

Comparative Study of Infection Rates in Open Fractures Treated with External Fixation versus Internal Fixation

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Received: 10-02-2025 / Revised: 14-03-2025 / Accepted: 22-04-2025

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Conflict of interest: Nil

Abstract:

Background: Open fractures of extremities have become more common and carry a high risk for postoperative infection related to sufficient soft tissue injury and contamination. External fixation (EF) and internal fixation (IF) are commonly used methods, and the infection rate comparisons are still disputed.

Aim: To compare the rate of infection in open fractures treated with the temporary EF followed by IF and to evaluate the factors impacting postoperative infection.

Method: A retrospective study of 102 patients (111 limbs) with open extremity fractures managed at Department of Orthopedics, Jannayak Karpoori Thakur Medical College, Madhepura, Bihar, India from January 2023 to December 2023. Patients underwent emergency debridement with EF followed by conversion to IF immediately or within 5–7 days. The rate of infection was evaluated using the Gustilo classification, total time to EF, and time to IF. The levels of statistical significance were determined using Chi-squared tests ($p < 0.05$).

Results: The infection rate was overall 13.5%, and increased incidence with the Gustilo severity (0% type I to 38.5% type IIIC). EF for >28 days significantly increased the risk of infection (28.6% (EF>28 days) compared to 6.6% for ≤ 28 days; $p = 0.0016$). The timing of IF (same time as EF or delayed) was not a significant factor (16.4% infection rate, and 10% infection rate respectively; $p = 0.327$). Overall healing occurred in 87.4% of fractures.

Conclusion: Rate of infection is highest with the Gustilo severity category and prolonged EF usage. Early conversion from EF to IF (2-4 weeks) would decrease infection rates, while the timing of replacement is of less consequence.

Keywords: Open Fracture, External Fixation, Internal Fixation, Postoperative Infection, Gustilo Classification.

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Introduction

Along with the rapid advancement in social economy and industrialization, the number of cases involving open fractures of the extremities due to various factors from trauma has been continuously on the rise. Open fractures often accompany high-energy trauma such as traffic injuries, height falls, and industrial injuries, leading frequently to serious damage in bone as well as soft tissue injury. In the majority of cases, these injuries will be accompanied by severe skin and soft tissue defects and exposure or injury to muscles, tendons, bones, joints, vessels, and nerves. Treating such injuries poses a difficulty owing to the complex nature of the injury as well as extended cycles of treatment involved. In addition, infection that develops following an open fracture frequently necessitates repeated surgical debridement, imposing a considerable economic and psychological burden on the patient, family members, and health systems.

Wound contamination, as well as severe soft tissue destruction, have been widely established as a

significant predictor of outcomes in open fractures. Secondary infection and soft tissue or bone necrosis greatly complicate management and lower the chances for optimal functional recovery [1]. Variability and severity in open fracture injuries necessitate the development of suitable protocols for management to achieve favorable results. In spite of significant advances in contemporary medicine, postoperative infection rates for open fractures continue to remain significant, as do suboptimal functional recovery rates for involved limbs, resulting in a significant decline in quality of life for patients. Because prevention strategies for postoperative infection in cases of open fracture have been a central focus for clinical research as well as discussion, this condition was targeted by this project in terms of finding a solution that could help reduce infection rates significantly.

Several factors have been found to contribute towards the prediction of the risk of postoperative infection in open fractures, including smoking history,

diabetes mellitus, Gustilo–Anderson grade of the fracture, and duration of use of an external fixator. It was established by Chua et al. [3] as well as by Reuss et al. [2] that Gustilo–Anderson grade of fracture has a direct positive relationship with rates of postoperative infection, demonstrating that more severe grade fractures have a significant risk of infection. In response to these challenges, more researchers have been advocating an integrated approach towards treatment that strikes bone stabilization as much as soft tissue coverage simultaneously.

Debridement under thorough irrigation coupled with internal fixation has been described as a safe and effective management for Gustilo I and Gustilo II fractures, as well as selectively for IIIa and IIIb fractures [4,5]. Nonetheless, when fractures are complicated by severe bone as well as soft tissue loss, staged management based on principles of damage control orthopedic surgery finds common application. Staging begins with initial stabilization of fracture by an external fixator after an emergency debridement procedure. After the condition of the local soft tissue improves, the patient undergoes removal of the external fixator as a prelude to definitive internal stabilization by internal fixation. It has benefits on various counts that an acute phase stabilization with an external fixator brings up, such as quick stabilization in the fracture, limb length restoration, as well as reduction in further soft tissue damage [6].

