone tissues with

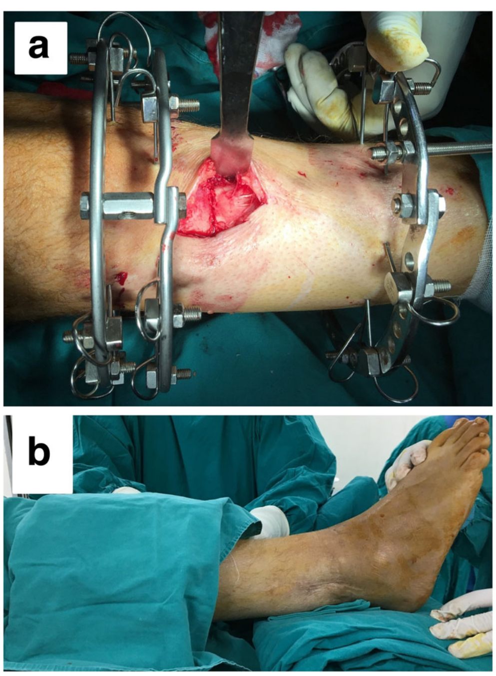

Fig. 2 **a** Intra-operative photo showing the upper tibial corticotomy after application of Ilizarov fixator to the intact tibial segment. **b** Intra-operative photo showing draping after finishing the proximal Ilizarov frame construct and corticotomy

removal of implants, if any (Fig. 3a). Bone debridement was done till the appearance of punctuate cortical or cancellous bleeding and creating transverse surfaces suitable for maximal compression. Acute compression was done for gaps of less than 3 cm, and bone transport was relied on for larger defects (Fig. 3b). Then, the rest of the Ilizarov frame was applied across the nonunion site with a ring block made of two connected rings. With shorter bone segments, one ring was used in addition to crossing the adjacent joint with a half ring. The nonunion site was then reduced and stabilized by four connecting rods. Lastly, wound closure over a suction drain was done followed by application of crepe bandage over sterile dressings (Fig. 3c).

Post-operative care

Patients were instructed to do isometric muscle and joint range of motion (ROM) exercises on the second postoperative day. Systemic antibiotics were given for six weeks based on the culture/sensitivity results. Clinical and radiographic follow-up was done every two weeks for one month (or more often if needed by the wound status), monthly till frame removal, every three months for one year, and yearly thereafter. The patients were monitored for condition of wounds, pin sites, maintenance of position and alignment, ROM, progression of weight-bearing, and progression of healing. After latency period of ten days, corticotomy distraction started at a rate of 1 mm daily and modified according to progression of consolidation. Bone transport was carried on till closure of the bone defect, and then distraction was continued till limb length equalization.

The Ilizarov fixator was removed after solid union evidenced radiographically by crossing trabeculae with the absence of any radiolucent line at the nonunion site and the presence of a minimum of three cortices in the distraction zone on standard orthogonal radiographs. Evaluation of bone and functional results was done according to Association for the Study and Application of the Method of Ilizarov (ASAMI) criteria [10].

Statistical analysis

The descriptive statistics and statistical analysis were performed with IBM SPSS Statistics for Windows, Version 22.0 (IBM Corp., Armonk, NY, USA). Level of significance was set at $p < 0.05$.

Results

The follow-up period ranged from 36 to 72 (mean 51.05; SD 11.24) months. After debridement, the combined defect secondary to both shortening and nonunion gap ranged from 3 to 10 (mean 5.98; SD 1.52) cm. The mean external fixation

