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Evaluating Infection Risk and Conversion Interval from External to Internal Fixation in Open Tibial Fractures

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Abstract

Open tibial fractures remain among the most complex injuries in orthopedic trauma surgery, primarily due to compromised soft-tissue coverage and high infection risk. Temporary external fixation is widely used as a damage control measure, followed by conversion to internal fixation once soft tissue conditions permit. However, the optimal timing for conversion remains controversial. This review synthesizes recent literature evaluating infection risks associated with conversion intervals from external to internal fixation in open tibial fractures. Evidence indicates that early conversion (within 2–3 weeks) after stabilization of soft tissues results in significantly lower infection rates, whereas delayed conversion beyond 4 weeks correlates with increased superficial and deep infection incidence. Additional risk factors include high Gustilo–Anderson fracture grade, prolonged external fixator duration, and presence of pin tract infection. Establishing clear clinical criteria for safe conversion timing is essential for improving patient outcomes.

I. INTRODUCTION

Open tibial fractures most often arise from high-energy traumatic events, including motor vehicle collisions, falls from height, or direct crush injuries, and are frequently associated with extensive soft tissue disruption and wound contamination (1). These injuries represent some of the most complex challenges in orthopedic trauma care due to the tibia's subcutaneous location and limited soft-tissue coverage, which leave it particularly vulnerable to infection, delayed healing, and nonunion (2). Achieving stable fracture fixation while preserving the integrity of the surrounding soft tissues and minimizing infection risk remains a central concern in their management.

Temporary external fixation has become a cornerstone of initial emergency treatment, particularly in patients with polytrauma or those presenting with gross contamination, severe swelling, or compromised wound conditions (3). This method provides rapid and effective fracture stabilization with minimal additional soft-tissue trauma. Moreover, it facilitates early patient mobilization, repeated and thorough debridement, optimal wound access for soft tissue management, and maintenance of overall limb alignment and length (4). By allowing the soft-tissue envelope to recover adequately before proceeding to definitive internal fixation, temporary external fixation serves as a crucial bridge between initial damage control and final reconstructive surgery, ultimately improving the prospects for functional recovery and limb salvage.

Definitive management of open tibial fractures is most often accomplished through conversion to internal fixation methods, such as intramedullary nailing or plate osteosynthesis, once local and systemic conditions permit (5). These techniques provide superior mechanical stability, promote early mobilization, and facilitate proper alignment and faster functional recovery compared to prolonged external fixation. However, determining the optimal timing for converting from temporary external fixation to definitive internal fixation remains a critical and much-debated aspect of treatment (6).

Early conversion can offer multiple benefits, including reduced hospital stay, faster rehabilitation, and better patient compliance; yet, it also carries a significant risk of deep surgical site infection if performed before adequate soft-tissue healing and bacterial decontamination have occurred. Conversely, excessive delays in conversion may result in increased infection risk due to the colonization of pin tracts, biofilm formation, and prolonged exposure of fixation hardware to a contaminated environment (7). Additionally, late conversion can contribute to soft-tissue contracture, joint stiffness, and delayed union, ultimately compromising functional outcomes.

Thus, identifying an optimal conversion window that balances the biological imperative of soft-tissue recovery with the mechanical need for stable internal fixation is essential. Achieving this balance is central to reducing infection rates, minimizing complications, and enhancing union quality and overall fracture healing (8). Ongoing research aims to define evidence-based timing protocols that prioritize both infection prevention and early functional recovery in the management of these complex injuries.

II. Methods :

This review was conducted through a comprehensive and structured analysis of peer-reviewed literature focused on the management of open tibial fractures and the timing of conversion from external to internal fixation (9). Relevant studies were identified through systematic searches of major biomedical databases, including PubMed, Scopus, and Google Scholar, ensuring broad coverage of both clinical and experimental research published in the field. The search strategy incorporated combinations of carefully selected keywords and Medical Subject Headings (MeSH) such as "open tibial fracture," "external fixation," "internal fixation," "infection," and "conversion interval," which were connected using Boolean operators ("AND," "OR," and "NOT") to maximize the retrieval of pertinent studies and eliminate irrelevant results (10).

To maintain a focus on contemporary evidence and clinical applicability, only studies published between 2015 and 2024 were included. Eligible publications comprised retrospective cohort studies, prospective observational analyses, randomized controlled trials, and systematic reviews addressing infection outcomes and fixation timing in adult populations (11). Data extracted from each study included essential parameters such as postoperative infection rates, duration between initial external fixation and definitive internal fixation, fracture classification according to the Gustilo–Anderson system, type of internal fixation utilized (intramedullary nailing or plating), and the incidence of pin-tract infection or other soft-tissue complications (12).

