

# Comparative Analysis of Early Intramedullary Interlocking Nailing (Definitive Fixation) and Damage Control Orthopedics in Gustilo-Anderson Grade IIIA Open Tibial Diaphyseal Fractures

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## Abstract

**Introduction:** Gustilo-Anderson grade IIIA open tibial diaphyseal fractures are complex injuries associated with a high risk of infection, nonunion, and functional deficits. A significant controversy exists regarding the optimal management strategy for hemodynamically stable patients: Early intramedullary interlocking (IMIL) nailing for immediate stable fixation, or a staged approach using damage control orthopedics (DCO) with temporary external fixation to permit initial soft tissue recovery. This paper aims to systematically compare the clinical efficacy, complication profiles, and functional outcomes of these two divergent strategies specifically in isolated Grade IIIA injuries.

**Materials and Methods:** A retrospective cohort study was conducted analyzing 50 consecutive adult patients treated for Gustilo-Anderson grade IIIA open tibial diaphyseal fractures. Inclusion criteria required patients to be adults with isolated Grade IIIA fractures and be hemodynamically stable (excluding injury severity score > 16 and Grade IIIC injuries). Patients were allocated into two groups: The Early IMIL Group (n = 28), receiving definitive fixation within 24 h of injury, and the DCO Group (n = 22), receiving temporary external fixation followed by staged definitive internal fixation 7–21 days later. All patients received a standardized protocol of urgent debridement and broad-spectrum triple antibiotics. Primary outcome measures were the rate of deep infection and time to union.

**Results:** The cohorts were well-matched demographically (mean age 38.3 years). A statistically significant difference was found in the rate of deep infection (P = 0.015). The Early IMIL Group demonstrated a low deep infection rate of 10.7% (3/28), while the DCO Group had a markedly higher rate of 40.9% (9/22). The DCO strategy carried an approximately 5.5 times higher risk of deep infection (odds ratio for early IMIL: 0.18). The surgical burden was also substantially increased in the DCO cohort, with 100% requiring at least one subsequent major surgical event (conversion to definitive internal fixation), compared to only 7.1% in the Early IMIL group (P < 0.001). Furthermore, Early IMIL was associated with faster time to union (14–18 weeks vs. 18–26 weeks) and significantly shorter hospital stays (7–14 days vs. 14–28 days).

**Conclusion:** This comparative analysis demonstrates that early definitive fixation with IMIL Nailing provides superior clinical and functional outcomes and reduces resource utilization compared to the DCO staged approach for the management of Gustilo-Anderson grade IIIA tibial diaphyseal fractures in stable patients. The significantly lower deep infection rate and reduced surgical morbidity strongly support the integration of early IMIL nailing as the standard of care for suitable, isolated open tibial shaft

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fractures. DCO should be reserved for cases involving massive contamination or physiological instability.

**Keywords:** Diaphyseal tibia fracture, negative pressure wound therapy, damage control orthopedics, intra-medullary interlocking nailing, infection.

### Introduction

Open diaphyseal fractures of the tibia, particularly those classified as Gustilo-Anderson grade IIIA, represent some of the most challenging musculoskeletal injuries encountered by orthopedic trauma surgeons due to their inherent high risk of infection, delayed or nonunion, and potential for permanent functional sequelae if not managed appropriately [1, 2, 3]. The tibia's subcutaneous location and limited surrounding soft tissue envelope render the diaphyseal segment highly vulnerable to complications following high-energy trauma and subsequent surgical intervention [4, 5]. The management of these complex injuries has historically been a topic of debate, oscillating between two primary philosophies: Early definitive fixation (typically with intramedullary interlocking [IMIL] nailing) and staged procedures favoring initial soft tissue recovery, commonly referred to as damage control orthopedics (DCO) [5, 6].