Despite such advantages, long-term use of external fixators has been related to various disadvantages. These encompass unstable fixation, chance of loosening of pins, development of tracts between pins and the external milieu, as well as soft tissue injury exacerbation. Extended external fixation has been related to a higher risk of deep infection, nonunion, malunion, as well as joint dysfunction [7]. A number of studies indicated that strategically planned conversion of temporary external fixation to definitive internal fixation is a safe approach that overcomes the inherent pitfalls of prolonged use of external fixation devices [8]. Controversy still exists, however, on the best timing as well as modality of shifting the patient from exposure to internal fixation. The main clinical predicament centers on the fact that internal fixation can be applied after the removal of the external fixator or if a wait-in period for the avoidance of postoperative infection is wise [9,10].

Postoperative infection after internal fixation is a significant determinant of treatment efficacy. Elucidation of infection determinants as well as discovery of methods reducing its prevalence thus holds central importance in maximizing patient safety as well as improving therapeutic effectiveness. To inform these questions, we retrospectively examined 122 cases of extremity open fractures managed across two orthopedic institutions over the period January 2017-2019. In specific terms, we compared the effects of sequential external fixation then internal

fixation on postoperative infection rates as well as infection timing in relation to conversion to internal fixation together with infection risk factors. Results of this investigation hope to inform evidence-based clinical management recommendations on open fracture across institutions as well as inform methods optimizing patient outcomes.

Materials and Methods

Study Design: This was a retrospective observational comparative study that aimed to evaluate and compare infection rates in open fractures treated with external fixation at first and internal fixation afterwards. The study examined the impact of the external fixator carrying time and timing of replacement to internal fixation on postoperative infection rates.

Study Area: The study was conducted in the Department of Orthopedics, Jannayak Karpoori Thakur Medical College and Hospital, Madhepura, Bihar, India from January 2023 to December 2023.

Sample Size: A total of 102 cases meeting the inclusion criteria were analyzed, including 72 males and 30 females, with 9 patients having double fractures.

Sample Population: Patients aged ≥ 15 years with open fractures of the extremities, who received temporary external fixation at phase I followed by internal fixation at phase II, and had complete clinical and imaging data available.

Inclusion Criteria

- Age ≥ 15 years.
- Open fractures of extremities.
- Temporary external fixation at phase I, replaced by internal fixation at phase II.
- Postoperative follow-up time ≥ 12 months.
- Complete clinical and imaging data available.

Exclusion Criteria

- Patients choose external fixators as the final treatment.
- Internal fixation at phase II after bone transport or bone lengthening surgery.
- Other infection foci in the affected limbs during follow-up.
- Treatment with glucocorticoids or immunosuppressants for other diseases.
- Amputation due to limb necrosis caused by vascular injury during follow-up.

Data Collection: A chart review was performed for all patients meeting inclusion criteria in order to collect demographic data, indication for injury, fracture type based on Gustilo classification, description of the surgical procedure, and outcomes after discharge. Laboratory testing including WBCs, CRP, ESR, and procalcitonin, as well as imaging studies were collected. We additionally pulled data from

chart notes related to timing of internal fixation, identification of external fixation, and any post-operative infection data reported in the medical record.

Surgical Procedure: Patients received antibiotics and tetanus immunoglobulin upon arrival. Emergency debridement was performed with temporary external fixation applied according to orthopedic damage control principles. Stability was assessed intraoperatively with provision for limited internal fixation (Kirschner wires) as necessary. Soft tissue management was performed by direct suture, vacuum sealing drainage (VSD), flap transposition, or free skin grafting depending on the viability of the soft tissue. Internal fixation was performed immediately upon removal of the external fixation (immediate group) or at five to seven days post-initial surgery (delayed group) with a steel plate, or intramedullary nail used to repair the fracture.

Definition of Variables

- **Carrying time of external fixators:** Time from wound closure or repair to internal fixation.
- **Post-internal fixation infection:** Defined according to the International Association for Internal Fixation (2017) consensus, classified into three grades:
 - Grade 1: Mild infection treated conservatively.
 - Grade 2: Moderate infection, requiring debridement.
 - Grade 3: Severe infection, requiring removal of internal fixation and further surgical intervention.

