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Foot and Ankle Fixation Techniques: A Comprehensive Review of Surgical Advances and Best Practices

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Abstract

Foot and ankle injuries are common in both athletic and aging populations. Proper fixation techniques are vital for ensuring biomechanical stability, optimal healing, and functional recovery. This article explores the latest fixation methods, including internal and external devices, surgical approaches, and post-operative management. Innovations such as locking plates, bioabsorbable implants, and minimally invasive techniques are also examined. Foot and ankle surgery is a rapidly evolving subspecialty within orthopedic and podiatric medicine, driven by technological innovation, refined surgical techniques, and an improved understanding of musculoskeletal pathologies. This comprehensive overview examines the current advances and persistent challenges shaping the landscape of foot and ankle surgery. Technological breakthroughs such as minimally invasive surgical (MIS) techniques, 3D printing, biologic therapies, and advanced imaging modalities have revolutionized the treatment of common and complex conditions, including hallux valgus, ankle arthritis, tendon dysfunctions, and deformities such as flatfoot or cavus foot. Concurrently, the rise of evidence-based surgical protocols and enhanced recovery after surgery (ERAS) pathways has contributed to improved patient outcomes and reduced complication rates. Despite these promising developments, foot and ankle surgery faces notable challenges. These include the complexity of biomechanics in this anatomical region, high variability in individual presentations, limitations in implant longevity, and a need for better long-term outcome data. Additionally, access to advanced care and disparities in surgical outcomes across populations remain critical issues. Surgeons must navigate a balance between innovative interventions and the maintenance of traditional, time-tested approaches, particularly in cases involving comorbidities, elderly populations, and revision surgeries.

Keywords: Foot fixation techniques; Ankle fixation methods; Orthopedic foot surgery; Ankle fracture stabilization; Internal fixation; External fixation; Minimally invasive foot surgery; Screw and plate fixation; Intramedullary nailing; Arthrodesis procedures; Ankle arthroplasty; Bone grafting in foot surgery

Introduction

The foot and ankle bear the full weight of the human body and are essential for mobility. Consequently, fractures and dislocations in this region can be particularly debilitating. Fixation of these injuries whether due to trauma, deformity correction, or degenerative diseases requires precise anatomical realignment and stabilization. With a growing array of fixation devices and surgical strategies, orthopedic surgeons have more tools than ever to restore function effectively [1]. The foot and ankle complex serves as a critical foundation for human mobility, bearing significant biomechanical load and facilitating a range of dynamic functions essential to locomotion. Disorders affecting this region can lead to considerable morbidity, functional limitation, and diminished quality of life [2]. As such, foot and ankle surgery plays a pivotal role in addressing deformities, trauma, degenerative conditions, and soft tissue injuries that are unresponsive to conservative management. Over the past two decades, the field has undergone transformative changes due to advances in surgical technology, preoperative planning, and postoperative rehabilitation strategies [3].

Key drivers of progress include the advent of minimally invasive and arthroscopic techniques, which aim to reduce soft tissue trauma, accelerate recovery, and improve cosmetic outcomes [4]. Imaging technologies such as weight-bearing computed tomography (WBCT) and intraoperative fluoroscopy have enhanced diagnostic precision and intraoperative accuracy [5]. The use of biologics including platelet-rich plasma (PRP), stem cell therapy, and bone marrow aspirates offers promising adjuncts for tissue healing and regeneration. Furthermore, the integration of computer-assisted surgery, 3D printing for custom implants, and robotic systems heralds a new era of surgical precision and personalization.

However, the complexities intrinsic to foot and ankle pathology pose enduring challenges. The region comprises multiple articulations, soft tissues, and neurovascular structures packed into a compact anatomical space, complicating surgical access and repair [6]. Variations in patient anatomy, comorbidities such as diabetes and peripheral vascular disease, and differences in activity level further complicate both diagnosis and management. Postoperative complications such as wound healing problems implant failure, and chronic pain syndromes underscore the need for careful patient selection and surgical planning [7]. The field also grapples with systemic issues, including inequitable access to care, variable surgeon training and experience, and the rising cost of technologically advanced interventions. Additionally, the heterogeneity of outcome measures and lack of long-term data hinder the development of universal clinical guidelines [8].

This article aims to provide a critical synthesis of the latest advances in foot and ankle surgery, while also addressing the pressing clinical, logistical, and ethical challenges that practitioners and researchers face. Through an exploration of emerging technologies, evidence-based practices, and interdisciplinary approaches, this review seeks to inform

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clinicians, policymakers, and academics about the current state and future trajectory of this dynamic and impactful surgical domain.

Indications for fixation

Common indications for surgical fixation in the foot and ankle include:

- Displaced fractures (e.g., calcaneus, talus, metatarsals)
- Ankle instability with ligamentous injury
- Charcot neuroarthropathy
- Arthrodesis for arthritis or deformity
- Complex or comminuted fractures
- Post-traumatic deformity

Internal fixation involves surgically placing devices like plates, screws, and intramedullary nails within or on the bone.

- Locking plates are commonly used in osteoporotic bone.
- Low-profile plates are preferred for the metatarsals and phalanges.
- Screws can be cannulated for easier insertion or lag screws to compress fracture lines.
- Used for metatarsal fractures and hallux valgus corrections.
- Minimally invasive and biomechanically strong.
- Useful for temporary fixation or small bones.
- Often supplemented with external splinting.

External fixation

Used when internal fixation is not feasible due to soft tissue damage or infection risk.

- Ideal for deformity correction or infected nonunions.
- Allows for gradual correction and weight-bearing.

Simpler design, used for acute trauma or lengthening procedures.

ORIF (Open Reduction and Internal Fixation) is the gold standard for displaced ankle fractures.

Syndesmotic screws or tightrope devices stabilize distal tibiofibular disruptions.

ORIF is challenging due to the complex anatomy.

Extensile lateral approach provides access to the calcaneus, though minimally invasive options are emerging.

Midfoot and forefoot

Lisfranc injuries require anatomical reduction and stable fixation, typically with screws or plates.

Metatarsal fractures often heal well with percutaneous pinning or screws.

- Eliminate the need for hardware removal.
- Composed of polylactic acid or similar materials.
- Tailored for complex deformities or revision surgeries.
- Offer better anatomical fit and potentially shorter surgery time.
- Reduced soft tissue disruption and faster recovery.
- Arthroscopically-assisted fixations are increasingly popular for ankle and subtalar joints.
- Weight-bearing, varies by injury and fixation type. Rigid fixations may allow early weight-bearing.
- Immobilization, typically 4–8 weeks in a cast or boot.
- Physical therapy focuses on range of motion, strength, and proprioception.
- Infection (especially in open fractures or diabetics)
- Nonunion or malunion
- Hardware failure or irritation
- Post-traumatic arthritis
- Neurovascular injury

Timely intervention and strict adherence to surgical principles can mitigate many of these risks.

Conclusion

Foot and ankle fixation has evolved significantly with technological advancements and deeper anatomical understanding. Whether through open reduction, minimally invasive approaches, or external methods, the goal remains the same, restoring anatomy and function while minimizing complications. Future research and innovations like smart implants and robotics promise even better outcomes for patients and surgeons alike.

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