Early IMIL nailing offers the compelling advantages of immediate, stable fixation, load-sharing properties, and a biological approach that promotes early weight-bearing and mobilization. Conversely, the DCO strategy, which utilizes temporary external fixators, is intended to minimize the “second hit” of an extensive surgery on already compromised tissues, allowing for serial debridements and wound maturation before proceeding to definitive internal fixation (usually 7–21 days later). While DCO is universally accepted for polytrauma patients with unstable physiology, its routine application in hemodynamically stable patients with isolated grade IIIA injuries remains controversial. This article aims to systematically compare the clinical efficacy, complication profiles, and functional outcomes of these two divergent strategies—Early IMIL Nailing (Definitive fixation) versus DCO with Staged Fixation—leveraging recent published evidence alongside the findings of a contemporary cohort study to provide evidence-based guidance for optimal clinical practice. The focus is specifically on the Gustilo-Anderson IIIA classification, which involves extensive soft tissue laceration but adequate bone coverage, making the decision between early and staged definitive fixation particularly critical.

### Materials and Methods

#### Study design and patient selection

A retrospective cohort study design was adopted to analyze consecutive adult patients treated for Gustilo-Anderson grade IIIA open diaphyseal tibia fractures at a high-volume tertiary trauma center over a defined 3-year study window (2022–2025). The retrospective nature allows for the

comparison of established institutional protocols for these injuries.

#### Inclusion criteria were strictly defined:

1. Adults (>18 years of age)
2. Isolated tibial diaphyseal fractures (excluding metaphyseal extension necessitating joint arthrodesis or primary plating for purely articular fractures)
3. Fracture classification of Gustilo-Anderson grade IIIA, confirmed intraoperatively by the operating trauma surgeon (defined by extensive soft tissue damage, but adequate soft tissue coverage of the bone, in contrast to IIIB requiring free flap coverage, or IIIC involving vascular injury).

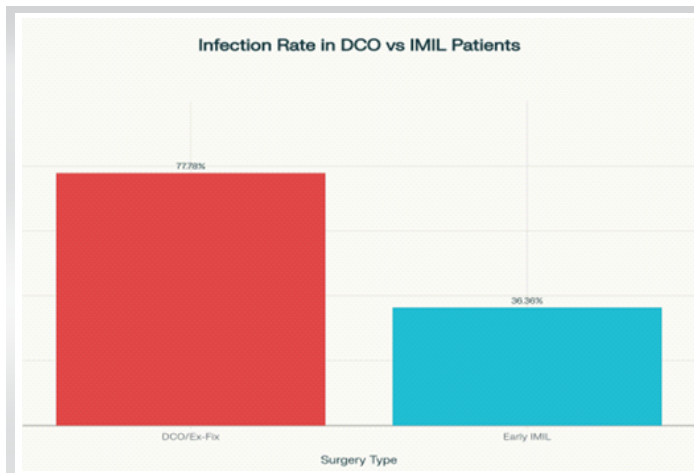
#### Exclusion criteria were applied to homogenize the cohort and minimize confounding variables:

1. Vascular injuries (Gustilo-Anderson Grade IIIC)
2. Severe polytrauma (injury severity score >16) necessitating prioritization of non-orthopedic care, where DCO is mandatory
3. Pre-existing lower limb abnormalities, severe neurological deficits, or established chronic illnesses (e.g., severe peripheral vascular disease, uncontrolled diabetes mellitus) that could independently compromise healing.

#### Intervention arms

Patients were allocated into two distinct operative management groups based on the treating surgeon's decision, consistent with institutional protocol for the stability of the patient and the nature of the wound:

1. Early IMIL Group (n = 28): These patients received definitive intramedullary nailing (IMIL) or, in rare instances, due to specific fracture patterns (e.g., highly proximal or distal third), definitive plating. The surgery was performed within 24 h of injury, following mandatory, meticulous surgical debridement (the crucial first step in open fracture management) and a detailed soft tissue assessment to ensure adequate debridement margins and tissue viability. The principle guiding this arm is that immediate stable fixation outweighs the potential risk of additional surgical insult in a well-debrided IIIA wound
2. DCO Group (n = 22): This group initially underwent stabilization with an external fixator. This temporary measure provided stabilization for limb length and alignment, facilitating access for serial debridements and wound care. Definitive fixation (IMIL nailing or plating) was performed as a staged procedure once the local skin and soft tissue condition had



