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Septic Nonunion of the Tibial Shaft with Bone Defect in a Gustilo-anderson Type II Open Fracture

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ABSTRACT

Introduction. Open fractures of the tibial shaft are mostly the result of high-energy trauma, the incidence is 17 to 21 per 100,000 inhabitants, represent 2% of all fractures and 36.7% of all long bone fractures in adults. More than 15% of tibial shaft fractures are classified as open, representing the most common open long bone injuries. The reported incidence of nonunion or delayed union of tibial shaft fractures after intramedullary nailing (IMN) ranges from 16% to 36%. Infection can complicate any stage of the fracture healing process and may contribute to nonunion in up to 38% of cases.

Case: A 64yo female with open fracture of the tibial shaft G-A II, initially treated with external fixators, then 3 internal fixations with IMN were performed at different surgical times due to complication of septic nonunion, managed with local and systemic antibiotics and tissue coverage.

Discussion: Some orthopedic surgeons prioritize bone union as the main treatment goal in septic nonunion and advocate retaining the implant with surgical cleaning and debridement of devitalized tissue, followed by suppressive intravenous antibiotic therapy. Conversely, others consider eradicating the infectious process as the most critical stage of treatment.

Conclusion: Pseudoarthrosis is one of the most devastating problems in orthopedic surgery. We consider it a priority to identify the pathogen associated with the nonunion for specific local and systemic antibiotic therapy associated with aggressive debridement surgery and stable fixation.

ARTICLE DETAILS

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KEYWORDS: septic nonunion, open fracture, tibial shaft, pseudoarthrosis, local antibiotic.

INTRODUCTION

Open fractures of the tibial shaft are primarily the result of high-energy trauma, with a reported incidence of 17 to 21 per 100,000 inhabitants. They represent 2% of all fractures and 36.7% of all long bone fractures in adults. More than 15% of tibial shaft fractures are classified as open, making them the most common open long bone injuries. Due to the tibial bone's limited blood supply, the initial contamination, and the suboptimal conditions under which these injuries are managed as urgent surgical cases, they are associated with high complication rates, including nonunion, delayed union, infection, and compartment syndrome [3].

Despite advancements in surgical techniques and modern implants, poor bone healing remains a challenging issue,

particularly in the tibia. The gold standard for treating tibial shaft fractures is intramedullary nailing [1]. However, in open tibial shaft fractures, the classic approach involves primary external fixation, especially in cases of severe soft tissue injury and/or hemodynamic instability. Due to its relative ease of application and its limited impact on the tibial blood supply. Nevertheless, these advantages are outweighed by the high incidence of pin-tract infections (up to 50%), challenges in soft tissue management, and the potential for delayed union (71%) and nonunion (10–41%) [2], [4], [16].

Nonunion remains one of the most devastating problems in orthopedic surgery. Infection can complicate any stage of the fracture healing process and may contribute to nonunion in up to 38% of cases [8], [9]. If nonunion occurs, the possibility of infection disrupting bone healing should always be considered. According to the literature, coagulase-negative Staphylococcus spp. and Staphylococcus aureus are the most common pathogens responsible for infections in infected nonunion cases [5], [6].

Based on the fracture-related infection (FRI) criteria defined by Metsemakers and colleagues [10], infected nonunion is diagnosed if one or more of the following criteria are present: the existence of a sinus tract, purulent discharge, exposed osteosynthesis material, a positive "probe-to-implant" test, histologically confirmed infection (>5 granulocytes per field at 400× magnification), >2,000 leukocytes/μl in synovial fluid, or >70% granulocytes in cases of concomitant infectious arthritis [6].

The reported incidence of nonunion or delayed union of tibial shaft fractures after intramedullary nailing ranges from 16% to 36%. According to the literature, the rate of deep infection after primary intramedullary nailing for open tibial shaft fractures classified as Gustilo I, II, and IIIa is between 6.5% and 12.9%. For Gustilo III-B fractures, the rate increases to 20–33% [2], [7], [9]. These rates are lower than those observed with external fixation, which range from 21.4% to 66.7% [2].

CASE

Female, 64 years old, with no prior medical history. On November 15, 2020, she was involved in a motor vehicle accident causing an open Gustilo-Anderson II tibia and fibula shaft fracture on the right side, was treated in the first 24 hours with mechanical lavage, debridement, external fixation (Image1), and primary wound closure.

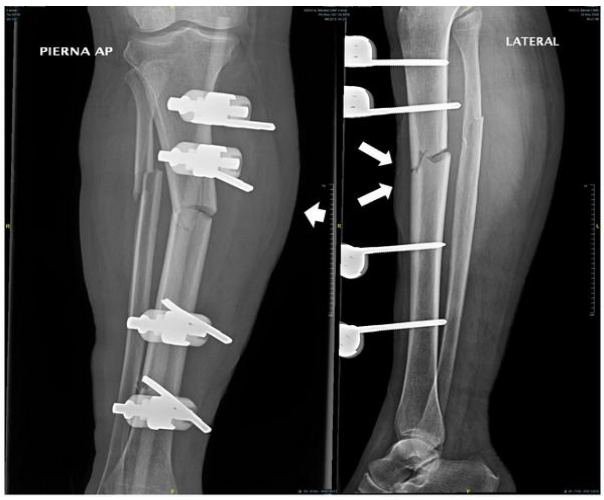

Image1. Swelling Tissue (White Arrows).

Intravenous ceftriaxone 1g and clindamycin 300 mg were administered. Seven days later, open reduction and internal fixation (ORIF) with a 320x10mm tibial intramedullary nail (Image2) was performed. The patient was discharged on cefalexin 500 mg orally (PO) and clindamycin 300 mg PO for 21 days.