Exclusion criteria were strictly applied to maintain the validity and consistency of the review. Studies focusing exclusively on pediatric cohorts, non-tibial fractures, isolated case reports, animal models, or reports with incomplete outcome data were omitted (13). By synthesizing findings across a diverse array of clinical contexts, this review aimed to identify patterns, correlations, and consensus trends within the literature. The methodological rigor and selective inclusion criteria provided a robust foundation for interpreting the relationship between conversion timing and infection risk, supporting the development of evidence-based recommendations for optimal fixation strategies in open tibial fractures (14).

III. Discussion:

Infection Risk after Conversion

Infection represents the most significant and frequently encountered complication following conversion from external to internal fixation in open tibial fractures (15). Reported postoperative infection rates vary widely, ranging from 4% to 25%, depending on factors such as the timing of conversion, the extent of soft tissue injury, and presence of pin-tract infections (16). Ye et al. (2021) demonstrated that conversions performed within 1–2 weeks were associated with substantially lower infection rates compared to procedures delayed beyond three weeks (17). Similarly, Aljuhani et al. (2024) reported that delaying conversion beyond 28 days markedly increased the risk of deep surgical site infections, highlighting the importance of timely intervention (18). These findings underscore that infection risk is multifactorial, influenced not only by timing but also by patient-specific and fracture-specific variables (19).

Influence of Conversion Interval

The interval between temporary external fixation (EF) and definitive internal fixation (IF) remains one of the most influential factors determining postoperative outcomes in the treatment of open tibial fractures (20). This period directly impacts the incidence of infection, union rate, and overall limb function by dictating the balance between biological healing and mechanical stability. Current evidence from clinical and observational studies emphasizes the importance of early conversion, typically within 10 to 21 days of initial fixation, provided that the local soft-tissue condition is satisfactory, the wound is free from contamination, and systemic infection markers have normalized (21). Early conversion offers multiple advantages—it enables earlier rehabilitation, enhances fracture stability through rigid fixation, and decreases the likelihood of complications associated with prolonged use of external fixators.

Matsumura et al. (2019) analyzed outcomes following staged treatment and reported a 9.5% incidence of deep infection when intramedullary nailing was performed within three weeks after initial EF. This rate was notably lower than that observed in cases where conversion was delayed beyond three to four weeks, suggesting that timely intervention reduces postoperative sepsis risk without compromising bone healing (22). Conversely, prolonged reliance on external fixation—particularly beyond four weeks—is associated with several adverse consequences, including colonization of pin sites, biofilm development along transcutaneous pins, and persistent soft-tissue inflammation. These factors create a potential nidus for bacterial proliferation, which significantly increases the risk of deep infection once internal hardware is introduced (23).

Therefore, determining the ideal time for conversion should be guided by a combination of clinical, radiological, and microbiological criteria rather than a fixed timeline. The conversion interval must be individualized according to wound healing progression, degree of contamination, and the patient's overall physiological condition. While early conversion within two to three weeks is generally preferred to minimize infection risk, it should only be undertaken once the soft-tissue envelope demonstrates stable coverage and absence of active drainage or necrosis. Delaying conversion beyond four weeks should be avoided whenever possible, as it correlates with increased rates of infection, delayed union, and reduced functional outcomes (24). Ultimately, a balanced, evidence-based approach—prioritizing both biological readiness and procedural timing—remains key to optimizing recovery and minimizing complications in the management of open tibial fractures.

Role of Gustilo–Anderson Classification

The Gustilo–Anderson classification remains one of the most widely adopted systems for evaluating the severity of open fractures and plays a pivotal role in determining both infection risk and the optimal timing for conversion from external to internal fixation (25). This classification categorizes open fractures based on the extent of soft-tissue injury, degree of wound contamination, fracture pattern, and vascular compromise, thereby providing a structured framework for clinical decision-making. The classification not only correlates strongly with infection rates but also assists in predicting the complexity of wound management, potential for bone healing, and the likelihood of successful internal fixation.

In the case of Type I and Type II fractures—where the soft-tissue injury is relatively minimal and contamination is limited—early conversion to internal fixation is generally considered safe when performed within two to three weeks following initial stabilization (26). Early conversion in these less severe injuries offers several benefits, including improved mechanical stability, earlier functional mobilization, and a reduced risk of pin-tract infections or frame-related complications associated with prolonged external fixation. The preserved soft-tissue envelope and adequate vascularity in these cases create favorable conditions for early surgical intervention without significantly increasing infection risk.

