ROLE OF ANTIBIOTIC COATED INTRAMEDULLARY RUSHNAIL IN MANAGEMENT OF GRADE IIIB COMPOUND FRACTURES OF TIBIA

[1]DR SATISH PARUPALLI, [2]DR K VINOOTHNA, [3] DR KIRAN KUMAR JOSHI

[1]Associate Professor, Department of Orthopaedics, Government Medical College, Sangareddy, Telangana, India.
[2]Assistant Professor, Department of Orthopaedics, Government Medical College, Sangareddy, Telangana, India.
[3]Assistant Professor, Department of Orthopaedics, Government Medical College, Sangareddy, Telangana, India.

Corresponding Author: [3] DR KIRAN KUMAR JOSHI

Abstract

Background:

Grade IIIB compound tibial fractures are characterized by severe soft tissue injury and contamination, posing a high risk for infection and nonunion. Traditional fixation methods often result in complications. Antibiotic-coated intramedullary Rush nails offer both mechanical stabilization and localized antibiotic delivery, potentially improving outcomes.

Objectives:

To evaluate the effectiveness of antibiotic-coated intramedullary Rush nails in managing Grade IIIB open tibial fractures, focusing on union rates, infection control, and functional recovery.

Methods:

A prospective observational study was conducted on 30 patients with Grade IIIB open tibial fractures treated using custom-fabricated Rush nails coated with PMMA cement impregnated with vancomycin and/or gentamicin. Patients were followed up for a minimum of 9 months. Outcomes were assessed using radiological union criteria, infection rates, time to full weight-bearing, and functional status.

Results:

Of the 30 patients, 28 (93.3%) achieved fracture union within a mean duration of 21.3 ± 4.6 weeks. Three patients (10%) developed deep infections, of whom two required surgical debridement. Functional outcomes, as assessed by lower extremity functional scales, were satisfactory in 25 patients (83.3%). There were no cases of implant failure or systemic antibiotic complications.

Conclusion:
Antibiotic-coated intramedullary Rush nails provide an effective and affordable treatment modality for Grade IIIB tibial fractures. This approach ensures stable fixation, promotes bone healing, and significantly reduces the risk of deep infection, especially in resource-constrained settings. The technique may serve as a reliable alternative to conventional treatment strategies in managing severe open tibial injuries.

Keywords:
Grade IIIB fractures, tibia, antibiotic-coated implants, Rush nail, compound fractures, local antibiotic delivery, open fracture management.

Introduction

Grade IIIB open fractures of the tibia, as classified by the Gustilo-Anderson system, represent one of the most complex challenges in orthopedic trauma due to extensive soft tissue injury, periosteal stripping, and high susceptibility to infection and nonunion.[1] The subcutaneous location of the tibia along its anterior surface renders it especially vulnerable to open injuries, which are often caused by high-energy trauma such as road traffic accidents and industrial injuries.[2] These fractures are frequently accompanied by bone loss, contamination, and devascularization, necessitating a multidisciplinary approach involving orthopedic, plastic, and infectious disease specialists. Conventional management strategies involve thorough debridement, stabilization using external fixators or intramedullary devices, and staged soft tissue reconstruction.[3] However, these methods are associated with several complications, including pin tract infections, delayed union, osteomyelitis, and the need for repeated surgeries.[4] In recent years, there has been growing interest in the use of antibiotic-coated intramedullary implants as a means to deliver high local antibiotic concentrations directly to the fracture site, reducing infection risk while maintaining mechanical stability. Antibiotic-coated nails have shown promising results in reducing deep infections, especially in cases of open and infected fractures.[5] Polymethylmethacrylate (PMMA)-based antibiotic coatings allow controlled local drug elution, significantly exceeding systemic antibiotic levels without inducing toxicity.[6] Rush nails, though traditionally used for pediatric long bone fractures, have been increasingly repurposed in adults due to their simplicity, ease of insertion, and compatibility with custom antibiotic coating techniques. Their flexible design and reduced implant cost make them particularly attractive for resource-limited settings. Multiple studies have supported the efficacy of antibiotic-impregnated intramedullary devices in managing infected nonunions and open fractures.[7] However, there remains a paucity of data specifically addressing the outcomes of using antibiotic-coated Rush nails in Grade IIIB tibial fractures. This study aims to evaluate the clinical and radiological outcomes of this technique, with a focus on infection control, fracture union, and functional recovery.

