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Research Article

Cadaveric Analysis of Intramedullary Nail and Plate Fixation in Tibia-Fibula Fracture: Anatomical, Biomechanical and Functional Perspective

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Abstract

Background: Cadaveric dissections serve as vital tools in medical education, providing detailed anatomical insights and fostering a deeper understanding of surgical interventions. The incidental identification of orthopaedic implants during dissection allows direct assessment of implant's bone interaction, tissue response and biomechanical stability beyond radiological interpretation. This study documents the discovery of an intramedullary nail and screw fixation in the lower shaft of the tibia and fibula during routine cadaveric dissection. Objective: To document and analyse the anatomical, biomechanical and educational significance of an intramedullary nail and screw fixation in the tibia and plate fixation in the fibula observed during cadaveric dissection. Methodology: This descriptive cadaveric case based observational study was conducted on a 65-year-old male cadaver where metallic implants were incidentally identified. Systematic dissection was carried out to expose the tibia and fibula along with surrounding soft tissues. Implant configurations, bone-implant interface, periosteal integrity, fibrotic response and muscular changes were examined and documented. Results: A well aligned intramedullary nail extending from the proximal metaphysis to the distal shaft of the tibia was identified, secured by two proximal and one distal interlocking screws. The fibula showed lateral plate fixation with two cortical screws. Minimal fibrosis, intact periosteum and absence of osteolysis were observed. Mild muscle atrophy suggested previous immobilization rather than surgical complication. Conclusion: This cadaveric dissection demonstrates successful long term anatomical integration of tibia-fibula fixation. Such findings enhance understanding of fracture biomechanics, tissue response and provide valuable learning material for anatomical and surgical education.

Keywords: Cadaveric dissection, Tibial fractures, Intramedullary nail, Screw fixation, Orthopaedic implants, Medical education.

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Introduction

Fractures of the tibia and fibula, especially in the lower third, are among the most common long bone injuries seen in orthopaedic treatment. High-energy trauma, such as car accidents, falls, or sports injuries, is a common cause of these fractures. Because of the tibia's weight-bearing role and subcutaneous position, these fractures present special challenges in terms of anatomical alignment and early mobilisation. (1) Among the different internal fixation techniques available, intramedullary nailing paired with interlocking screws has become the universally acknowledged standard, particularly for diaphyseal and metaphyseal tibial fractures. (2) These interventions provide mechanical stability, promote fracture healing, and enable early mobilization. Intramedullary nail fixation enables stable internal splinting by aligning the bone along its anatomical axis, using locking screws at the proximal and distal ends to resist rotational and axial forces. (3) This approach promotes early weight-bearing and functional recovery, shortens hospital stays, and reduces the likelihood of malunion and implant failure. Similarly, fibular fractures are frequently treated with lateral plate and screw fixation, which helps restore the structural integrity of the distal leg and adds to ankle joint stability. (4)

Although orthopaedic implants are often studied using radiographic imaging or clinical outcome analysis, the unexpected discovery of such implants during cadaveric dissection provides a unique opportunity for anatomical and educational research. Cadaver-based investigations enable direct visualisation of surgical outcomes, implant location, tissue integration, and long-term anatomical changes following intervention. Unlike radiographic tests, cadaveric examinations provide a tactile and three-dimensional insight of implant-bone connections, peri-implant fibrosis, muscle atrophy, and healing patterns.

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The discovery of such surgical artifacts in cadavers presents an opportunity to understand the clinical and biomechanical aspects of these interventions. This article describes the unforeseen finding of an intramedullary nail with interlocking screws in the tibia and a lateral plate with screws in the fibula during normal dissection of a 65-year-old male cadaver. The observed implant was made of AISI 316L stainless steel, which is a biocompatible and corrosion-resistant material commonly utilised in orthopaedic surgery. The absence of considerable fibrotic reaction or osteolysis, together with intact periosteum and minor muscle atrophy, indicates effective integration and low post-operative problems. Documenting surgical artefacts during cadaveric dissection not only helps us understand anatomy and biomechanics, but it also improves the teaching experience for medical students and surgical trainees. It fills the gap between academic understanding and clinical application, particularly in orthopaedic and trauma surgery training. This article provides the cadaveric findings in detail, analyse the implant's clinical and biomechanical consequences, and emphasise the importance of such incidental discoveries in furthering medical education and orthopaedic practice.

Materials and Methods

This work is a presented as a descriptive cadaveric case-based observational study conducted during routine anatomical dissection. The subject was a preserved male cadaver, approximately 65 years of age at the time of death, embalmed using standard formalin-based techniques. During the dissection of the left lower limb, the presence of orthopaedic implants was incidentally observed in the tibia and fibula. The cadaver was procured through the institutional body donation program. Detailed clinical history, nature of trauma, surgical timing and post-operative rehabilitation details were not available. However, implant configuration, fixation strategy, bone response and soft tissue adaptation allowed inferential analysis regarding fracture type, stability and long-term biological response were available.

