General Principles

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1 Biomechanics

Take-Home Message

- The complex bony and ligamentous anatomy of the foot and ankle allows multiple foot positions and motion in three axes of rotation.
- Transverse tarsal joints provide both flexibility and stability to the hindfoot and midfoot.
- The midfoot is an important bridge between hindfoot and forefoot and is stabilized by longitudinal and transverse arches.
- The gait cycle is composed of a stance and swing phase, the mechanics of which are influenced by important soft-tissue contributions.

Ankle Biomechanics

Ankle joint: articulation between tibial plafond, medial malleolus, lateral malleolus, and talus.

- Mortise widens and ankle is more stable in dorsiflexion due to shape of talar dome.
- Responsible for most sagittal plane motion of foot and ankle: dorsiflexion (10–23°) and plantarflexion (23–48°). Secondary motion rotation and inversion and eversion.
- Medial deltoid ligament complex is the main stabilizer of the ankle during stance. Functions to resist lateral translation and valgus forces, i.e., talar tilt.
- Lateral ankle ligaments function as a restraint to varus forces.

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Distal tibiofibular joint: consists of distal fibula (medial convex surface) and incisura fibularis of distal tibia (lateral concave surface).

- Fibula rotates within the incisura (~2°) during normal gait.
- Along with syndesmotic ligaments, provides stability against lateral talar translation.

Hindfoot Biomechanics

Subtalar joint: articulation between talus and calcaneus.

- Functions in eversion and inversion.
- Limited eversion accommodation contributes to disability derived from even a mild cavovarus foot deformity.

Transverse tarsal joint (Chopart): articulation between talus and navicular (TN) and between calcaneus and cuboid (CC).

- Important for providing stability to the hindfoot and midfoot to produce rigid lever at toe-off.
- During heel strike, these joints are supple and parallel to adapt to uneven ground, then during toe-off become divergent and lock, providing stiffness to the foot.
- Failure of the posterior tibial tendon to lock the transverse tarsal joints is the biomechanical etiology for lack of a heel rise in patients with posterior tibial tendon dysfunction.

Midfoot and Forefoot Biomechanics

Midfoot: consists of intercuneiform joints, naviculocuneiform joint, and tarsalmetatarsal joints (TMT).

- Midfoot functions in adduction and abduction.
- Provides important bridge between hindfoot and forefoot and both flexibility and stability for normal gait.
- TMT joint complex (Lisfranc joint) divided into medial, middle, and lateral columns.
  - Lateral column has most sagittal mobility and allows for flexibility during necessary for walking on uneven ground.
  - Middle column is least mobile and allows for rigidity during push-off.
  - Medial column experiences the most force while in stance.
- The foot has longitudinal and transverse arches → stabilized by bony architecture, ligaments, and muscle forces.
  - The plantar ligaments are thicker and stronger than the dorsal ligaments.
  - The interosseous ligaments are the primary stabilizer of the longitudinal arch. The plantar fascia is a secondary stabilizer.
  - The specialized architecture of the Lisfranc joint complex imparts a bony "keystone" effect which stabilizes the transverse arch. The Lisfranc ligament (from medial cuneiform to base of the 2nd MT) is the largest and strongest of the ligaments which stabilize the Lisfranc joint.

Forefoot: consists of all structures distal to TMT joints.

- First metatarsal is the widest and the shortest and bears 50 % of weight during gait.
- Second metatarsal experiences more stress than the other lesser metatarsals (commonly involved in stress fractures).
- Lesser toes are balanced by the extrinsic muscles (EDL, FDL), intrinsic muscles (interossei, lumbricals), and passive restraints (plantar plate, extensor hood, joint capsule, collateral ligaments).
- Loss of intrinsic function predictably leads to claw toes.

Foot Positions Versus Foot Motions
Foot positions are defined in a manner different from foot motions → they are varus/valgus (hindfoot), abduction/adduction (midfoot), and equinus/calcaneus (ankle).
Foot motions are in three axes of rotation (Table 1).

Gait Cycle

- One gait cycle, or "stride," is measured from heel strike to heel strike.
- Ground reaction forces are approximately 1.5 times body weight during walking and 3–4 times body weight during running.

Stance phase: 62 % of gait cycle. Heel strike to toe-off

- Heel strike:
  - Hindfoot valgus, forefoot abduction, dorsiflexion of ankle.
  - Anterior tibialis contracts eccentrically to control rate at which foot strikes the ground.
  - Quadriceps contract to stabilize knee.
  - Hindfoot unlocked/everted for energy absorption.
- Foot flat: Single-limb support
  - Gastrocnemius-soleus complex contracts eccentrically.
  - Knee extends, hip extensors under concentric contraction.
  - Hindfoot unlocked/everted for ground accommodation.