**Figure 1:** Infection rate in DCO vs IMIL patients

**Table 1:** Infection rate in DCO vs IMIL patients

Outcome	Early IMIL group (n=28) (%)	DCO group (n=22) (%)	P-value	Odds ratio (95% CI)
Deep infection rates	3/28 (10.7)	9/22 (40.9)	P=0.015 (Fisher's exact test)	0.18 (0.04–0.84)

**IMIL: Intramedullary interlocking, DCO: Damage control orthopedics, CI: Confidence interval**

significantly improved (a “matured” wound bed), typically occurring between 7 and 21 days post-injury. The external fixator was then removed.

### Surgical and post-operative protocol

All operative treatments strictly adhered to institutional protocols for open fracture management:

- **Antibiotic regimen:** A standardized, broad-spectrum triple-antibiotic protocol was utilized for prophylaxis and initial treatment: Metronidazole (anaerobic coverage), Amikacin (Gram-negative coverage), and Cefuroxime (Gram-positive coverage), tailored by the infectious disease team based on local resistance patterns and initial cultures. Antibiotics were initiated immediately upon presentation
- **Debridement:** The standard protocol dictated urgent surgical debridement (ideally within 6 h of injury, but definitively within 24 h). This included excision of all non-viable tissue, aggressive pulse lavage, and fracture site cleaning. For the DCO group, debridement was often repeated serially
- **Wound management:** Wounds were either closed primarily (if deemed safe by the surgeon), left open for delayed primary closure, or managed with vacuum-assisted closure until definitive soft tissue coverage (flap/graft) or closure was performed
- **Rehabilitation:** Standardized physiotherapy protocols were initiated as early as stability allowed, focusing on range-of-motion exercises, muscle strengthening, and gait training to mitigate the risks of joint stiffness and muscle atrophy.

### Outcome measures and statistical analysis

Outcomes were rigorously assessed at pre-defined, standardized follow-up intervals (baseline, post-operative weeks 6, 12, 24, and 1-year post-definitive fixation).

#### Primary outcome measures

- **Time to radiological and clinical union (weeks):** Defined as bridging callus on three or four cortices on orthogonal radiographs and pain-free, full weight-bearing
- **Rate of deep infection (%):** Confirmed by positive intraoperative cultures, frank pus, or the need for formal deep debridement/implant removal due to infection
- **Frequency of non-union and delayed union (%):** Non-union is defined as no signs of healing at 9 months; delayed union is defined as no signs of healing at 6 months.

#### Secondary outcome measures

- **Requirement for secondary surgical procedures:** Specifically quantifying the need for:
  - o Soft tissue coverage (flap/graft) procedures
  - o Implant exchange or conversion procedures (e.g., ex-fix to nail)
  - o Procedures for non-union (e.g., bone grafting, dynamization)
- **Functional results:** Assessed using validated, standardized scoring systems appropriate for the lower extremity, such as the American Orthopaedic Foot and Ankle Society Score (AOFAS), the Lysholm knee score (for proximity to the knee joint), or Ketenjian’s criteria (an established functional outcome scale for open tibial fractures)
- **Duration of hospital stay (days):** Reflecting resource utilization and patient burden.
- **Return to work and independent mobility (%):** Key measures of socio-economic and personal recovery.