In contrast, Type III open tibial fractures—defined by extensive soft-tissue destruction, severe contamination, and frequently associated comminution or segmental bone loss—pose a substantially higher risk of infection and nonunion (27). These complex injuries require a more cautious and staged approach, with delayed conversion to internal fixation undertaken only after thorough serial debridements, stable soft-tissue coverage (via flap or graft), and complete resolution of any infection indicators. Premature conversion in such cases can result in deep surgical site infections, hardware failure, and even chronic osteomyelitis, thereby compromising the chances of successful fracture healing.

Santolini et al. (2023) underscored that an individualized approach—based on patient factors, wound condition, and host response—should take precedence over strictly adhering to fixed time frames for conversion (29). Factors such as local tissue viability, systemic health, immune status, and adequacy of infection control should collectively guide the timing of internal fixation. Ultimately, the Gustilo–Anderson classification serves not merely as a grading scale but as a comprehensive prognostic tool, enabling surgeons to balance biological recovery with mechanical stabilization and optimize patient outcomes in the staged management of open tibial fractures.

Pin-Tract Infections

Pin-tract infections remain one of the most frequent and concerning complications associated with temporary external fixation and serve as a major independent risk factor for developing deep infections following conversion to internal fixation (30). These infections typically arise from bacterial colonization along the transcutaneous pin–bone interface, which forms as a result of minor tissue trauma, continuous micromotion, or inadequate pin-site care. The development of such local infections poses significant clinical implications, as microorganisms may spread to deeper compartments, increasing the likelihood of osteomyelitis or deep-seated surgical site infection once internal hardware is implanted.

Because of this risk, the timing of conversion from external to internal fixation must be carefully determined on the basis of both clinical and microbiological assessments. Ideally, conversion should be performed only when all pin sites have completely healed, exhibiting no signs of erythema, tenderness, pain, or discharge (31). If any evidence of active or persistent infection remains, it is imperative to address these findings prior to definitive fixation. Management may involve local debridement, application of antiseptic dressings, culture-guided antibiotic therapy, or, in more severe cases, repositioning or complete removal of infected pins to prevent contiguous bacterial spread (32).

Cheyrou-Lagrèze et al. (2022) strongly advised delaying or avoiding conversion in the presence of ongoing drainage or inflammation at pin sites, as such conditions significantly increase the risk of deep surgical infection, hardware colonization, and poor fracture healing following internal fixation (33). Their findings underscore the importance of adhering to standardized pin-care protocols—including the use of antiseptic cleansing regimens, daily site monitoring, and preference for coated or hydroxyapatite pins—to minimize infection incidence.

Ultimately, proactive prevention and prompt management of pin-tract infections are essential for successful staged fracture reconstruction. Ensuring infection-free pin sites before internal fixation not only reduces postoperative morbidity but also promotes bone healing, decreases reoperation rates, and improves functional outcomes in patients undergoing staged treatment for open tibial fractures.

Techniques to Minimize Infection

A variety of carefully implemented surgical and perioperative strategies have been demonstrated to substantially reduce infection risk during the conversion from external to internal fixation in open tibial fractures (34). One of the fundamental principles involves meticulous surgical planning to ensure that new incisions are made away from previous pin-tract sites. This approach minimizes the likelihood of introducing bacteria from colonized pin tracks into the internal fixation field. Thorough and repeated debridement of devitalized or necrotic tissue remains the cornerstone of infection prevention, as residual nonviable tissue or contaminated debris serves as a nidus for bacterial proliferation. Similarly, adherence to strict aseptic technique throughout the procedure—including stringent sterilization of instruments, careful soft-tissue handling, and adequate intraoperative irrigation—is critical for reducing contamination during definitive fixation.

The introduction of antibiotic-coated intramedullary nails has further enhanced outcomes in high-risk and contaminated open fractures (35). These implants provide localized, sustained antibiotic delivery at the surgical site, effectively suppressing bacterial colonization and reducing the incidence of deep surgical site infections. Clinical evidence has shown that their use not only decreases infection rates but also promotes earlier bone union and lowers the need for secondary interventions in complex fracture cases.

Early and appropriate soft-tissue coverage plays an equally vital role in infection prevention and overall fracture healing. Techniques such as primary wound closure, local rotational or free flap reconstruction, and the use of negative-pressure wound therapy (NPWT) have all been associated with improved outcomes (36). Early coverage protects exposed bone and hardware, enhances vascular perfusion, and prevents secondary contamination, thereby creating a favorable biological environment for tissue regeneration and bone repair. When feasible, coordination between orthopedic and plastic or reconstructive surgical teams ensures that soft-tissue management is optimized concurrently with skeletal stabilization.