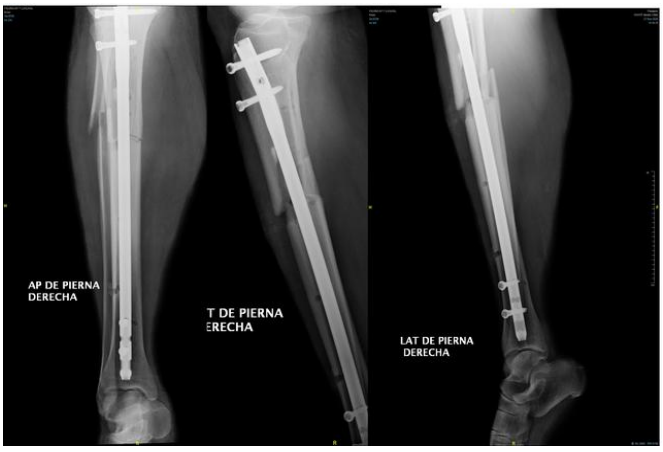

Image2. Postoperative X-ray. 320x10mm IMN.

At 4 weeks post-injury, the patient presented with wound dehiscence and bone exposure. X-rays revealed anterior translation of the proximal fragment (Image3).

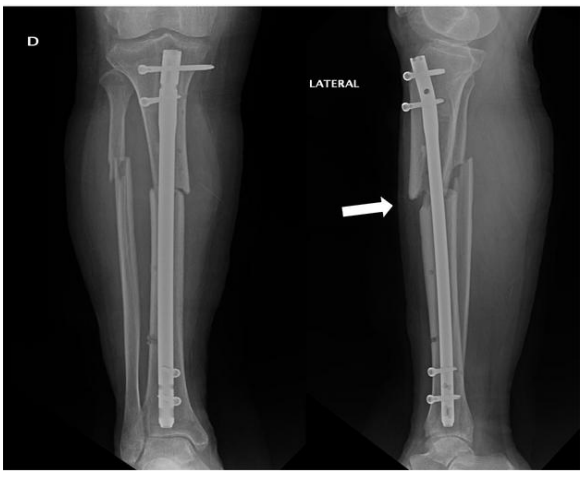

Image3. X-ray at 4 Weeks. Swelling Tissue (white arrows)

At 12 weeks, there was mobility at the fracture site. A CT scan showed a posterolateral bone defect with no evidence of union (Image4). Bone densitometry reported T-score (-2.3) and a Z-score (-1.0), treated with oral risedronate 5mg. At 16 weeks, the patient reported pain at the fracture site, and radiographs showed delayed union and loosening of the proximal screws (Image5).

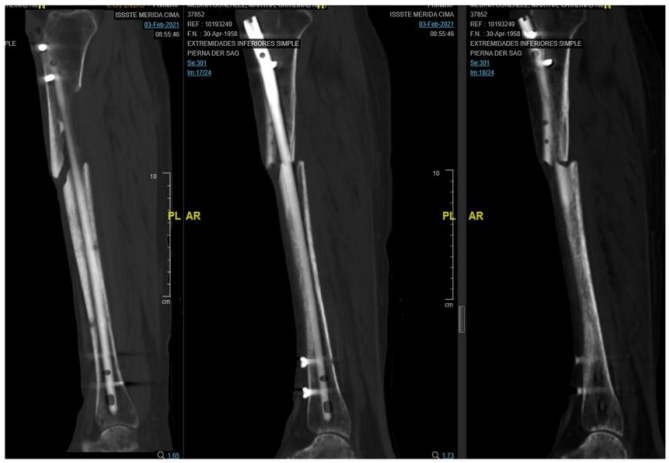

Image4. CT-Scan at 12 Weeks. Posterolateral Bone Defect (left), Anterior Translation of Proximal Fragment (center), Medial Cortical Contact (right).

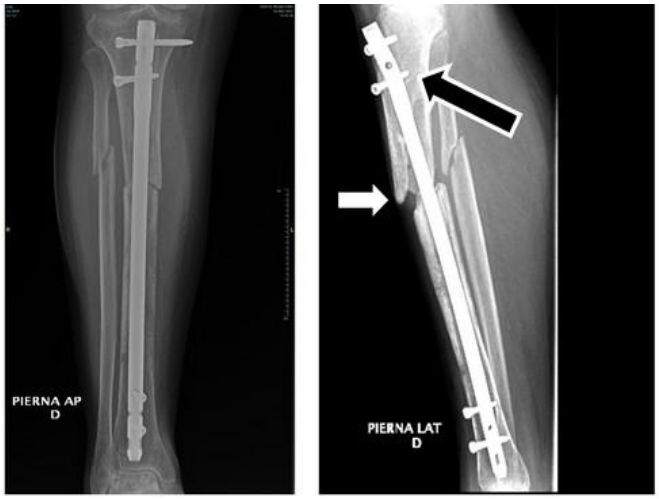

Image5. X-Ray 16 weeks PO. Loosing of Proximal Screws (Black Arrow), Proximal Fragment on Imminent Exposure (White Arrow).

At 24 weeks, the patient developed a 2 mm wound in the area of bone exposure with serosanguinous discharge. A CT scan confirmed oligotrophic nonunion of the tibial shaft (Image6). At 32 weeks, a second surgery was performed: removal of the 320x10 mm intramedullary nail, debridement, scarification, fibular osteotomy, placement of a 300x10 mm intramedullary nail, application of tricalcium phosphate beads (Stimulant), and external fixation (Image7).

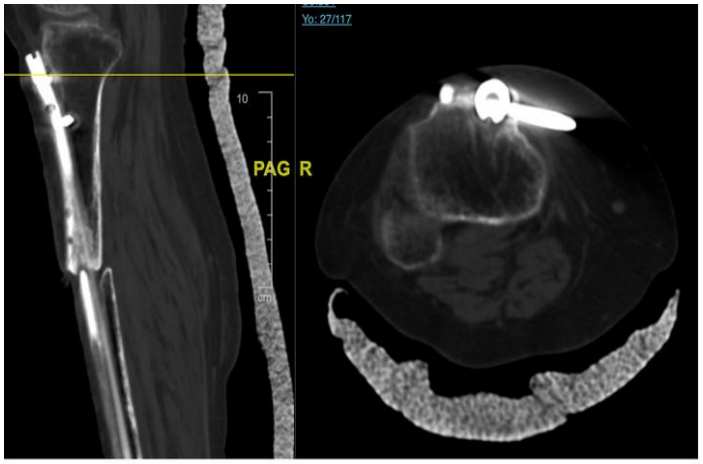

Image6.CT-Scan 6 Months Post Surgery.