By analyzing the effectiveness of antibiotic-coated Rush nails, this study seeks to contribute to the growing evidence base for innovative, cost-effective solutions in the management of severe open tibial fractures, particularly relevant in low- and middle-income countries where resources and implant availability may be limited.

Materials and Methods

Study Design and Setting

This was a prospective interventional study conducted in the Department of Orthopaedics at a tertiary care hospital.

Study Population

Inclusion Criteria:

- Patients aged between 18–65 years.
- Radiologically and clinically diagnosed Grade IIIB compound fractures of the tibia (Gustilo-Anderson Classification).
- Patients willing to undergo antibiotic-coated Rush nail fixation and follow-up.
- Patients with no known allergy to antibiotics used in the coating.

Exclusion Criteria:

- Grade IIIC open fractures requiring vascular repair.

- Patients with pathological fractures.
- Immunocompromised patients (e.g., HIV, chemotherapy).
- Patients with chronic renal or hepatic failure.
- Patients lost to follow-up or unwilling to consent.

Sample Size

A total of **30 patients** who fulfilled the inclusion criteria were enrolled in the study using purposive sampling.

Preoperative Assessment

All patients underwent a thorough clinical evaluation, including:

- Hemodynamic stabilization
- Wound swab culture and sensitivity
- Baseline blood investigations (CBC, ESR, CRP, renal function tests)
- Radiographs (Anteroposterior and Lateral views of the leg including knee and ankle joints)

Fractures were classified using the **Gustilo-Anderson classification** and **AO/OTA system**.

Surgical Technique

Initial Wound Management:

- Immediate thorough debridement under general or spinal anesthesia within 6 hours of presentation.
- Removal of all devitalized tissue and foreign bodies.
- Fracture temporarily stabilized using external fixators when required.

- Broad-spectrum IV antibiotics initiated empirically, later modified based on culture sensitivity.

Preparation of Antibiotic-Coated Rush Nail:

- Titanium Rush nails were manually coated with polymethylmethacrylate (PMMA) bone cement mixed with appropriate antibiotics.
- Antibiotics used included heat-stable agents such as gentamicin and vancomycin (as per culture sensitivity).
- Cement was manually layered onto the nail in a uniform fashion, ensuring sufficient thickness without compromising insertion.

Definitive Fixation:

- After wound stabilization (within 7–10 days), external fixators were removed.
- Definitive fixation was done using the **custom-prepared antibiotic-coated intramedullary Rush nail** inserted through a standard medial entry point into the tibial canal.
- The nail was gently hammered into position under fluoroscopic guidance.
- Wound closure was done primarily or with flap coverage as required (in collaboration with plastic surgery when needed).

Postoperative Protocol

- IV antibiotics continued for 5–7 days postoperatively, then switched to oral antibiotics for 2–3 weeks depending on infection markers.
- Wound inspection done at 48–72 hours postoperatively.
- Early physiotherapy initiated focusing on joint mobility.
- Partial weight-bearing was allowed after 6 weeks depending on clinical and radiological progress.
- Full weight-bearing was delayed until radiological union.

Follow-Up and Outcome Assessment

Patients were followed up at **2 weeks, 6 weeks, 3 months, 6 months, and 9 months**.

Outcome Measures:

1. **Radiological Union:**
    - Defined as the presence of bridging callus in at least 3 cortices on orthogonal views.
    - Assessed at every follow-up using standard X-rays.
2. **Infection Control:**
    - Monitored using clinical parameters (pain, swelling, discharge, fever) and laboratory markers (ESR, CRP, WBC count).
    - Infections were categorized as superficial or deep.
3. **Functional Outcome:**
    - Evaluated using the **Johner and Wruhs criteria**, including parameters such as range of motion, pain, gait, and return to work.
4. **Complications:**
    - Documented throughout, including re-infection, non-union, malunion, nail migration, and soft tissue complications.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using **SPSS version 25.0**.

- **Descriptive statistics** (mean, SD, percentages) were used for baseline variables.
- **Chi-square test** was used for categorical variables.
- **Student's t-test or ANOVA** was used for comparing means.
- A **p-value < 0.05** was considered statistically significant.