Standard Operative Procedure for Dissection

Dissection was performed following standard institutional protocols. Instruments used included a BP handle No. 4 with surgical blade No. 24, toothed and non-toothed forceps, blunt and sharp scissors, artery forceps and retractors. A longitudinal incision was made over the anterior compartment of the leg, followed by systematic reflection of the skin, superficial fascia and deep fascia. Muscles, tibialis anterior, extensor hallucis longus and extensor digitorum longus were carefully separated to expose the tibia and fibula without disturbing the implant-bone interface. Sequential photographic documentation was carried out at each stage.

Cadaveric Anatomy of Tibia and Fibula

Tibia: In cadaveric specimens, the tibia presents as a robust bone located medially in the lower leg, adjacent to the fibula. Proximally, the tibia articulates with the femur to form the knee joint, featuring prominent medial and lateral condyles separated by the intercondylar eminence. The tibial tuberosity, located anteriorly on the proximal tibia, serves as the insertion point for the patellar ligament. The shaft of the tibia exhibits a triangular cross-section, with distinct borders and surfaces. The anterior border is particularly pronounced and provides attachment sites for muscles such as the tibialis anterior. Distally, the tibia forms the medial malleolus, a bony prominence that extends inferiorly and medially to articulate with the talus, contributing to the stability of the ankle joint. (5)

Fibula: In cadaveric dissection, the fibula appears slender and lies laterally to the tibia in the lower leg. The proximal end of the fibula comprises the head, which articulates with the tibia, and the neck, which connects the head to the shaft. The shaft of the fibula is elongated and runs parallel to the tibia. It features various muscle attachment sites and contributes to the stability of the ankle joint. Distally, the fibula forms the lateral malleolus, a bony projection that extends inferiorly and laterally to articulate with the talus, providing lateral stability to the ankle joint. (6)

Results

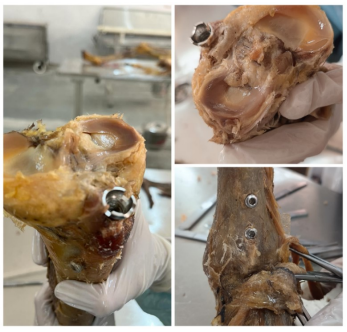
Upon examination, a metallic intramedullary nail was seen spanning the tibia's medullary canal, reaching from the proximal metaphysis to the distal diaphysis. Two proximal and one distal interlocking screws were discovered that held the nail in place. The fibula has a lateral metallic plate secured with two cortical screws. (Figure 1)

Figure 1: Showing Tibia and Fibula Shaft Fracture

Nail and Screw Fixation: During the comprehensive dissection of the left lower limb of a 65-year-old male cadaver, orthopaedic implants were discovered in both the tibia and fibula. Further examination revealed a well-aligned intramedullary nail within the tibial medullary cavity. The nail ran longitudinally from the proximal metaphysis to the distal part of the shaft. It was fastened in place with two proximal and one distal interlocking screws, confirming the conventional interlocking intramedullary nailing approach. The fibula showed signs of surgical stabilisation, including a lateral compression plate attached by two cortical screws, indicating internal fixation for an accompanying fibular fracture. The implants' design suggested that the surgical intervention was conducted to treat a complex fracture involving both the tibia and fibula, most likely a comminated or segmental fracture. (Figure 2)

Implant Description: The intramedullary nail bore an engraved identification marking—AISI 316L 130611 0935, 09 mm × 35 cm —denoting that the implant was composed of AISI 316L stainless steel, a corrosion-resistant, biocompatible material commonly used in orthopedic surgeries.

Surrounding Tissue Analysis: Examination of the surrounding tissues indicated a modest fibrotic response, indicating that the implant is biocompatible for the long term. The periosteum appeared intact across the exposed areas of the tibial shaft, indicating proper bone-implant integration with no evidence of chronic inflammation, infection, or osteolysis. The anterior compartment's musculature, including vestiges of the tibialis anterior and extensor muscles, revealed modest atrophy, which was most likely due to earlier immobilisation or disuse rather than surgical complications. (Figure 3)

Figure 2: Showing Nail and Screw Fixation at Tibia and Fibula Shaft Fracture	Figure 3: Showing Tissue Analysis
	

Biomechanical Consideration: The use of interlocking screws at both ends of the nail improved mechanical stability by reducing axial migration and increasing rotational control over the fracture site. Notably, the transverse screw at the tibial tuberosity served as a proximal anchor, while the anteriorly positioned distal screw improved rotational stability and fracture compression, resulting in optimal conditions for primary bone healing. The fibular plate served a supplementary role in maintaining the alignment and structural integrity of the distal leg, especially important in weight-bearing and gait dynamics. Together, the tibial and fibular implants formed a biomechanically stable construct that would have facilitated early mobilization and functional recovery in a clinical setting.