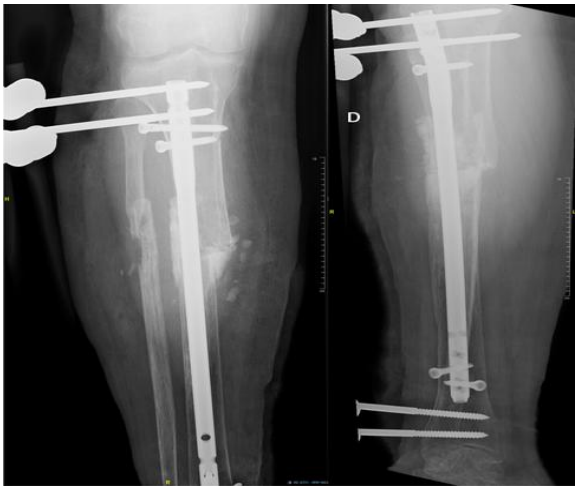

Image 7. X-Ray of Second Surgery.

At 2 weeks post-surgery, the patient presented with a 4 cm anterior wound with serosanguinous discharge (Photo1) and control X-rays (Image8). After 8 weeks, she reported pain at the fracture site, a 1x1cm cutaneous defect with serosanguinous discharge, and residual tricalcium phosphate beads. The wound was debrided, and a culture sample was obtained. Radiographs showed consolidation Montoya II (Image9).

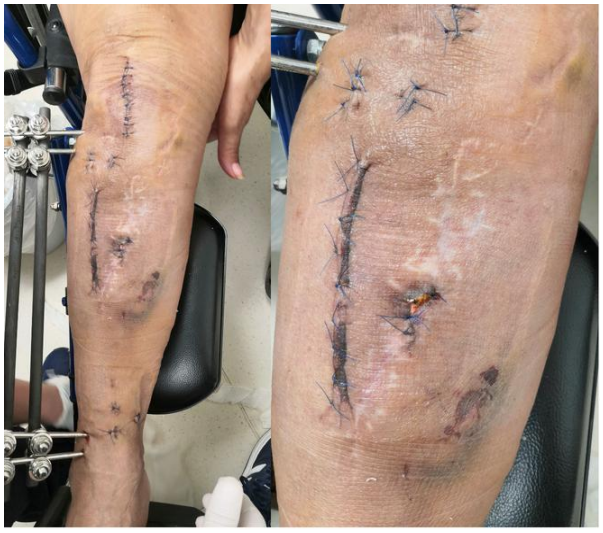

Photo1. 2 Weeks After Second Surgery.4cm Wound in Bone Exposure Area.

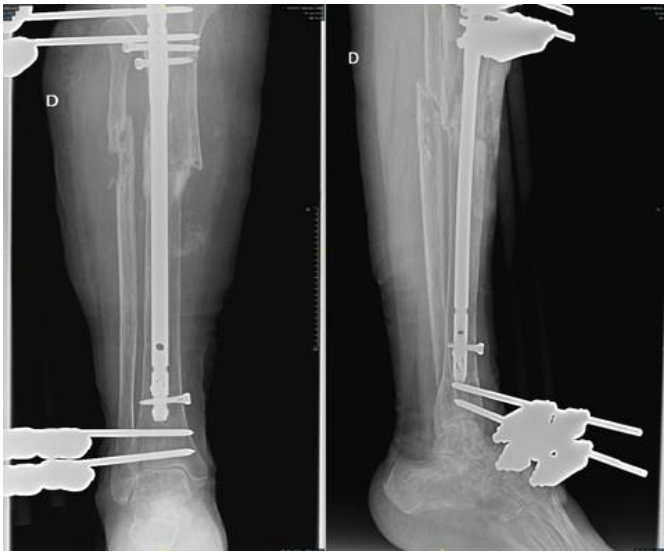

Image8. X-Ray 2 Weeks After Second Surgery

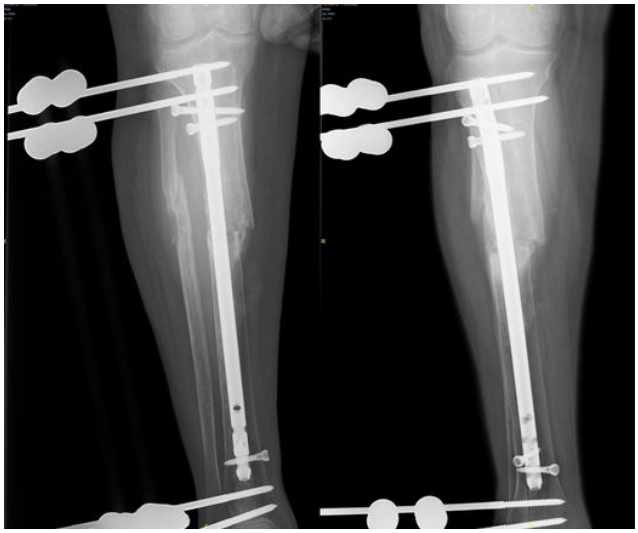

Image9. X-Ray 8 Weeks After Second Surgery.

Culture results revealed *Staphylococcus Lugdunensis* (Image10), sensitive to quinolones, and treatment with ciprofloxacin 500mg PO per 12 weeks. At 20 weeks post-surgery (52 weeks post- injury), the patient presented to the emergency department with fever (38°C) and pain in the right leg. Examination revealed a cutaneous defect with yellowish discharge. The wound was debrided, and a culture sample was taken. A CT scan reported a posterolateral bone defect and no evidence of union (Image11). The culture (Image12) confirmed, once again, *Staphylococcus Lugdunensis*, now sensitive to gentamicin. The patient received inpatient treatment with gentamicin for 5 days, with clinical improvement, negative CRP, and an ESR of 15mm/hr.