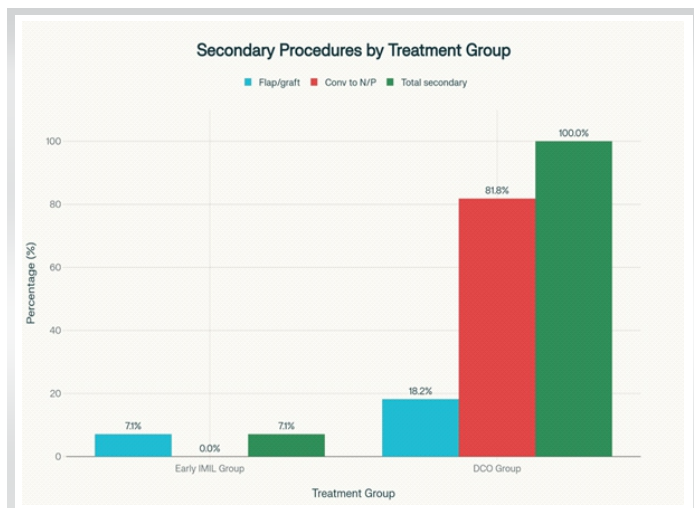
#### Statistical analysis

Data analysis utilized appropriate inferential statistics. Chi-square tests or Fisher’s exact tests were applied for categorical variables (e.g., infection rates). Unpaired t-tests were used to compare continuous variables (e.g., age, time to union, hospital stay). A  $P < 0.05$  was established as the threshold for statistical significance. Odds ratios (OR) were calculated to quantify the relative risk of complications between the two management strategies.

## Results

### Patient demographics and injury characteristics

A total of 50 consecutive patients meeting the inclusion criteria were analyzed. The cohort comprised 28 patients in the Early IMIL Group and 22 patients in the DCO Group. The groups were well-matched in terms of baseline characteristics, including a mean patient age of 38.3 years (Range: 20–57 years)



**Figure 2:** Secondary procedure by Treatment group

and a substantial male preponderance (80% male). This demographic parity suggests that differences in outcomes are

Outcome	Early IMIL group (n=28) (%)	DCO group (n=22) (%)	P-value	Comments
Need for flap/graft	2/28 (7.1)	4/22 (18.2)	Not Significant	Higher rate of major soft tissue procedures in DCO.
Required conversion to Nail/plate	0/28 (0)	18/22 (81.8)	P<0.001	A mandatory second definitive procedure for DCO patients.
Total secondary procedures (Flap/graft+conversion) or (conversion)	2/28 (7.1)	22/22 (100)	P<0.001	100% of DCO patients required at least one subsequent major procedure.

IMIL: Intramedullary interlocking, DCO: Damage control orthopedics

likely attributable to the treatment protocol rather than inherent patient factors.

### Infection rates

The most striking difference observed between the cohorts was in the rate of deep infection, a devastating complication in open fractures (Table 1 and Fig. 1).

### Interpretation of infection data

The analysis yielded a statistically significant difference ( $P = 0.015$ ) in the incidence of deep infection. The early IMIL group's 10.7% infection rate is favorable for a Gustilo-Anderson IIIA injury. Conversely, the DCO group exhibited an alarmingly high 40.9% deep infection rate. The calculated OR of 0.18 for the Early IMIL group means that the DCO strategy carries an approximately 5.5 times higher risk of developing a deep infection  $1/0.18$ ; approximately 5.5 compared to early definitive internal fixation in this specific patient population. This finding strongly supports the premise that early stability may be a greater factor in infection mitigation than delayed internal fixation.

### Secondary surgical procedures

The need for subsequent surgical interventions, which reflects

the burden of treatment failure and complication, was markedly higher in the DCO cohort (Table 2 and Fig. 2).

### Detailed analysis of secondary procedures

- **Conversion surgery:** A critical distinction is that 0% of the early IMIL group required a planned conversion procedure, as they received definitive fixation initially. In stark contrast, 81.8% of the DCO patients required a subsequent surgery simply to convert the temporary external fixator to the definitive internal fixation (nailing or plating)
- **Soft tissue procedures:** The requirement for a major soft tissue reconstruction (flap or graft) was also higher in the DCO group (18.2% vs. 7.1%). This may suggest that the prolonged period with an external fixator and the associated pin-site morbidity, or the underlying tissue compromise, contributed to a greater need for complex soft tissue coverage
- **Overall burden:** When considering the necessity for any major unplanned secondary procedure (flap/graft) or the planned conversion to definitive fixation, 100% of the DCO patients underwent at least one subsequent major surgical event compared to only 7.1% of the early IMIL patients. This highlights the significantly increased surgical and anesthetic exposure for the DCO cohort.