RESULTS

Table 1: Demographic Profile of Study Participants (n=30)

Variable	Frequency (%)
Age (years)	
18–30	9 (30%)
31–45	13 (43.3%)
46–60	6 (20%)
>60	2 (6.7%)
Gender	
Male	24 (80%)
Female	6 (20%)
Mode of Injury	
Road Traffic Accident	23 (76.7%)
Fall from Height	5 (16.7%)
Industrial Accident	2 (6.6%)
Side Involved	
Right	17 (56.7%)
Left	13 (43.3%)

Interpretation: Most patients were males aged between 31–45 years with road traffic accidents being the predominant mode of injury.

Table 2: Time to Radiological Union

Time to Union (weeks)	Number of Patients (%)
≤16 weeks	5 (16.7%)
17–24 weeks	17 (56.7%)
>24 weeks	6 (20%)
Nonunion	2 (6.6%)

Mean time to union: 21.3 ± 5.6 weeks
Interpretation: The majority of patients achieved union between 17 and 24 weeks. Only 2 patients (6.6%) had nonunion requiring further intervention.

Table 3: Infection Control Outcomes

Parameter	Number of Patients (%)
No infection	22 (73.3%)
Superficial infection	5 (16.7%)
Deep infection	3 (10%)

Interpretation: Infection was controlled in 90% of the patients with only 3 cases progressing to deep infection. All superficial infections responded well to antibiotics and dressing.

Table 4: Functional Outcome at Final Follow-Up (Johner and Wruhs Criteria)

Functional Grade	Number of Patients (%)
Excellent	8 (26.7%)
Good	13 (43.3%)
Fair	6 (20%)
Poor	3 (10%)

Interpretation: A majority of the patients (70%) had excellent to good functional outcomes at the 9-month follow-up. Poor outcome in 3 patients was primarily due to persistent infection and nonunion.

Table 5: Association Between Infection and Time to Union

Infection Status	Mean Union Time (weeks) ± SD	p-value (ANOVA)
No infection	19.2 ± 4.8	**0.014**

Infection Status	Mean Union Time (weeks) ± SD	p-value (ANOVA)
Superficial infection	22.4 ± 5.1	
Deep infection	27.1 ± 6.7	

Interpretation: Patients with deep infections had significantly delayed union times ($p < 0.05$), highlighting the importance of early infection control.

Summary of Key Outcomes

- **Mean time to radiological union:** 21.3 weeks
- **Union rate:** 93.4%
- **Infection-free rate:** 73.3%
- **Excellent/Good functional outcome:** 70%
- **Complications:** Nonunion (2), deep infection (3), superficial infection (5)

DISCUSSION

Grade IIIB open fractures of the tibia represent one of the most complex injuries in orthopedic trauma due to their combined skeletal and soft tissue involvement, high risk of contamination, and compromised vascularity. The treatment objectives—achieving infection control, fracture union, and limb salvage—are complicated by the need for simultaneous skeletal stabilization and soft tissue reconstruction. Traditional methods of fixation in such settings often fall short due to high rates of infection and delayed union. Hence, the emergence of antibiotic-coated implants, particularly intramedullary Rush nails, has marked a significant shift in managing these injuries, especially in low-resource and high-burden environments. Our study findings affirm the efficacy of antibiotic-coated Rush nails in achieving satisfactory clinical outcomes in Grade IIIB tibial fractures. Of the 30 patients included, 28 (93.4%) showed fracture union, while only 3 (10%) developed deep infections, indicating excellent infection control and healing potential. These results are consistent with the work of Thonse and Conway, who highlighted the benefit of antibiotic cement-coated rods in controlling infection in open fractures and infected nonunions [8]. Their study revealed high union rates and a significant reduction in reinfection, particularly when implants were combined with local antibiotic delivery. The biomechanical properties of Rush nails, such as their flexibility, easy contouring, and load-sharing capacity, make them suitable for intramedullary fixation in open fractures. When coated with polymethylmethacrylate (PMMA) cement impregnated with antibiotics, these nails become dual-purpose: offering both mechanical stability and sustained local antibiotic elution. As noted by Hake et al., antibiotic delivery through coated implants achieves drug concentrations at the fracture site that are 100–1000 times higher than systemic therapy, which is critical in the contaminated milieu of Grade IIIB fractures [9]. This high concentration not only prevents bacterial colonization but also disrupts biofilm formation on implant surfaces.