Examen	Valor
ORGANISMO	1.Staphylococcus lugdunensis
ORIGEN	CULTIVO DE HERIDA
DETECCION DE CEFOXITINA	Neg -
OXACILINA	2 S
GENTAMICINA	<=0.5 S
CIPROFLOXACINO	1 I
LEVOFLOXACINO	1 S
MOXIFLOXACINO	1 S
RESISTENCIA INDUCIBLE A C	Neg -
ERITROMICINA	>=8 R
CLINDAMICINA	>=4 R
LINEZOLID	2 S
DAPTOMICINA	0.25 S
VANCOMICINA	<=0.5 S
DOXICICLINA	<=0.5 S

Image10.Wound Culture 9 Weeks After Second Surgery.

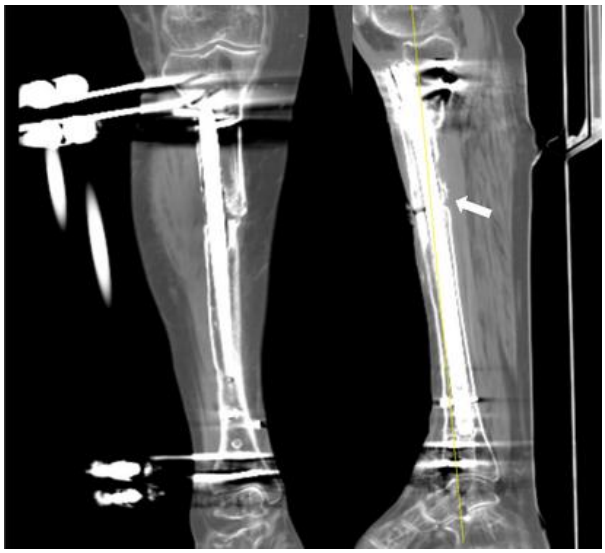

Image11. CT-Scan 20 Weeks After Second Surgery. Delayed Union (White Arrow).

Examen	Valor
ORGANISMO	1.Staphylococcus lugdunensis
ORIGEN	CULTIVO DE HERIDA
DETECCION DE CEFOXITINA	Pos +
OXACILINA	1 R
GENTAMICINA	<=0.5 S
CIPROFLOXACINO	1 S
LEVOFLOXACINO	1 S
MOXIFLOXACINO	1 S
RESISTENCIA INDUCIBLE A C	Neg -
ERITROMICINA	>=8 R
CLINDAMICINA	>=4 R
LINEZOLID	1 S
DAPTOMICINA	0.25 S
VANCOMICINA	1 S
DOXICICLINA	<=0.5 S

Image12. Wound Culture 20 Weeks After Second Surgery.

The patient was discharged on clindamycin 300mg PO every 8 hours for 12 weeks. At 30 weeks post-surgery (62 weeks post-injury), the patient had a 1x1 cm defect with no discharge. Radiographs revealed nonunion (Image13). Intravenous zoledronic acid 4 mg/5 mL was administered.

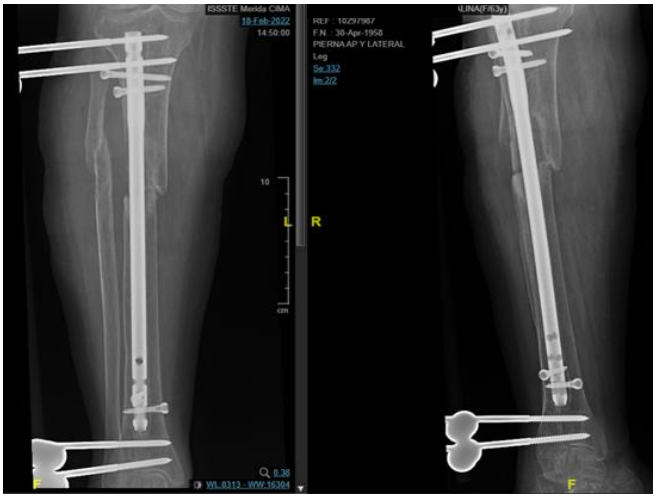

Image13. X-Ray 8 Months After Second surgery

At 44 weeks post-surgery (76 weeks post-injury), the external fixator was removed. A CT scan confirmed oligotrophic nonunion (Image14), and a 3D reconstruction showed a posterolateral bone defect and tibial shaft nonunion (Image15). A fistula appears in the distal locking screw area (Photo2). Wound Culture confirmed *Staphylococcus Pseudintermedius* (Image16), the patient was treated with vancomycin 500mg IV for 8 weeks.

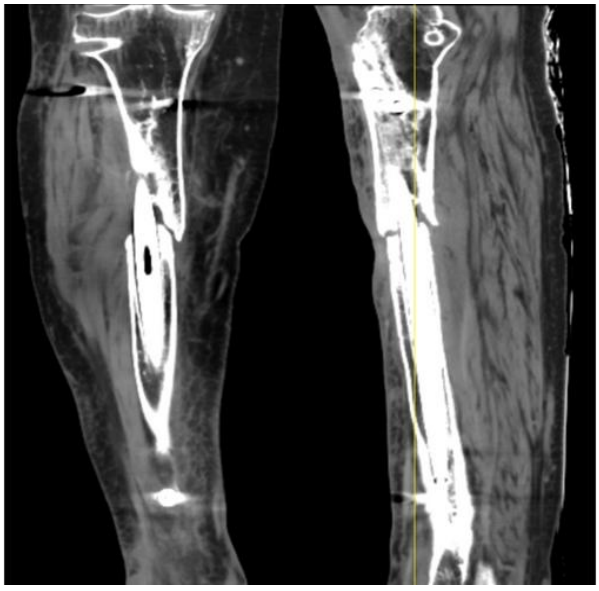

Image14. CT Scan 11 Months After Second Surgery.