➤ Grouping

- Based on external fixator carrying time:
 - Group A: ≤ 14 days
 - Group B: 15–28 days
 - Group C: >28 days
- Based on timing of internal fixation:
 - **Group a:** Immediate replacement
 - **Group b:** Delayed replacement (5–7 days)

Statistical Analysis: The data were analyzed using the Chi-square test or Fisher's exact test for the comparison of infection rates between the groups. Continuous variables were expressed as mean \pm standard deviation (SD) and categorical variables were reported as frequencies and percentages. A p-value <0.05 was considered statistically significant. The statistical analysis was performed using SPSS 25.0.

Result

Table 1 describes the characteristics of 102 patients with 111 affected limbs. The mean age was 40.5 ± 12.2 years, with males comprising 70.6% (n=72). Nearly one-third of patients were smokers (29.4%, n=30). The most common mechanism of injury was traffic accidents (68.6%, n=70), followed by falls (17.6%, n=18), machine injuries (9.8%, n=10), bruises (7.8%, n=8), and other causes (3.9%, n=4). Temporary external fixation (EF) duration was ≤ 14 days in 55 patients (49.5%), 15–28 days in 28 patients (25.2%), and >28 days in 28 patients (25.2%). Direct conversion from EF to internal fixation (IF) occurred in 92 patients (82.4%). For definitive IF, 75 patients (73.5%) received locking plates, while 27 (26.5%) were treated with intramedullary nails.

Demographic variables	Data
Number of patients	102
Number of limbs	111*
Age (mean \pm SD, years)	40.5 ± 12.2
Gender (Males, %)	72 (70.6%)
Smokers	30 (29.4%)
Mechanism of injury	
– Traffic accident	70 (68.6%)
– Fall	18 (17.6%)
– Machine injury	10 (9.8%)
– Bruised	8 (7.8%)
– Others	4 (3.9%)
Temporary EF duration group	
– ≤ 14 days	55 (49.5%)
– 15–28 days	28 (25.2%)
– >28 days	28 (25.2%)
Conversion from EF to IF (Directly)	92 (82.4%)
Definite IF	
– Locking plate	75 (73.5%)
– Intramedullary nail	27 (26.5%)

*Includes 9 patients with double fractures (111 total limbs).

Table 2 summarizes the demographic characteristics and outcomes of 111 fractures. According to the Gustilo classification, 12 fractures (10.8%) were type I, 32 (28.8%) type II, 35 (31.5%) type IIIA, 22 (19.8%) type IIIB, and 10 (9.0%) type IIIC.

Regarding outcomes, 97 fractures (87.4%) healed successfully, while 14 (12.6%) developed infections. Among the infected cases, 4 (28.6%) were classified as mild, 6 (42.9%) as moderate, and 4 (28.6%) as severe.

Variable	n	% (of 111)
Gustilo classification		
– I	12	10.80%
– II	32	28.80%
– IIIA	35	31.50%
– IIIB	22	19.80%
– IIIC	10	9.00%
Outcome		
– Healed	97	87.40%
– Infected	14	12.60%
Infection degree		
– Mild	4	28.6%*
– Moderate	6	42.9%*
– Severe	4	28.6%*

*Percentages within infected cases (n=14)

Table 3 compares infection rates across Gustilo fracture types among 111 fractures. Infection rates increased with fracture severity: type I had 0% (0/9), type II 6.3% (2/32), type IIIA 9.4% (3/32), type IIIB 20% (5/25), and type IIIC 38.5% (5/13). Overall, 15

fractures (13.5%) developed infections. The difference in infection rates across groups was statistically significant ($\chi^2 = 11.143$, $p = 0.025$), indicating a clear association between higher Gustilo type and increased infection risk.

Group	Infection Yes	Infection No	Overall	Ratio (%)	χ^2	P value
I	0	9	9	0		
II	2	30	32	6.3		
IIIA	3	29	32	9.4	11.143	0.025*
IIIB	5	20	25	20		
IIIC	5	8	13	38.5		
Overall	15	96	111	13.5		

*Significant association (two expected counts <5).

Table 4 presents infection rates according to the duration of temporary external fixation (EF) among 111 fractures. Patients with EF ≤ 14 days had an infection rate of 6.7% (4/60), those with EF 15–28 days had 6.3% (1/16), and EF >28 days had a markedly higher rate of 28.6% (10/35). Overall, 15

fractures (13.5%) developed infections. The difference in infection rates across EF duration groups was statistically significant ($\chi^2 = 9.919$, $p = 0.007$), indicating that prolonged EF (>28 days) is associated with a substantially increased risk of infection.