Biofilm-associated infections are particularly resistant to systemic antibiotics and host immunity. By delivering antibiotics directly at the site of infection, coated implants circumvent systemic barriers and improve local drug penetration. Metsemakers et al. have demonstrated that gentamicin-coated intramedullary nails reduce deep infection rates significantly, especially in cases with extensive soft tissue compromise [10]. Their data aligns with our findings, where the majority of our cases remained infection-free postoperatively. Furthermore, the coating process using PMMA or biodegradable carriers like calcium sulfate can be customized intraoperatively depending on the pathogen sensitivity pattern. Rush nails provide an ideal scaffold for such coatings due to their slender and smooth surface. Moriarty et al. emphasized that implant surface topography and coating adherence are crucial for effective antibiotic release, and Rush nails meet these criteria effectively [11].

In addition to infection control, the coated Rush nail promotes early fracture healing through biological preservation. The minimally invasive nature of the intramedullary technique avoids further periosteal stripping and preserves endosteal blood supply, both of which are essential for bone regeneration. Ferguson et al. supported this by showing that local antibiotics delivered via biodegradable calcium sulfate promote osteogenesis while eradicating infection in chronic osteomyelitis cases [12]. In our study, callus formation was observed by an average of 8.7 weeks, and complete radiological union by 21.3 weeks, comparable to findings from Wasko and Borens [13]. Despite these advantages, complications are not entirely avoidable. Three patients in our study developed deep infections, with two requiring revision debridement and one undergoing delayed soft tissue coverage. Ostermann et al. described similar findings where inadequate initial debridement and severe contamination led to poor outcomes despite antibiotic-impregnated devices [14]. Hence, the cornerstone of success remains aggressive debridement and early soft tissue cover, regardless of implant choice. The cost-effectiveness and practicality of antibiotic-coated Rush nails also deserve emphasis, particularly in developing countries. Hickok and Shapiro stressed that the integration of antimicrobial biomaterials in orthopedics can significantly reduce the economic burden of prolonged hospital stays, revision surgeries, and long-term antibiotic use [15]. Given that our institution is a tertiary care center in a semi-urban region, the low-cost fabrication of these coated nails provided an accessible and sustainable solution without compromising efficacy.

Additionally, McKee et al. observed that the customization of local antibiotic therapy based on intraoperative culture results enhances outcomes and minimizes resistance development [16]. In our study, vancomycin and gentamicin were the most frequently used antibiotics in the cement, selected based on their broad-spectrum efficacy and heat stability.

Thus, the combination of mechanical stability, infection prophylaxis, and biological compatibility positions the antibiotic-coated Rush nail as a promising alternative to more expensive locking nails or staged bone transport procedures. Its utility is particularly pronounced in settings with delayed presentations, contaminated wounds, or where resources are constrained.

CONCLUSION

Grade IIIB compound fractures of the tibia present a formidable challenge in orthopedic trauma care due to extensive soft tissue damage, high infection risk, and delayed fracture union. The use of antibiotic-coated intramedullary Rush nails offers a promising solution by combining local infection control with effective fracture stabilization. In our study, this method demonstrated high rates of union, low incidence of deep infection, and favorable functional outcomes, especially in resource-limited settings. The antibiotic coating, typically using PMMA cement impregnated with broad-spectrum agents like vancomycin and gentamicin, provided sustained local drug delivery, significantly reducing microbial colonization and biofilm formation. The Rush nail’s minimally invasive application also preserved bone biology and allowed early mobilization. Our findings support the integration of antibiotic-coated Rush nails into the treatment algorithm for Grade IIIB tibial fractures, especially where standard locking nails or external fixators may be contraindicated or unavailable. However, the technique's success still hinges on meticulous debridement, appropriate soft tissue management, and individualized antibiotic selection. Further multicentric, randomized studies with larger sample sizes are recommended to establish standardized guidelines and compare long-term outcomes against conventional fixation methods.

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