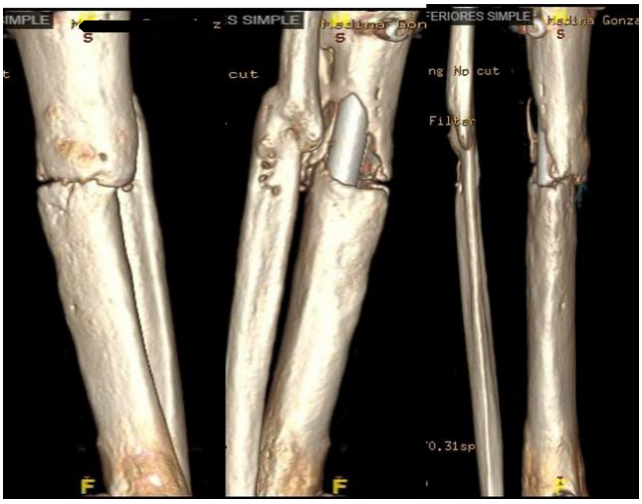

Image15. 3D Image 12 Months After Second Surgery.

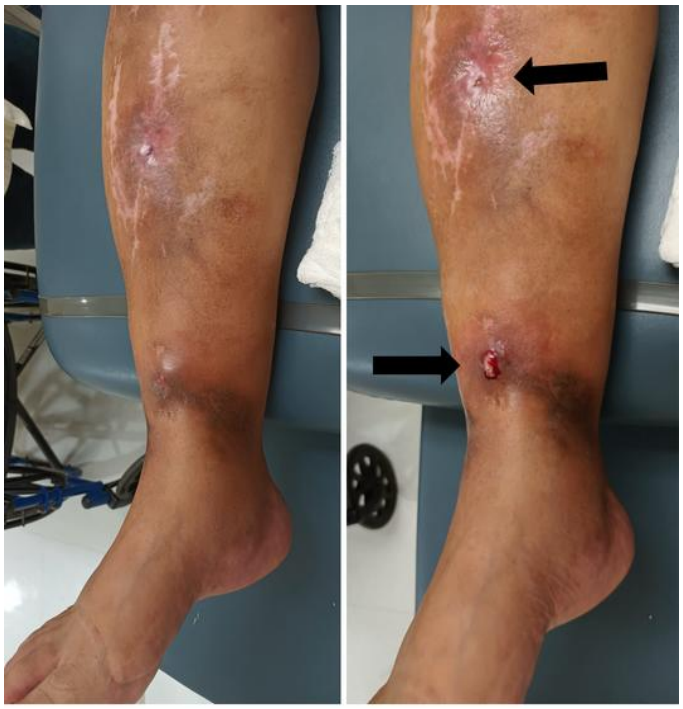

Photo2. Two Fistulas (Black Arrows) 11 Months After Second Surgery.

Examen	Valor
ORGANISMO	2.Staphylococcus pseudintermedius
ORIGEN	CULTIVO DE HERIDA
DETECCION DE CEFOXITINA	Neg -
OXACILINA	<=0.25 S
GENTAMICINA	8 I
CIPROFLOXACINO	>=8 R
LEVOFLOXACINO	>=8 R
MOXIFLOXACINO	4 I
RESISTENCIA INDUCIBLE A C	Neg -
ERITROMICINA	>=8 R
CLINDAMICINA	>=4 R
LINEZOLID	2 S
DAPTOMICINA	0.25 S
VANCOMICINA	<=0.5 S
DOXICICLINA	8 I

Image16. Wound Culture 1 Year After Second Surgery.

At 82 weeks post-injury, a third surgery was performed: removal of the 300x10mm intramedullary nail, debridement, bone culture sampling, intramedullary reaming, decortication and scarification, tricalcium phosphate beads (Stimulan) impregnated with vancomycin and gentamicin were placed (Image17).

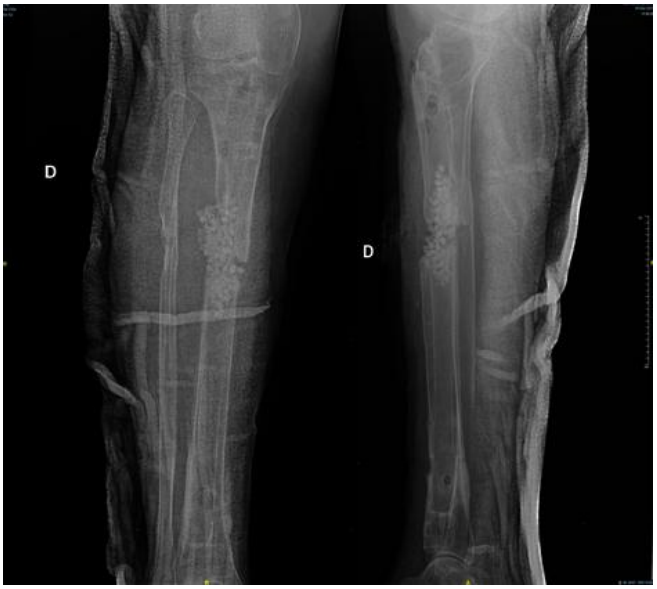

Image17. After Surgical X-Ray with Tricalcium Phospate Beads.

24 hours after third surgery, the surgical wounds were clean and well-approximated (Photo3). Bone culture results confirmed Staphylococcus Lugdunensis (Image18), sensitive to vancomycin, linezolid, and gentamicin. The patient was treated as an inpatient for 3 weeks. X-rays at 3 weeks post-surgery showed regular borders and residual tricalcium phosphate beads (Image 19).

Examen	Valor
ORGANISMO	1.Staphylococcus lugdunensis
ORIGEN	CULTIVOS DIVERSOS
DETECCION DE CEFOXITINA	Neg +
OXACILINA	>=4 R
GENTAMICINA	<=0.5 S
CIPROFLOXACINO	2 I
LEVOFLOXACINO	2 S
MOXIFLOXACINO	1 S
RESISTENCIA INDUCIBLE A C	Neg -
ERITROMICINA	>=8 R
CLINDAMICINA	>=4 R
LINEZOLID	1 S
DAPTOMICINA	0.25 S
VANCOMICINA	<=0.5 S
DOXICICLINA	<=0.5 S
TETRACICLINA	<=1 S
TIGECICLINA	<=0.12 S
NITROFURANTOINA	<=16 S
RIFAMPICINA	<=0.5 S

Image18. Biofilm Culture

Photo3. 24 Hours After Third Surgery.