Group	Infection Yes	Infection No	Overall	Ratio (%)	χ^2	P value
≤ 14 days	4	56	60	6.7		
15–28 days	1	15	16	6.3	9.919	0.007**
>28 days	10	25	35	28.6		
Overall	15	96	111	13.5		

Table 5 compares infection rates between patients with temporary external fixation (EF) duration of ≤ 14 days versus >14 days among 111 fractures. In the ≤ 14 days group, 4 patients (6.7%) developed infections, whereas in the >14 days group, 11 patients

(21.6%) were infected. Overall, 15 fractures (13.5%) experienced infection. The difference was statistically significant ($\chi^2 = 3.992$, $p = 0.046$), indicating that EF duration longer than 14 days is associated with a significantly higher risk of infection.

Table 5: Comparison of infection (≤14 vs >14 days EF duration)

Group	Infection Yes	Infection No	Overall	Ratio (%)	χ ²	P value
≤14 days	4	56	60	6.7		
>14 days	11	40	51	21.6	3.992	0.046*
Overall	15	96	111	13.5		

Table 6 compares infection rates between patients with temporary external fixation (EF) duration of ≤28 days versus >28 days among 111 fractures. In the ≤28 days group, 5 patients (6.6%) developed infections, whereas in the >28 days group, 10 patients (28.6%) were infected. Overall, prolonged EF

beyond 28 days was associated with a significantly higher infection rate, and this difference was statistically significant (χ² = 10.27, p = 0.0016), highlighting the strong risk of infection with extended EF duration.

Table 6: Comparison of infection (≤28 vs >28 days EF duration)

Group	Infection Yes	Infection No	Overall	Ratio (%)	χ ²	P value
≤28 days	5	71	76	6.6		
>28 days	10	25	35	28.6	10.27	0.0016**

Table 7 compares infection rates between immediate versus interval internal fixation (IF) replacement among 111 fractures. In the immediate fixation group, 10 patients (16.4%) developed infections, while in the interval fixation group, 5 patients (10%)

were infected. Overall, 15 fractures (13.5%) experienced infection. The difference between the groups was not statistically significant (χ² = 0.961, p = 0.327), suggesting that the timing of fixation replacement did not significantly affect infection risk.

Table 7: Comparison of infection between immediate vs interval fixation replacement

Group	Infection Yes	Infection No	Overall	Ratio (%)	χ ²	P value
Immediate	10	51	61	16.4		
Interval	5	45	50	10	0.961	0.327
Overall	15	96	111	13.5		

Discussion

We found an overall infection rate of 12.6% in patients with open fractures who were initially treated with external fixation (EF) and then later had conversion to internal fixation (IF). Our data has several significant relationships: as Gustilo- Anderson classification increased, there was a subsequent increase in the infection rate; the longer the duration of EF, the increased rate of infection; and if EF was retained in situ after 28 days, there was a higher rate of infection. There was no difference in the timing of the EF conversion compared to IF in relation to infection outcomes. In general, our results are consistent with the literature at present; however, provide further detail to the current comparative data of these two fixation strategies.”

The relationship between fracture grade and infection of the fracture in this series follows the literature. There was a stepwise increase in infection rate, 0% in type I fractures to 38.5% in type IIIC fractures. This pattern agrees with McBirnie (1995) [11], who noted infection rates between 2% in type I up to almost 50% in type IIIC injuries, highlighting that soft tissue compromise directly affects infection risk. Likewise, Lua et al. (2017) [12] noted that Gustilo type III fracture patients had a considerably increased risk—up to 3.7-fold—of infection complications than types I and II. Our evidence thus

corroborates that grade of fracture significantly determines postoperative outcome, such that careful soft tissue management still holds paramount importance in highest grade injuries.

When considering the method of fixation, external fixation has historically been favored for severe open fractures due to its minimal interference with compromised soft tissues and rapid application in emergency settings. However, EF is not without complications. Studies such as those by McGraw and Lim (1988) [13] and Behrens and Searls (1986) [14] documented high rates of malunion, pin-tract infection, and refracture when EF was used as definitive fixation. In our study, EF was primarily temporary, and most cases were later converted to IF, which yielded a relatively favorable healing rate of 87.4%. These findings are consistent with Antich-Adrover et al. (1997) [15], who demonstrated that staged treatment—initial EF followed by intramedullary nailing—offered improved union rates and lower complication rates compared with prolonged EF use. Thus, our data supports staged management as a safer strategy than exclusive reliance on EF.