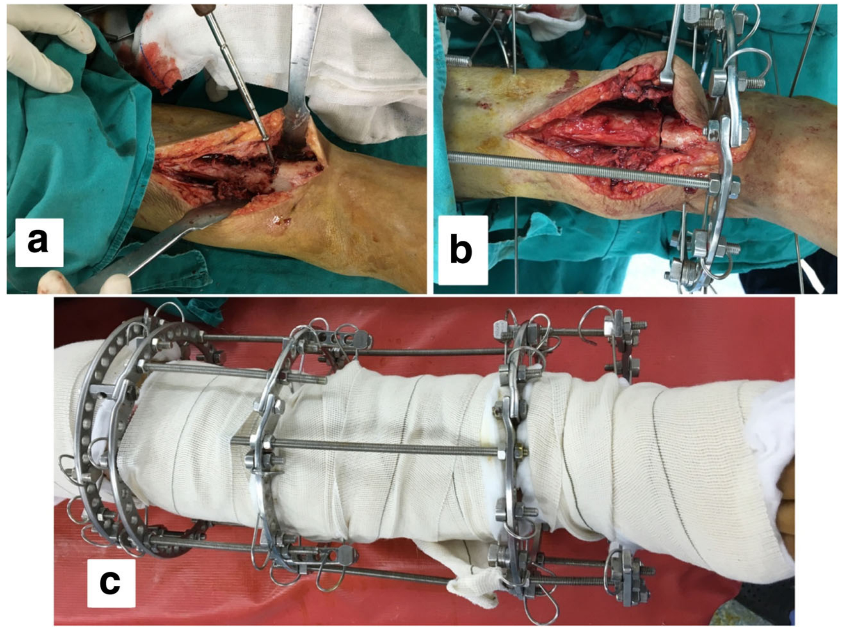

Fig. 3 **a** Intra-operative photo during debridement and implant removal. **b** Intraoperative photo after debridement, distal Ilizarov frame application, and fracture reduction. **c** Post-operative photo with crepe bandage application

period (EFP) was 9.12 (range 6–16; SD 2.27) months. Union was successfully achieved in 141 cases (97.92%) without bone grafting. Five cases (3.47%) showed delayed consolidation in the distraction region treated by compression and slower distraction. None of the cases developed an infection in the corticotomy site or in the distraction osteogenesis segment. Repeated debridement was needed to manage recurrence of infection at nonunion site in 17 cases (11.81%) (15 cases during the external fixation period, and two after frame removal). Infection was eventually controlled in 138 cases (95.83%). Pin track infection was the most common complication and occurred in almost all patients. It was managed by pin site dressing and oral antibiotics in most cases. Complications are summarized in Table 2.

The ASAMI bone grade was excellent in 109 patients (75.69%), good in 26 (18.06%), fair in three (2.08%), and poor in six (4.17%). The ASAMI functional grade was excellent in 98 patients (68.06%), good in 31 (21.53%), fair in 12 (8.33%), and poor in three (2.08%). A significant correlation was found between EEP and smoking habit (Spearman's rho = − .180, p = .030), between EFP and number of previous surgeries (Pearson correlation = .225, p = .007), between EFP and the combined bone defect (Pearson correlation = .903, p = .000). There was no correlation between EFP and the gender (Spearman's rho = .055, p = .511) or between EFP and age of patients (Pearson correlation = − .082, p = .330).

Table 2 Complications

Complication	Number of cases
Persistent nonunion	3 (2.08%) in the distal tibia
Nonunion re-fracture	1 (tibial)
Lengthening segment fracture	2 (1 humeral and 1tibial)
Septic wire and/or pin loosening	11 (7.64%)
Common peroneal palsy	1 (% of the tibial cases)
Radial nerve palsy	1 (% of humeral cases)
Residual deformity	3 tibial valgus
Residual LLD	1 cm (9 cases; %) 2.5 cm (4 cases)

Discussion

The ground of the presented technique was an early case of corticotomy site infection that occurred in a 47-year-old male patient during treatment of infected draining tibial nonunion by one stage Ilizarov fixator and corticotomy for bone transport. About 40 days later, the patient presented with fever, acute leg pain, and swelling. ESR and CRP were elevated with leucocytosis. Intravenous antibiotic was given. One week later, the patient presented with pus draining from the corticotomy incision scar with improving general condition, pain, and swelling. The distraction zone was compressed gradually till closure of the gap and cessation of drainage (Fig. 4). Thereafter, cycles of compression and re-distraction were done till consolidation. Following that case scenario, the authors used the described modified technique sequence as a prophylaxis against the occurrence of such complication in the bifocal management of nonunited fractures with active infection.

Surgical site infection (SSI) is one of the most dreaded complications in orthopaedic practice with associated prolonged total hospital stays, increased health care costs by more than 300%,