Overall, the results confirmed a successful surgical operation with proper implant location and favourable long-term anatomical outcomes, as evidenced by retained periosteum, little soft tissue reaction, and structural stability of the fixation.

Discussion

The incidental finding of an intramedullary nail and screw fixation in the lower shaft of the tibia and fibula during routine cadaveric dissection provides a unique opportunity to explore the clinical, biomechanical, and educational implications of such surgical interventions. The present cadaveric finding extends beyond simple anatomical observation and allows analytical interpretation of future management and long-term tissue response. Although detailed clinical history and operative records were unavailable, several anatomical features permitted inferential assessment of the fracture characteristics and healing process. The presence of intramedullary fixation with interlocking screws in the tibia along with plate fixation of the fibula suggests that the original injury was likely an unstable or comminuted fracture involving both bones of the leg, requiring rotational and axial stabilization. Combined fixation is generally adopted in fractures where maintenance of alignment and load sharing is essential for functional recovery.

In the observed cadaver, the implant was well-positioned within the medullary cavity of the tibia, with interlocking screws providing adequate stability both proximally and distally. The fibula, reinforced by a lateral plate and screws, further complemented the stability of the construct. The absence of excessive callus formation, together with preserved periosteum and minimal fibrotic tissue around the implant, indicates that fracture healing had reached a mature stage and that biological integration between bone and implant was favourable. These findings suggest that the fracture was not recent and that sufficient time had elapsed for remodeling and stabilization. Mild muscular atrophy observed in the anterior compartment may represent prolonged immobilization or reduced limb usage during the postoperative period rather than implant related complications. Importantly, no evidence of osteolysis, infection or implant loosening was identified, indicating satisfactory long term host response to the metallic implant material. The identification of the implant material, labelled as AISI 316L stainless steel, further highlights the role of biocompatible and corrosion-resistant materials in orthopaedic surgery.(7)

From a biomedical perspective, the intramedullary nail acted as a long sharing internal splint, while interlocking screws prevented axial migration and rotational instability. The fibular plate likely provided additional lateral stability, continuing to restoration of limb alignment and gait mechanics. The placement of screws at the tibial tuberosity and anterior distal end ensures rotational and axial stability, promoting primary bone healing while minimizing the risks of non-union and implant failure. The use of lateral plate fixation for the fibula further contributes to the overall stability of the lower leg, particularly in weight-bearing and dynamic movements.(8) Such direct visualization offers insights that are often difficult to appreciate through imaging studies alone.

For new researchers, incidental implant findings in cadavers provide a valuable model to study long-term surgical outcomes, bone remodelling patterns, tissue compatibility with implant materials and functional anatomical changes following trauma management. The educational value of such findings in a cadaveric setting cannot be overstated. Medical students and surgical trainees can gain firsthand insights into the anatomy, biomechanics, and clinical considerations of orthopedic implants through the dissection of cadavers with surgical artifacts.(9) This experience bridges the gap between theoretical knowledge and practical application, enabling learners to visualize how implants interact with anatomical structures and adapt to physiological conditions over time. Additionally, the preserved state of the implants and surrounding tissues in this cadaver illustrates the long-term outcomes of surgical interventions, offering valuable lessons in postoperative care and implant longevity.(10)

Thus, the present study is unique in documenting an incidental cadaveric finding of combined tibial intramedullary nail and fibular plate fixation with emphasis on anatomical, biomedical and biological interpretation rather than mere descriptive observation. Unlike conventional implant studies based primarily on imaging or clinical follow-up, this work provides direct anatomical evidence of long-term bone implant integration and soft tissue response. The analysis enables inferential understanding of fracture characteristics and healing status in the absence of clinical history, highlighting the scientific value of cadaver-based evaluation. Furthermore, the study demonstrates how incidental surgical findings can serve as a bridge between anatomical education and applied orthopaedic knowledge. This approach offers a novel perspective for future researchers by promoting analytical use of cadaveric observations in interdisciplinary medical research.

Conclusion

Although direct clinical details were unavailable, cadaveric evidence permits inference regarding fracture biomechanics and healing response. The implant configuration suggests management of an unstable tibia-fibula fracture, where combined intramedullary and plate fixation enhances rotational stability. The intact periosteum and absence of osteolysis reflect favourable long-term biocompatibility of AISI 316L stainless steel. Such

observations provide anatomical researchers insight into tissue behaviour following internal fixation which cannot be appreciated through imaging alone. From an educational perspective, implant bearing cadavers offer a unique opportunity for students and researchers to correlate surgical interventions with real anatomical outcomes, thereby bridging the gap between theoretical learning and clinical application. The insights help researchers in anatomy, orthopaedics and integrative disciplines like Ayurveda get a better knowledge of musculoskeletal structure, tissue reaction and functional restoration following surgical intervention. Systematic documentation of similar incidental findings may further enhance knowledge regarding long term implant integration and strengthen interdisciplinary medical education and research.

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