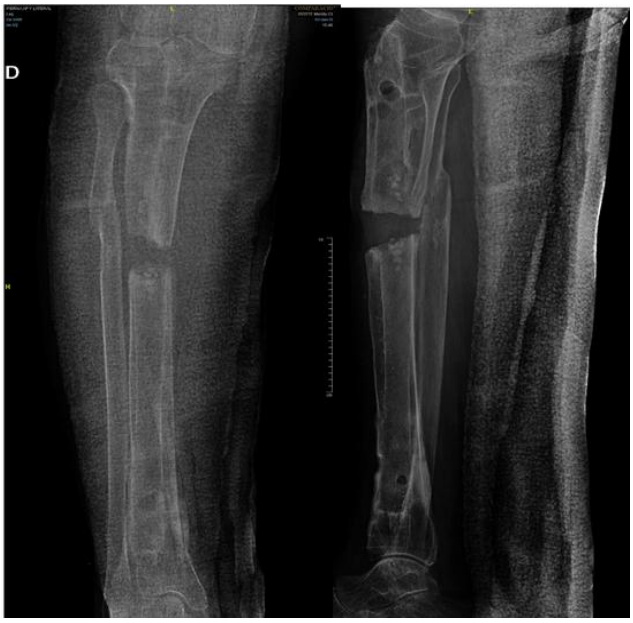

Image19. X-Ray 3 Weeks After Third Surgery.

At 86 weeks post-injury, a fourth surgery was performed, including debridement, a 5cm fibular osteotomy, and 275x11mm intramedullary nail with polar screws in coronal and sagittal planes, the defect was treated with bone chips and antibiotic-laden tricalcium phosphate beads (Stimulant) (Image20).

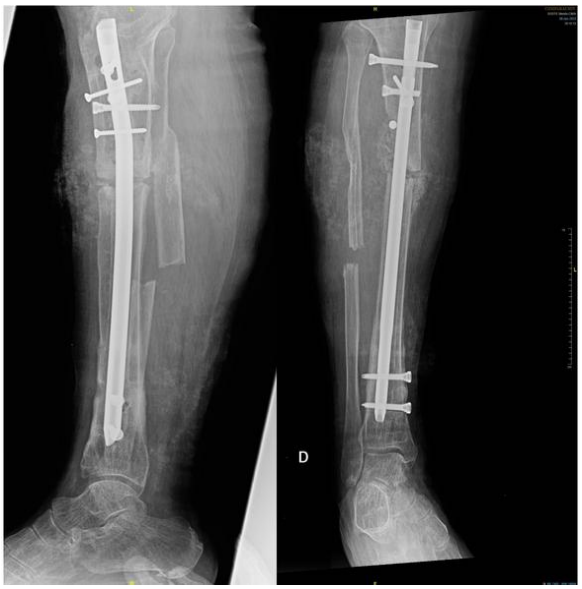

Image20. Fourth Surgery X-Ray.

The patient was treated with linezolid 600mg IV for 6 weeks, follow-up bone densitometry showed T-score of -2.1 and a Z-score of -0.7, treated with zoledronic acid 4mg/5ml IV. Two-week postoperative radiographs confirmed bone graft integration (Image 21), and at 6 weeks, fragment contact without loosening was observed (Image22), enabling progressive weight-bearing.

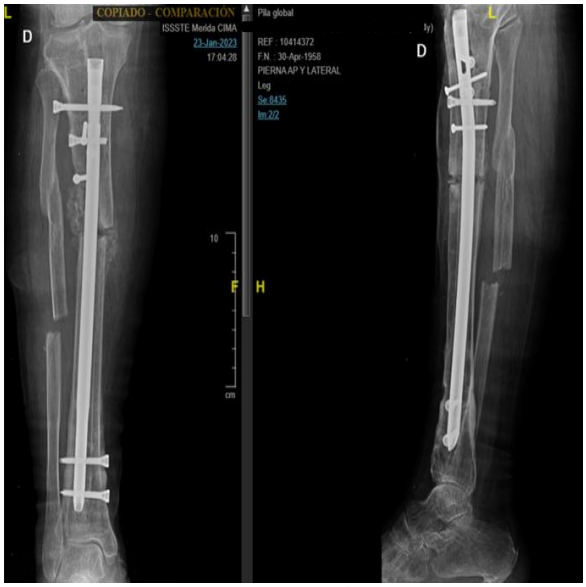

Image21. X-Ray 2 Weeks After Fourth Surgery.

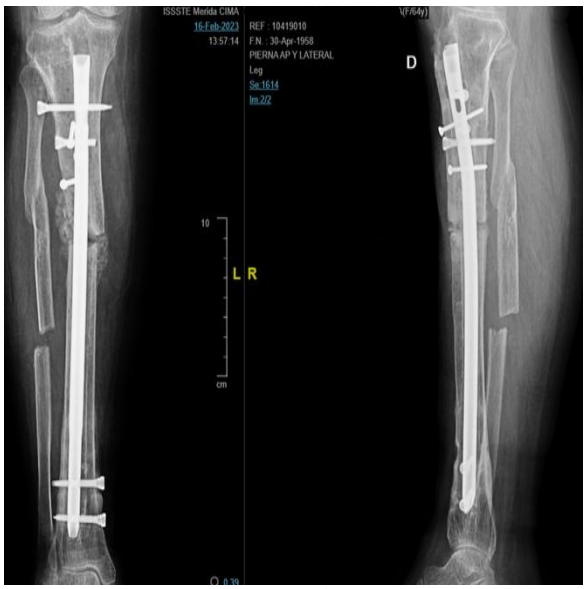

Image22. X-Ray 6 Weeks After Fourth Surgery.

At 20 weeks post-surgery, X-rays showed bone bridges (Image23).

Image23. X-Ray 20 Weeks After Fourth Surgery.