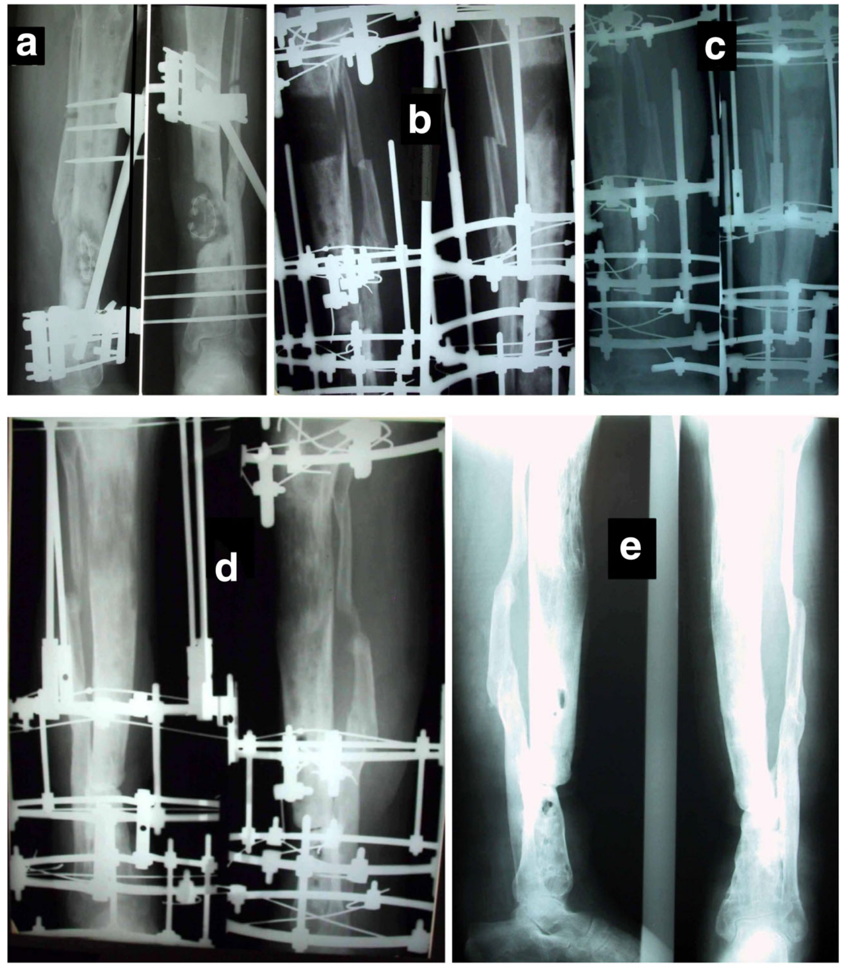

Fig. 4 Radiographs of the infected tibial nonunion complicated by corticotomy site infection. **a** Pre-operative radiographs. **b** Radiographs during the corticotomy site infection showing weak regenerate. **c** During cycles of compression and re-distraction. **d** After distraction to the planned length with consolidation of the regenerate. **e** After frame removal

and greater physical limitations of patients and reductions in their quality of life. Therefore, prevention of these infections, when possible, and their prompt and appropriate treatment are important [11]. In their prospective study of orthopaedic surgeries, Maksimovic et al. [12] reported an SSI incidence rate of 13.5% after surgeries classified as clean, increasing by 70% when the surgery was classified as infected.

This has led many authors to use a two-stage management protocol for treatment of septic conditions such as infected arthroplasty. The purpose of such staged surgical approaches was to reduce or eliminate the infection risk. A first stage of debridement and implant removal with antibiotic impregnated cement application is followed by a period of intravenous antibiotics administration before the second stage of either revision arthroplasty [13] or arthrodesis [14]. Similarly, staged management was used in many studies involving infected nonunions. In their review article, Struijs et al. [15] reported 18 of the 34 studies describing a two- or multiple-stage strategy for the management of infected nonunion of the long bones.

Conventional methods of non-union management are successful in cases of non-infected non-unions with adequate vascular supply and soft tissue integrity. Infection adds complexity to the situation leading to the delay of fracture union, loosening of the fixation methods, and chronic osteomyelitis. Infected nonunion is a challenging problem necessitating complex management strategies taking into consideration different treatment modalities, deformity correction, treatment of infection, and rapid patient rehabilitation. In these conditions, Ilizarov method is the modality of choice and can be considered as limb salvage surgery [4, 16]. The complexity is exaggerated by associated segmental defects. Masquelet et al. [17] used the two-stage induced membrane technique for reconstruction of segmental bone defects. They reported union in all 35 patients with upper and lower extremity segmental defects. However, El-Alfy and Ali [18] used the same technique in 13 tibial and four femoral nonunions and reported five nonunions of the graft, two failures of graft maturation, two cases of infection reactivation, and one refracture after frame removal.