Table 1 Description of foot motion in three axes of rotation

Plane of motion	Motion
Sagittal (X-axis)	Dorsiflexion/plantar flexion
Frontal (coronal) (Z-axis)	Inversion/eversion
Transverse (Y-axis)	Forefoot/midfoot: adduction/abduction
	Ankle/hindfoot: internal rotation/external rotation
Tri-planar motion	Supination: adduction, inversion, plantar flexion
	Pronation: abduction, eversion, dorsiflexion

Swing phase: 38 % of gait cycle. Toe-off to heel strike

- Toe-off:
  - Hindfoot varus, forefoot adduction, plantarflexion of ankle.
  - Hip flexors contract. Gastrocnemius-soleus complex contracts concentrically.
  - Plantar fascia tightens, longitudinal arch is accentuated (windlass mechanism), and transverse tarsal joint locks → allows foot to convert from flexible shock absorber to rigid propellant.
- Mid-swing: Foot clearance
  - Ankle dorsiflexors contract concentrically.
  - Loss of function results in steppage gait.
- Terminal swing: Hamstring muscles decelerate forward motion of thigh.

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2 Ankle Arthroscopy

Take-Home Message

- Indications for arthroscopy include treatment of OCLT, debridement of osteophytes and synovitis, removal of loose bodies, and cartilage debridement for ankle fusions.
- Joint distraction, correct instrumentation, and systematic arthroscopic approach are vital to successful surgical procedure.
- Arthroscopic portal options include anterolateral, anteromedial, posterolateral, and posteromedial and require a systematic approach for a thorough procedure.
- Superficial peroneal nerve is most at risk from iatrogenic injury.

Relevant Anatomy

- Tibiotalar joint: comprised of the ankle mortise superiorly and talar dome inferiorly (Fig. 1).

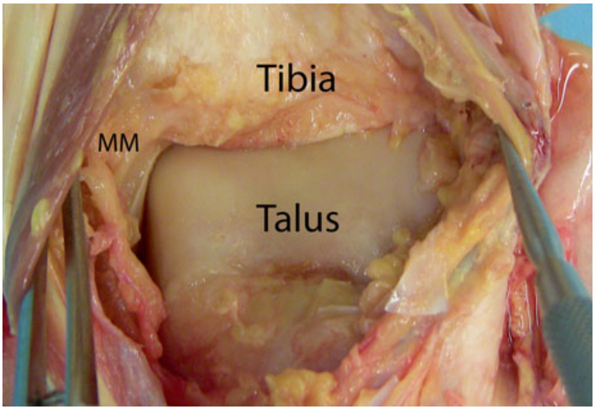

Fig. 1 Anatomic dissection of the anterior aspect of the ankle. The anterior aspect of the distal tibia, medial malleolus, and the talus are visualized

- Distal tibiofibular joint: convex surface of medial fibular articulates with incisura fibularis. Syndesmotic ligaments include anterior inferior tibiofibular ligament, posterior inferior tibiofibular ligament, interosseous tibiofibular ligaments, and interosseous membrane.
- Deltoid ligament complex: deep and superficial deltoid → to resist lateral talar translation and valgus.
- Lateral ankle ligaments: anterior talofibular (ATFL), calcaneofibular (CFL), posterior talofibular (PTFL) → to resist varus forces.
- Anterior neurovascular structures: superficial peroneal nerve (SPN), saphenous nerve, anterior tibial artery, vein, and deep peroneal nerve (DPN) (Fig. 2).
- Posterior neurovascular structures: sural nerve, tibial nerve, posterior tibial artery and vein.

Surgical Indications

- Osteochondral lesions – chronic (debridement with microfracture) or acute (fixation of bony component)
- Debridement of synovitis
- Ankle impingement – excision of soft tissue and tibial/talar osteophytes
- Removal of loose bodies
- Cartilage debridement in conjunction with ankle fusion

Perioperative Considerations

- Thorough history and physical examination provide a differential diagnosis and guide acquisition of appropriate imaging studies.
- Positioning: supine, bump under ipsilateral pelvis to achieve neutral foot rotation. Flex hip and knee to allow distraction and relax gastrocnemius tension.
- Use noninvasive distraction methods in a sterile fashion to access tibiotalar articular surface (Fig. 3). Anterior ankle arthroscopy for impingement and synovitis without distraction minimizes risk to the deep neurovascular structures and articular cartilage as the ankle can be dorsiflexed during the procedure.
- 2.7 mm 30-degree angle arthroscope is suitable in most cases. Small joint instruments are useful, in addition to 3.5 mm shaver, 4.0 mm round burr, and microfracture awl.