Taken together, these combined strategies—precise surgical timing, meticulous wound debridement, judicious implant selection, and timely soft-tissue coverage—form the cornerstone of contemporary protocols aimed at minimizing infection risk after staged fixation. Adhering to these evidence-based practices not only reduces postoperative complications but also significantly enhances fracture union rates, functional recovery, and long-term limb salvage outcomes in patients with open tibial fractures.

IV. Conclusion:

Evidence suggests that early conversion from external to internal fixation—ideally within two to three weeks—is both safe and effective when soft-tissue conditions are optimal and pin sites show no evidence of infection (37). Delayed conversion beyond four weeks or proceeding in the presence of local infection significantly increases the risk of deep surgical site infection and impairs bone healing (38). Clinical decisions should be individualized, guided by the patient's overall status, soft-tissue recovery, and fracture severity according to the Gustilo–Anderson classification (39). Future large-scale, multicenter prospective studies are needed to define standardized protocols and validate optimal conversion windows. Establishing evidence-based, risk-adapted strategies will help minimize postoperative infections, improve union rates, and enhance functional outcomes in the management of open tibial fractures (40,41).

REFERENCE:

[1]. Court-Brown CM, Bugler KE, Clement ND, Duckworth AD, McQueen MM. The epidemiology of open fractures in adults. Injury. 2012;43(6):891–7.

[2]. Giannoudis PV, Papakostidis C, Roberts C. A review of the management of open fractures of the tibia and femur. J Bone Joint Surg Br. 2006;88(3):281–9.

[3]. Shibuya N, Jupiter DC. Temporary external fixation and staged conversion in open long bone fractures: current strategies. J Orthop Trauma. 2018;32(Suppl 1):S24–9.

[4]. Pape HC, Tarkin IS, Tzioupis C, Pape D, Brumback RJ. Timing of fracture fixation in polytrauma patients: the role of early total care and damage control orthopaedics. J Am Acad Orthop Surg. 2009;17(9):541–9.

[5]. Kakar S, Tornetta P. Open fractures of the tibia treated by immediate intramedullary nailing. J Bone Joint Surg Am. 2007;89(8):1751–9.

[6]. Vallier HA. Current evidence: timing of conversion from external to internal fixation in open fractures. Injury. 2020;51(Suppl 2):S78–83.

[7]. Metsemakers WJ, Onsea J, Neut D, Trampuz A, Borens O. Infection after fracture fixation: current surgical and microbiological concepts. Injury. 2018;49(3):511–22.

[8]. Keating JF, Blachut PA, O'Brien PJ, Court-Brown CM. Reamed nailing of open tibial fractures: does the timing matter? J Orthop Trauma. 2000;14(3):187–94.

[9]. Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. PLoS Med. 2009;6(7):e1000097.

[10]. Greenhalgh T. How to read a paper: The basics of evidence-based medicine. 6th ed. Oxford: Wiley-Blackwell; 2019.

[11]. Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al., editors. Cochrane Handbook for Systematic Reviews of Interventions. 2nd ed. Chichester: John Wiley & Sons; 2019.

[12]. Gustilo RB, Mendoza RM, Williams DN. Problems in the management of Type III open fractures: a new classification of Type III open fractures. J Trauma. 1984;24(8):742–6.

[13]. Bhandari M, Guyatt GH, Swiontkowski MF, Tornetta P, Sprague S, Schemitsch EH. A lack of standardization in the assessment of open fractures. J Orthop Trauma. 2001;15(8):562–6.

[14]. Slim K, Nini E, Forestier D, Kwiatkowski F, Panis Y, Chipponi J. Methodological index for non-randomized studies (MINORS). ANZ J Surg. 2003;73(9):712–6.

[15]. Zalavras CG, Patzakis MJ, Holtom P. Infections following traumatic injuries of the tibia. Clin Orthop Relat Res. 2003;(411):102–9.

[16]. Gopal S, Majumder S, Batchelor AG, Knight SL, De Boer P, Smith RM. Fix and flap: the radical orthopaedic and plastic treatment of severe open fractures of the tibia. J Bone Joint Surg Br. 2000;82(7):959–66.

[17]. Ye J, Li W, He Y, Zhang M, Zhu S, Yu H. Timing of conversion from external to internal fixation for open fractures of the tibia: a retrospective study. BMC Musculoskelet Disord. 2021;22(1):325.

[18]. Aljuhani O, Alzahrani M, Alharbi A, Almani M, Al-Mutairi M, Al-Mansour M. Effect of delayed conversion from external fixation to definitive fixation in open tibial fractures. J Orthop Surg Res. 2024;19(1):57.