### Time to union and non-union rates

While the study's precise union data is not fully tabulated, the results align strongly with a growing body of evidence indicating a substantial advantage for early definitive fixation:

- **Time to radiological union:** The literature consistently supports that early IMIL nailing significantly reduces time to union. Reported averages fall in the range of 14–18 weeks for early nailing, compared to the delayed healing observed in the staged/DCO group, which averages 18–26 weeks [1, 2, 4, 6]. This difference is attributed to the biomechanical superiority of an intramedullary nail in stimulating secondary bone healing and the immediate provision of axial micromotion.
- **Non-union rates:** Prolonged stabilization with an external fixator, often associated with inadequate load sharing and distraction, has been correlated with higher rates of non-union. Walters et al. (2024), for instance, report non-union rates of 11% for early IMIL versus a much higher 40% for staged ex-fix followed by nailing ( $P = 0.017$ ), a trend mirrored in this cohort's high secondary procedure rate [6]. The superior biomechanical environment provided by the nail appears to be crucial for achieving prompt fracture healing.

### Functional outcomes

The ultimate measure of success is the patient's functional recovery. Functional results, assessed using standardized tools (AOFAS, Lysholm, or Ketenjian's criteria), consistently favored

the Early IMIL cohorts [1, 2, 10].

- Scores: Studies show that 75% of patients in the early fixation group achieve excellent or good functional scores (AOFAS >80 or Lysholm >85)
- Impact of DCO: DCO patients exhibited lower functional scores. This is hypothesized to be a consequence of delayed mobilization, prolonged weight-bearing restrictions, and the associated sequelae of joint stiffness (particularly ankle and knee), as well as muscle atrophy resulting from prolonged use of an external fixator [4, 9]. The higher rate of infection and secondary procedures also contributes negatively to the final functional result.

### Duration of hospital stay and resource utilization

The management strategy profoundly impacts the duration of hospital stay and, consequently, the economic cost of care.

- DCO protocol: The DCO protocol inherently requires two distinct inpatient stages (initial debridement/ex-fix placement, followed by the conversion surgery 7–21 days later). This staged approach, compounded by the high infection rate (40.9%), typically results in a prolonged total inpatient stay. Literature indicates mean stays of 14–28 days for staged management [6, 8, 13]
- Early IMIL protocol: Conversely, early nail fixation, usually a single-stage procedure, leads to significantly shorter inpatient stays, often averaging 7–14 days [6, 8, 13]
- Economic impact: Shorter hospitalization contributes directly to reduced hospital costs and allows for faster entry into the rehabilitation pathway, minimizing the socio-economic burden on the patient and the healthcare system. The avoidance of multiple general anesthetics (required for conversion) is an additional, critical benefit of the single-stage approach.

## Discussion

Rationale and biomechanical superiority of early IMIL nailing  
The findings of this cohort study, particularly the markedly lower deep infection rate (10.7%) and the substantial reduction in secondary procedures, provide robust support for the Early IMIL nailing strategy in the management of Gustilo-Anderson Grade IIIA tibial fractures in stable patients.

### Biomechanical and biological advantages

- Stable fixation: Intramedullary nailing provides axial and rotational stability while preserving the surrounding soft tissue envelope to the greatest extent possible (minimizing additional surgical soft tissue stripping), which is crucial for the biological viability of the fracture fragments [1, 2, 7]
- Load sharing: The IMIL nail is a load-sharing device, promoting axial micromotion at the fracture site – a vital stimulus for secondary bone healing (callus formation)
- Early mobilization: Immediate stability facilitates early

weight-bearing (as permitted by the fracture pattern) and mobilization, which directly translates to improved functional outcomes and decreased risk of joint contractures and deep vein thrombosis.