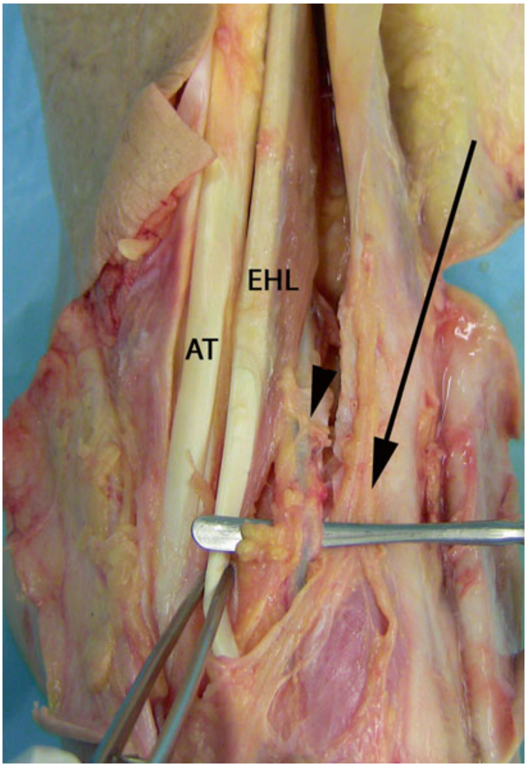

Fig. 2 Anterior tibial artery, vein, and deep peroneal nerve (*arrowhead*). The bundle lies deep the EHL at the level of the ankle and visualizing of the structures requires retraction of the tendon. The superficial peroneal nerve is also seen distally; it has been transected proximally (*arrow*)

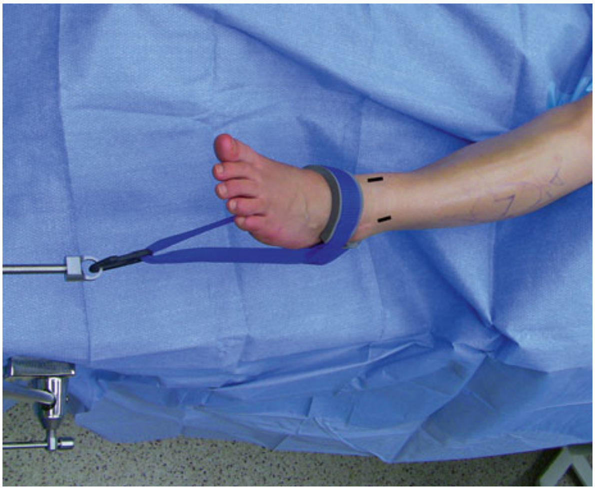

Fig. 3 Patient positioning and noninvasive ankle distractor. Ipsilateral flexion of the thigh elevates the ankle to allow for posterior portal placement and stabilizes the proximal leg to allow for ankle distraction. The anteromedial and anterolateral portals have been marked in this case (*black lines*)

Portal Placement

Many arthroscopic portals have been described to access the ankle, but anteromedial and anterolateral remain the staple.

- Anteromedial: primary viewing portal. Established first. Make portal 2.5 mm medial to tibialis anterior tendon directly at level of joint. Incise skin; bluntly dissect to joint capsule. Enter joint with trochar and cannula; introduce arthroscope and distend joint.
- Anterolateral: primary working portal. Create once arthroscope is introduced and joint is distracted. Make portal at level of joint line, just lateral to peroneus tertius tendon. Incise skin sharply; bluntly dissect carefully to protect the superficial peroneal nerve.
- Posterolateral: Make portal just lateral to Achilles tendon, 2 cm superior to the distal tip of the lateral malleolus. Incise skin; bluntly dissect to capsule. Direct trochar slightly medially, toward 1st and 2nd interdigital webspace. Portal is at the level of the posterior process of the talus.
- Posteromedial: rarely indicated given proximity to the posterior neurovascular bundle (posterior tibial artery, vein, tibial nerve). Incision just medial to the Achilles tendon above 2 cm superior to distal tip of lateral malleolus. Enter joint capsule under direct visualization from the posterolateral portal. All instruments must remain lateral to the FHL tendon.

Diagnostic Arthroscopy

- Begins in anterior aspect of joint. Inspect for synovitis, loose bodies, and osteophytes.
- Visualize articular surfaces of tibiotalar joint. Probe gently for softening to assess for an OCLT (Fig. 4).