The advantages of the Ilizarov fixator include percutaneous application, high stability permitting early weight-bearing, three-dimensional deformity corrections, and LLD correction. However, it is disadvantaged by its limited use for

Table 3 Some studies reporting outcome of management of infected nonunions by Ilizarov fixator

		Current study	McNally et al. 2017 [20]	Yin et al. 2015 [3]	Sahu and Ranjan 2016 [21]	Maini et al. 2000 [22]	Krishnan et al. 2006 [23]	Peng et al. 2015 [24]	Magadum et al. 2006 [25]	Saridis et al. 2006 [26]
Number of cases		144 (74 T, 52 F, 18 H)	79 T	110 (72 T; 38 F)	60 T	30 (6 F; 23 T; 1 H)	20 F	58 T	25 T	13 F
Nonunion duration		28.69 mon	15.8 mon	25.53 mon	9 mon	7 mon	9.5 mon	30.5 mon	NA	12.3 mon
EFP		9.12 mon	7.5 mon	10.85 mon	12 mon	150 days	234 days	10.6 mon	NA	309.8 days
Follow-up		51.05 mon	40.8 mon	23.12 mon	36 mon	23.5 mon	62.8 mon	31.6 mon	27 mon	42.4 mon
Union		141 (97.92%)	78 (98.7%)	110 (100%)	60 (100%)	30 (100%)	19 (95%)	58 (100%)	24 (96%)	13 (100%)
Bone grafting		No	8	12	22	3	No	58	No	2
Infection control		138 (95.83%)	76 (96.2%)	110 (100%)	1 (1.67%)	27 (90%)	19 (95%)	57 (98.28%)	24 (96%)	13 (100%)
ASAMI bone Results	E	109	74	68	50	21	13	30	19	8
	G	26	3	28	7	3	4	23	5	4
	F	3	0	12	2	0	1	5	0	1
	P	6	2	2	1	6	1	0	1	0
ASAMI functional results	E	98	55	37	45	8	3	28	15	3
	G	31	16	42	10	12	9	18	8	4
	F	12	6	21	3	3	3	12	1	4
	P	3	1 + 1 Amp	0	2 + 1 Amp	7	4 + 1 Amp	0	1	2

T tibia, *F* femur, *H* humerus, *mon* months, *E* excellent. *G* good, *F* fair, *P* poor, *Amp* amputation, *NA* not available

non-complaint and psychologically impaired patients, cost of the device, long learning curve, and external fixation-related complications as pin track infection, and neurovascular injury hazard [3, 5, 19]. Table 3 summarizes the current study and some studies reporting outcome of the management of infected nonunions by Ilizarov fixator [3, 20–26].

Reports of corticotomy site infection are scarce. Rohilla et al. [27] reported a single case of corticotomy site infection in a prospective randomized study of 70 patients with infected gap nonunion of tibia. However, they did not report on the presentation, the management, or the result of that case. Infection is known to have a negative effect on fracture healing and is one of the possible causes of nonunion. Similarly, infection of the corticotomy site is a serious complication and can be deleterious to bone regeneration.

The routine technique for the management of infected nonunited fractures by bifocal Ilizarov method begins with debridement followed by application of the Ilizarov external fixator. Corticotomy is the last step of the procedure [3, 15, 23, 25–27]. While the Ilizarov external fixator can be applied in the presence of active infection, some authors preferred to postpone corticotomy into the second stage in the management of nonunited fractures with active infection [21, 23, 25, 26].

In this article, the authors present their experience with infection at the distraction zone. Thence, the presented corticotomy-first technique while isolating the septic nonunion zone was used to reduce the possibility of contamination of the planned corticotomy area in the treatment of non-unions with active draining infections in one stage procedure. Isolation of the active draining infected nonunion zone in the first part of the surgical procedure allowed performance of a clean corticotomy. Moreover, the corticotomy surgical site closure and isolation by dressing and separate draping could protect against its affection by the gross contamination occurring during the second part of the procedure of debridement and completing fixation.

Despite the limitation of retrospective nature, the current study is considered as one of the largest reported series of infected nonunited fractures with presentation of a technique that could refine the management of this challenging problem. More than 140 cases of long bone infected nonunions were managed with that protocol without occurrence of infection in the corticotomy site or the distraction zone.

Conclusions

Infection in the distraction zone is a potential serious complication of bone transport especially in the presence of active infection and/or lowered systemic immunity. The aforementioned surgical technique is reproducible and may minimize or eliminate the risk of local bacterial contamination of the corticotomy site from the active draining infection of non-united fractures of long bones in different sites.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. For this retrospective type of study formal consent is not required.

Conflict of interest The authors declare that they have no conflict of interest.

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