At 24 weeks, the patient had a 2 cm clinical shortening (Photo4) but was ambulating freely (Photo5). Radiographs confirmed Montoya III consolidation (Image24). A CT scan showed consolidation (Image25).

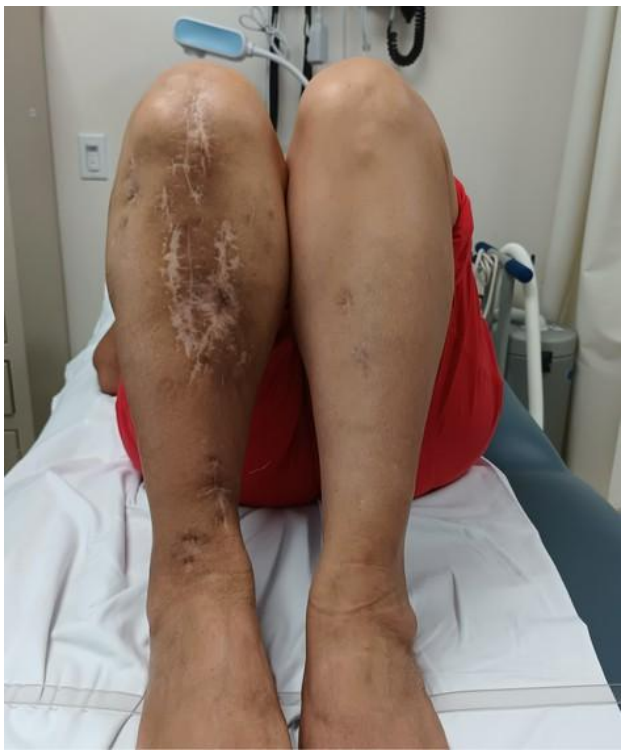

Photo4. Shortening of Right Leg.

The patient was discharged on January 8, 2024 (3 years post-injury) with free ambulation and a 2cm leg-length discrepancy managed with a shoe lift. 1 year after fourth surgery X- rays confirmed Montoya IV consolidation (Image 26). She continues treatment with zoledronic acid every 6 months and follow-up bone densitometry.

Photo5. Full Weight Bearing Walking.

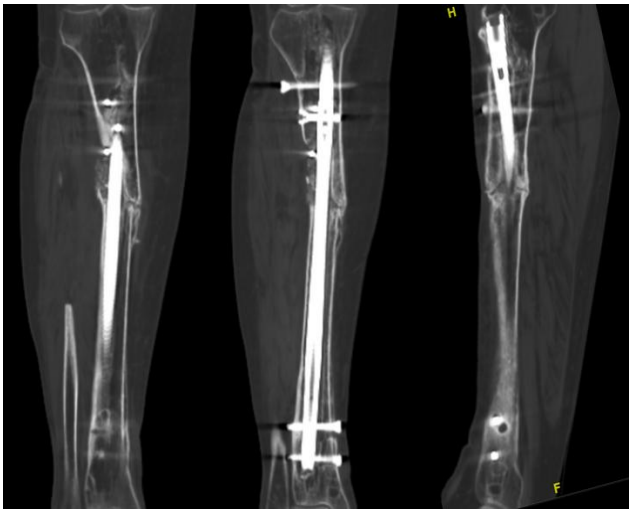

Image24. X-Ray 24 Weeks After Fourth Surgery.

Image25. CT-Scan 30 Weeks After Fourth Surgery.

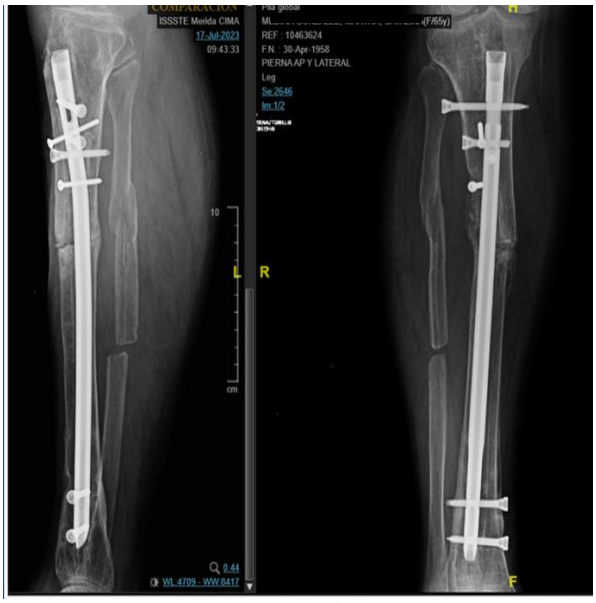

Image26. X-Ray 1 Year After Fourth Surgery.

DISCUSSION

Intramedullary nailing (IMN) is considered the gold standard for the treatment of closed and many open tibial shaft fractures due to its biomechanical and biological advantages [4], [13].

Infections following intramedullary nailing are classified into three stages [12], [13]. The first stage (early) occurs in the immediate postoperative period, typically within 2 to 6 weeks. This stage can usually be managed with high doses of intravenous antibiotics, and as long as fracture stability is maintained and there is no underlying pus accumulation, wound exploration or implant removal is unnecessary. The second stage, defined as occurring between 2 and 9 months postoperatively, is associated with delayed wound healing, wound necrosis, or discharge from the surgical site. At this stage, nail removal followed by fracture re-stabilization is recommended. However, assuming the implant (nail) still provides a stable mechanical environment, revision fixation may not be necessary, and local soft tissue management should be combined with appropriate antibiotic therapy to suppress the infection until union is achieved. The third stage (late), occurring after 9 months, represents intramedullary osteomyelitis. In this case, management principles include determining the extent of nonviable hard and soft tissue (the zone of necrosis) and the extent of infection (the disease zone). After debridement and irrigation, the most appropriate fracture stabilization method is employed if the fracture remains unhealed. In cases of bone loss, restoration is performed once an aseptic environment is achieved, using the most suitable option (e.g., bone grafting, bone transport). If the fracture has consolidated, implant removal with debridement and irrigation of the intramedullary canal is generally recommended [13].