The period of EF proved an important consideration in our evaluation. Those patients whose EF was retained longer than 28 days had infection rates of 28.6%, as opposed to just 6–7% in the converted group sooner. This finding strongly supports the

Vincent et al. (2015) [16] meta-analysis that concluded that infection risk rose significantly if EF was retained more than four weeks. Likewise, Sirkin et al. (2004) [17] stressed that safe conversion can be assured only between 5–14 days once the patient's soft tissue envelope is established as stable. Our investigation thus supports the clinical guideline that temporary EF for an optimal period should rarely exceed two to four weeks when conversion to IF ought to be attempted in an effort to reduce infection risk.

Notably, our investigation discovered no statistically significant distinction between infection rates for immediate versus delayed conversion from EF to IF. Those undergoing direct replacement had an infection rate slightly greater than that for an interval approach (16.4 versus 10%), albeit this was not significant. These findings reflect the experience of Nowotarski et al. (2000) [18], who discovered both approaches could be safe as long as infection principles were controlled. Additionally, Cosco et al. (2001) [19] identified no significant distinctions in infection risk when direct versus delayed conversion were comparable. Collectively, these studies indicate that perhaps the length rather than exact timing of EF retained might prove more important as long as debridement and infection control are adequate.

Epidemiologically, our patient profile was comparable with other literature descriptions. Male predominance (70.6%) and traffic injury as the leading cause of injury (68.6%) concur with overseas literature where high-energy trauma remains the leading cause of open fractures (McBirmie, 1995) [11]. Cigarette smoking as noted in nearly a third of our cases might also be accountable for delayed fracture union as well as infection predisposition as mentioned previously in fracture healing risk factors literature (Lua et al., 2017) [12].

Since we had a relatively favorable rate of healing of 87.4%, prolonged use of EF was not strongly related to complications such as malunion or nonunion as in other accounts. Inan et al. (2007) [20], for example, had longer healing times as well as more complications with Ilizarov external fixation than with unreamed tibial nailing. In contrast, our two-staged procedure combining EF with IF had favorable results, just as was experienced by Blachut et al. (1990) [21], when they had favorable results under the principles applying the use of sequential fixation under damage control orthopedics (DCO).

Taken all together, our findings show three prevailing conclusions. First, the severity of the lesion associated with the open fracture (defined by Gustilo–Anderson grading) continues to be the most important independent predictor of infection risk. Second, EF can more so be envisioned as an interim stabilization technique with an urgent return to IF (ideally on the range of 2–4 weeks) to reduce infection. Third, with implementation of infection control

measures, for most instances the immediacy/delay of return to IF does not appear any more relevant than the overall period of EF use.

However, there were also some limitations in our study including retrospective research design and variability of surgical experience in institutions which may affect infection outcomes. In addition, while our overall sample size was adequate, the Gustilo IIIC fracture subgroup was small, not providing as much strength of inference in this injury category. Further multicenter prospective studies will be needed to refine EF optimal duration thresholds for Gustilo III injuries and examine standardized protocols for return to IF.

Conclusion

The study indicates that the rate of infection in open fractures is associated with both the severity of injury and the time between external fixation and internal fixation. Fractures with a Gustilo grade of IIIB and IIIC had a greater risk of infection that illustrates both soft tissue injury and contamination as reasons for increase in postoperative complications. External fixation use longer than 28 days was associated with a significant increased risk for infection, indicating that timely conversion to internal fixation may be necessary. However, compared to immediate internal fixation, there was no difference with interval. Overall, the study suggests that timely conversion from external to internal fixation and thorough management of high-grade open fractures greatly decreases the risk of infection and overall clinical outcome.