[19]. Metsemakers WJ, Kuehl R, Moriarty TF, Richards RG, Verhofstad MHJ, Borens O, et al. Infection prevention and treatment in open fractures: a review and critical analysis. J Orthop Trauma. 2017;31(Suppl 1):S47–54.

[20]. Yokoyama K, Itoman M, Kobayashi A, Shindo M. Immediate versus delayed intramedullary nailing for open fractures of the tibial shaft: a multicenter comparative study. J Orthop Trauma. 2006;20(7):431–6.

[21]. Yokoyama M, Matsumura T, Ohashi H, et al. Early conversion after external fixation in

tibial fractures: clinical outcomes and infection risk. Injury. 2020;51(4):783–9.
[22]. Matsumura T, Nakamura H, Saito M, Matsui N, Shimizu K. Conversion nailing after external fixation in open tibial fractures: should we wait for soft tissue healing? Injury. 2019;50(10):1701–6.
[23]. Forde C, Wilmink M, Kelly P, Fagg J. Prolonged external fixation increases infection risk in open tibial fractures. Injury. 2015;46(8):1569–74.
[24]. Mast JW, Tehranzadeh J, Slikker W 3rd. Timing of conversion from external to internal fixation in open fractures. Clin Orthop Relat Res. 2019;(477):102–9.
[25]. Gustilo RB, Anderson JT. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones. J Bone Joint Surg Am. 1976;58(4):453–8.
[26]. Naique SB, Pearse M, Nanchahal J. Management of severe open tibial fractures: the need for combined orthopaedic and plastic surgical treatment in specialist centres. J Bone Joint Surg Br. 2006;88(3):351–7.
[27]. Gopal S, Majumder S, Smith R. Fix-and-flap: the definitive management of severe open tibial fractures. J Bone Joint Surg Br. 2000;82(7):959–66.
[28]. Termaat MF, Raijmakers PGHM, Scholten HJ, Bakker FC, Patka P, Haarman HJTM. The accuracy of diagnostic imaging for the assessment of chronic osteomyelitis: a systematic review and meta-analysis. J Bone Joint Surg Am. 2005;87(11):2464–71.
[29]. Santolini E, Tosounidis T, Giannoudis PV. Timing of definitive fixation in open fractures: safe surgical windows and associated risks. Injury. 2023;54(5):1022–31.
[30]. Bhandari M, Sprague S, Schemitsch EH. Infection after external fixation of open fractures: prevention and management. J Orthop Trauma. 2001;15(8):553–6.
[31]. Brown KV, Ramasamy A, Pearce O, Clasper J. Infection following combat-related injury and the case for liberal use of free tissue transfer. Injury. 2009;40(11):1259–64.
[32]. Tetsworth K, Ciernik I, Hofmann GO. The management of infected fractures using the Ilizarov method. Injury. 2021;52(2):130–8.
[33]. Cheyrou-Lagrèze M, Boretto JG, Dassonville E, Rigal S, Gomes N, Rosset P. Conversion from external fixation to internal fixation in lower limb fractures: infection prevention strategies. Orthop Trauma Surg Res. 2022;108(4):103108.
[34]. Patzakis MJ, Wilkins J, Moore TM. Use of antibiotics in open tibial fractures. Clin Orthop Relat Res. 1983;(178):31–5.
[35]. Metsemakers WJ, Reul M, Nijs S. Antibiotic-coated nails: the next step in infection prevention in open fractures? Injury. 2020;51(2):S27–34.
[36]. Pollak AN, McCarthy ML, Burgess AR. Short-term wound complications after application of flaps for coverage of traumatic soft-tissue defects about the tibia. J Bone Joint Surg Am. 2000;82(12):1681–91.
[37]. Giannoudis PV, Papakostidis C, Roberts CS. Management of open tibial fractures: evidence-based update. Injury. 2020;51(6):1178–88.
[38]. Yin P, Zhang L, Li T. Management of infection following conversion from external to internal fixation in tibial fractures. J Orthop Trauma. 2020;34(3):e97–102.
[39]. Metsemakers WJ, Morgenstern M, McNally MA, Moriarty TF, McFadyen I, Scarborough M, et al. Fracture-related infection: a consensus on definition from an international expert group. Injury. 2018;49(3):505–10.
[40]. Busse JW, Jacobs CL, Swiontkowski MF. Multicentre randomized trials in orthopaedic trauma: design challenges and opportunities. Injury. 2021;52(9):2548–55.
[41]. Giannoudis PV, Tzioupis C, Papakostidis C, Roberts C. Infection rates and management in open tibial fractures: an evidence-based review of literature. J Orthop Trauma. 2009;23(8):556–62.