The removal of the nail and surgical debridement are vital for treating infections after intramedullary nailing, as they disrupt the biofilm produced by bacteria, thereby improving the efficacy of antibiotics and increasing the infection remission rate. Intramedullary reaming and irrigation are essential components of surgical debridement, as they remove endosteal sequestra from the canal, reduce intraosseous pressure, enhance bone vascularization, and eliminate bacterial biofilm. After debridement, residual bacteria may remain in the medullary canal or surrounding soft tissue, and biofilm formation and maturation can occur in approximately 72 hours [14], [15].

Some orthopedic surgeons prioritize bone union as the main treatment goal and advocate retaining the implant with surgical cleaning and debridement of devitalized tissue, followed by suppressive intravenous antibiotic therapy [15]. Conversely, others consider eradicating the infectious process as the most critical stage of treatment. Nail removal is crucial for biofilm elimination, followed by intramedullary reaming, soft tissue debridement, local and systemic antibiotic therapy, and the insertion of a new IM nail in cases of nonunion [9], [15].

Bone stabilization, management of dead space, and administration of local and systemic antimicrobial therapy are key factors in managing infected nonunion. Fracture stability is essential for bone healing and infection eradication. Contaminated fractures without internal fixation are more prone to infection than similar fractures treated with internal fixation. Indeed, the advantages of implants for stabilization outweigh their increased susceptibility to infection [11].

A meta-analysis by Morgenstern et al. demonstrated a significant reduction in the risk of infection when additional local prophylactic antibiotics, primarily polymethylmethacrylate (PMMA; bone cement), were used for open fractures. This is because systemic antibiotics alone are often insufficient due to damage to the surrounding tissues and blood vessels, which normally allow systemic antibiotics to reach the tissue- implant interface. In addition to the benefit of maintaining a high antibiotic concentration at the infection site, antibiotic-laden calcium sulfate beads can be an important treatment option for "dead space management" [11], [6].

In septic nonunion, the identification of inflammatory markers is unreliable, as the local reaction often lacks adequate vascularization. A systematic review of the literature reveals that CRP is the most useful marker, but it has moderate sensitivity and specificity [17]. In defining fracture-related infection, W.J. Metsemakers considers CRP one of the suggestive serological markers (Image27). In recent studies on infected fractures and nonunion, blood markers had very limited predictive value. They cannot be used to confirm or exclude an infection [17].

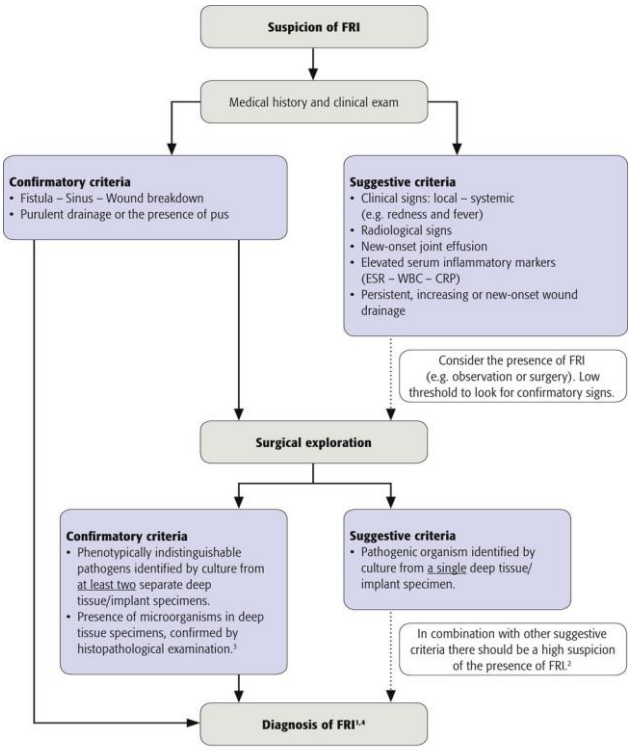

Image27. Definition for Fracture-Associated Infection.

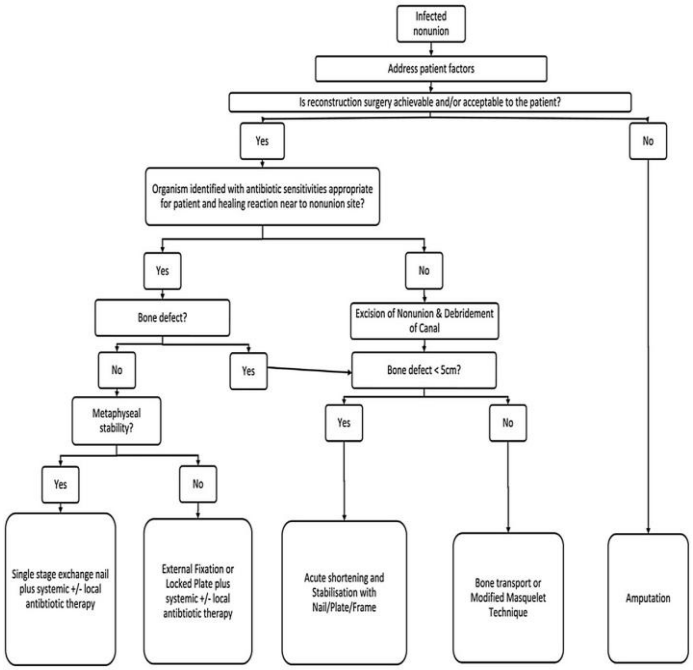

Image28. Treatment of Infected Nonunion.

CONCLUSION

Pseudoarthrosis is one of the most devastating problems in orthopedic surgery. Infection can complicate any stage of the fracture healing process and may contribute to nonunion in up to 38% of cases.

In 2017, H. Simpson and S.T.J. Tsang proposed an algorithm for treatment of infected nonunion (Image28) [9], which we used as the basis for managing our case. We consider it a priority to identify the pathogen associated with the nonunion for specific local and systemic antibiotic therapy associated with aggressive debridement surgery and stable fixation.

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CONFLICT OF INTEREST

No conflicts of interest are declared for this work.

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