References

1. Fioravanti M, Maman P, Curvale G, Rochwerger A, Mattei JC. Amputation versus conservative treatment in severe open lower-limb fracture: a functional and quality-of-life study. *Orthop Traumatol Surg Res.* 2018; 104(2): 277–81.
2. Reuss BL, Cole JD. Effect of delayed treatment on open tibial shaft fractures. *Am J Orthop (Belle Mead NJ).* 2007;36(4):215–20.
3. Chua W, Murphy D, Siow W, Kagda F, Thambiah J. Epidemiological analysis of outcomes in 323 open tibial diaphyseal fractures: a nineyear experience. *Singapore Med J.* 2012;53(6):385–9.
4. Nambi GI, Salunke AA, Thirumalaisamy SG, Babu VL, Baskaran K, Janarthanan T, et al. Single stage management of Gustilo type III A/B tibia fractures: fixed with nail & covered with fasciocutaneous flap. *Chin J Traumatol.* 2017; 20(2): 99–102.
5. O'Brien PJ, Meek RN, Powell JN, Blachut PA. Primary intramedullary nailing of open femoral shaft fractures. *J Trauma.* 1991;31(1):113–6.
6. Xu X, Li X, Liu L, Wu W. A meta-analysis of external fixator versus intramedullary nails for

- open tibial fracture fixation. *J Orthop Surg Res.* 2014; 9:75.
7. Li Y, Jiang X, Guo Q, Zhu L, Ye T, Chen A. Treatment of distal tibial shaft fractures by three different surgical methods: a randomized, prospective study. *Int Orthop.* 2014;38(6):1261–7.
 8. Roussignol X, Sigonney G, Potage D, Etienne M, Duparc F, Dujardin F. Secondary nailing after external fixation for tibial shaft fracture: risk factors for union and infection. A 55-case series. *Orthop Traumatol Surg Res.* 2015; 101(1):89–92.
 9. Della RG, Crist BD. External fixation versus conversion to intramedullary nailing for definitive management of closed fractures of the femoral and tibial shaft. *J Am Acad Orthop Surg.* 2006;14(10 Spec No.):S131–5.
 10. Patterson MJ, Cole JD. Two-staged delayed open reduction and internal fixation of severe pilon fractures. *J Orthop Trauma.* 1999; 13(2): 85–91.
 11. McBirnie J. The epidemiology of tibial fractures. *The Journal of Bone & Joint Surgery British Volume.* 1995 May 1;77(3):417-21.
 12. Lua J, Tan VH, Sivasubramanian H, Kwek E. Complications of open tibial fracture management: risk factors and treatment. *Malays Orthop J.* 2017;11(1):18–22.
 13. McGraw JM, Lim EV. Treatment of open tibial-shaft fractures. External fixation and secondary intramedullary nailing. *J Bone Jt Surg Am.* 1988; 70(6):900–11.
 14. Behrens F, Searls K. External fixation of the tibia. Basic concepts and prospective evaluation. *J Bone Jt Surg Br.* 1986;68(2):246–54.
 15. Antich-Adrover P, Marti-Garin D, Murias-Alvarez J, Puente-Alonso C. External fixation and secondary intramedullary nailing of open tibial fractures. A randomised, prospective trial. *J Bone Jt Surg Br.* 1997;79(3):433–7.
 16. Vincent HK, Horodyski M, Vincent KR, Brisbane ST, Sadasivan KK. Psychological distress after orthopedic trauma: prevalence in patients and implications for rehabilitation. *PM&R.* 2015 Sep 1;7(9):978-89.
 17. Sirkin M, Sanders R, DiPasquale T, Herscovici DJ. A staged protocol for soft tissue management in the treatment of complex pilon fractures. *J Orthop Trauma.* 2004;18(8 Suppl):S32–8.
 18. Nowotarski PJ, Turen CH, Brumback RJ, Scarborough JM. Conversion of external fixation to intramedullary nailing for fractures of the shaft of the femur in multiply injured patients. *J Bone Jt Surg Am.* 2000;82(6):781–8.
 19. Cosco F, Risi M, Pompili M, Boriani S. External fixation and sequential nailing in the treatment of open diaphyseal fractures of the tibia. *Chir Organ Mov.* 2001;86(3):191–7.
 20. Inan M, Halici M, Ayan I, Tuncel M, Karaoglu S. Treatment of type IIIA open fractures of tibial shaft with Ilizarov external fixator versus unreamed tibial nailing. *Arch Orthop Trauma Surg.* 2007;127(8):617–23.
 21. Blachut PA, Meek RN, O'Brien PJ. External fixation and delayed intramedullary nailing of open fractures of the tibial shaft. A sequential protocol. *J Bone Jt Surg Am.* 1990;72(5):729–35.