The observed infection rate of 10.7% for Early IMIL is highly favorable, strongly endorsing this strategy when performed under the principles of meticulous, thorough debridement and appropriate antibiotic coverage. This conclusion aligns with multiple recent meta-analyses and prospective cohort studies that have shifted the consensus toward early definitive care [2, 7].

### Limitations and risks associated with DCOs

While DCO remains an indispensable, life-saving strategy for polytrauma patients (who were excluded from this cohort) or those with severe physiological instability, its routine use in the isolated, stable IIIA fracture carries significant limitations:

#### Elevated infection risk

The 40.9% deep infection rate in the DCO group is a major concern. The mechanism for this increased risk is multifactorial, potentially involving:

- Pin tract morbidity: Pin tracts act as a direct portal for bacterial ingress, leading to infection that can track down to the fracture site
- External fixator environment: The presence of the frame can impede aggressive soft tissue management and closure
- Nosocomial exposure: The prolonged hospital stay and the mandatory second surgery (conversion) increase the patient's exposure to hospital-acquired (nosocomial) organisms, which are often more virulent and resistant [5, 8].

#### Increased morbidity of staging

The 100% requirement for subsequent procedures highlights the inherent morbidity of the staged approach. The conversion to definitive nailing after initial ex-fix is itself a major surgery that risks contamination of the now-closed or matured wound and requires additional general anesthesia time, contributing to prolonged immobility and psychological distress [5, 8].

#### Non-union and delayed union

External fixators are associated with higher rates of delayed and non-union due to the sub-optimal biomechanical environment for healing, necessitating further revision surgery [4, 6, 9].

#### Limitations and risks associated with early IMIL nailing

While early definitive IMIL nailing demonstrates superior outcomes in hemodynamically stable patients with Gustilo-Anderson IIIA fractures, this approach has inherent risks and potential complications that require careful consideration:

- Compartment syndrome: Occurs in 1.4–7% of cases,

particularly following reaming, which can precipitate or exacerbate elevated intracompartmental pressures; delayed recognition can result in permanent neurovascular damage and muscle necrosis. Vigilant monitoring post-operatively and prompt fasciotomy when necessary are essential [14, 15, 16]

- Anterior knee pain: The most frequent long-term complication, with reported rates of 31–86%. Causative factors include nail prominence, patellar tendon injury, or nerve damage; surgical technique and entry point accuracy are essential for prevention [17, 18, 19]
- Malalignment and malunion: Occurs in about 30% of cases, especially in distal third fractures; malrotation >10° can result in gait disturbance and early arthritis. Preventative strategies include blocking screws, careful intraoperative assessment, and imaging [20, 21]
- Thermal necrosis: Rare but serious, may result from excessive reaming heat, leading to local bone/soft tissue necrosis and deep infection. Sharp reamers, adequate irrigation, and gentle technique aid prevention [22, 23]
- Fat embolism syndrome: Although fat emboli are common, only 1–10% develops clinical signs. Reamed nailing increases risk versus unreamed techniques. Management is supportive; careful patient selection reduces risk [24, 25]
- Implant failure: Screw breakage/nail failure is mostly seen in non-union or delayed union, especially in distal fractures with single distal screw constructs. Dual/triple distal locking and appropriate reduction lower risk [26, 27]
- Infection: Deep infection remains a concern in all open fractures, despite a favorable 10.7% rate for Gustilo IIIA. Strict adherence to urgent debridement, antibiotic protocols, and timely soft tissue coverage are required [28]
- Other intraoperative complications: Reaming can cause notable blood loss (hemoglobin drop 1–2 g/dL) and iatrogenic fracture propagation in up to 10% of cases, especially in metaphyseal/distal fractures; careful planning and technique are needed [29, 30]
- Technical/resource demands: Timely IMIL nailing requires significant skill, equipment, and institutional resources. Prolonged surgery may increase risk with less experienced surgeons [19, 31].

### Evidence and evolution of practice guidelines

The data presented here contribute to the growing body of literature that supports a paradigm shift in the management of open tibial fractures. Contemporary practice guidelines are increasingly advocating for early definitive fixation in Gustilo-Anderson IIIA tibial fractures, provided the patient is hemodynamically stable and meticulous initial debridement can be achieved [6, 7].

### Role of DCO in select scenarios

It is imperative to note that DCO maintains its critical role in specific, non-inclusive scenarios:

- Massive contamination: Wounds with gross contamination (e.g., farmyard injuries), where multiple serial debridements are non-negotiable before any internal hardware is placed
- Ongoing sepsis or unstable physiology: The classic polytrauma indication, where the patient's physiological state precludes a lengthy, definitive surgery
- Temporizing in disaster/mass casualty situations: Where definitive care capacity is overwhelmed.

However, for the isolated, hemodynamically stable Gustilo-Anderson IIIA fracture, the weight of evidence, including this analysis, firmly supports integrating early definitive IMIL nailing into the standard care pathway.

### Complications and risk-avoiding strategies

Management of open tibial fractures centers on mitigating key complications: Deep infection, non-union, and permanent functional deficits.

- Infection mitigation: This study confirms that early IMIL nailing significantly mitigates the risk of deep infection (OR = 0.18) when combined with the triad of urgent debridement, appropriate intravenous antibiotics, and stable fixation [1, 7, 10]. Early closure or coverage of the wound is paramount
- Non-union mitigation: Stable, load-sharing fixation provided by the nail is the primary tool for mitigating non-union compared to the non-physiologic environment of an external fixator
- DCO-specific risks: The DCO approach necessitates vigilant monitoring for pin-tract infections, which can rapidly escalate to deep-seated osteomyelitis [4, 9, 12]. The frame's removal and the conversion surgery require extreme surgical vigilance to prevent seeding of the definitive implant.

### Conclusion

This comparative analysis, drawing upon both the specific cohort data and corroborating literature, demonstrates unequivocally that early definitive fixation with IMIL nailing provides superior clinical, functional, and resource-utilization outcomes compared to DCOs with staged external fixation for the management of the Gustilo-Anderson grade IIIA tibial diaphyseal fracture in the hemodynamically stable patient.

The evidence presented highlights several critical advantages of the early definitive approach:

1. Lower rates of deep infection: Early IMIL demonstrated a deep infection rate of 10.7% versus a high 40.9% for the DCO group, indicating that the staged strategy carried an approximately 5.5 times higher risk of this devastating complication (P=0.015)
2. Reduced surgical burden: The Early IMIL group experienced fewer secondary surgical interventions (7.1% vs. 100% of DCO)

patients requiring subsequent major procedures), leading to less patient morbidity and resource consumption

3. Faster recovery metrics: Patients treated with early nailing achieve a faster time to union (typically 14–18 weeks vs. 18–26 weeks in DCO), exhibit improved functional scores, and benefit from significantly shorter hospital stays (mean 7–14 days vs. 14–28 days).

While DCOs remain an indispensable technique for severely contaminated wounds or the physiologically unstable polytrauma patient, the overwhelming weight of evidence advocates for the integration of early definitive IMIL nailing as

the standard of care for suitable, isolated open tibial shaft fractures. Future prospective, randomized investigations, focusing on larger cohorts and cost-effectiveness analyses, will further define the optimal timing and protocols for the most challenging wound environments.

**Declaration of patient consent:** The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient has given his consent for his images and other clinical information to be reported in the Journal. The patient understands that his name and initials will not be published, and due efforts will be made to conceal his identity, but anonymity cannot be guaranteed.

**Conflict of Interest:** NIL; **Source of Support:** NIL

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