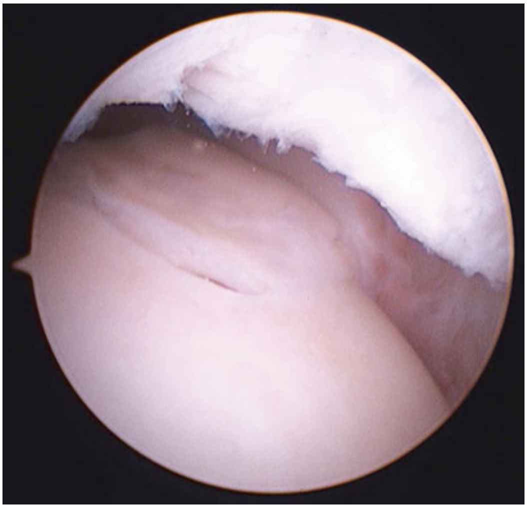

Fig. 4 Osteochondral lesion of the talus with fissuring of the articular surface

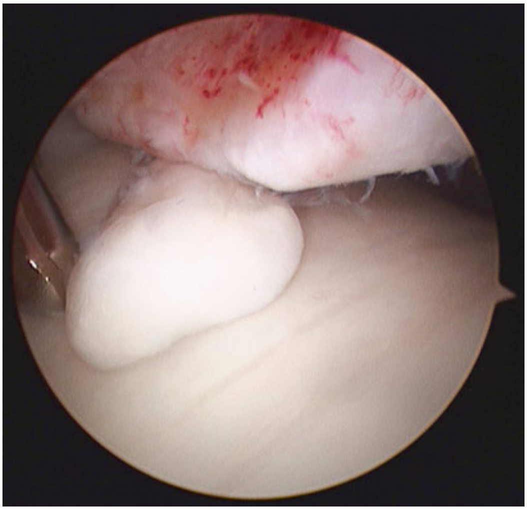

Fig. 5 Loose body noted in the anterior aspect of the ankle joint. These commonly reside in the posterior ankle capsule. Use of the shaver to provide suction can "pull" the loose bodies into the shaver and allow for removal

- View the lateral gutter, between the lateral talar dome and fibula, both from the anterior ankle and within the tibiotalar articulation. Inspect inferior aspect of syndesmosis.
- View the medial gutter, between the medial talar dome and medial malleolus in a similar fashion.
- May view the posterior aspect of joint by rotating the arthroscope appropriately, but some pathology may necessitate a posterior portal due to curvature of talar dome.
- Loose bodies commonly reside posteriorly, so a thorough inspection of the posterior aspect is essential (Fig. 5).

Complications

- Reported complication rates range from 3 to 17 %.
- Neurovascular injury from portal placement is the most commonly reported complication (SPN is the most commonly injured).
- Others include instrument failure, damage to articular cartilage, infection, and complex regional pain syndrome.

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3 Ankle Arthrodesis

Take-Home Message
- Ankle arthrodesis is indicated for the patient with recalcitrant arthritic ankle pain.
- The most common etiology of ankle arthritis is posttraumatic.
- Surgical techniques can involve arthroscopic or open procedures and rely on adequate joint preparation for bony union.
- The results from ankle arthrodesis are excellent overall but with time will result in adjacent joint arthritis; the most common is the subtalar joint.
- Position of the arthrodesis in neutral dorsiflexion, 5° of valgus, and slight external rotation is critical to maximize function and minimize adjacent joint stress.

Introduction

- Nonoperative treatment of symptomatic ankle arthritis includes the use of shoe inserts or shoe modifications (SACH heel with rocker bottom), anti-inflammatory medications, and intra-articular injections (corticosteroid or hyaluronate) and use of either an ankle-foot orthosis or a rigid lace-up leather brace (Arizona type).
- The use of a walking cast has been suggested as a trial device to evaluate patient acceptance and degree of pain relief prior to arthrodesis.

Surgical Indications

- Persistent ankle arthritic pain that is functionally debilitating to the patient and is not relieved by nonoperative treatment methods.
- Etiology: most commonly posttraumatic arthritis (cause of more than 70 % of ankle arthritis).
- Other causes of painful arthritis include postinfectious, chronic instability, inflammatory arthropathy, neuropathic arthropathy, primary osteoarthritis, failed total ankle arthroplasty, and avascular necrosis.

Perioperative Considerations

- Need weight-bearing standing anteroposterior, lateral, and mortise views to assess radiographic changes in the joint, arthritis in the subtalar joints, and bony alignment (Fig. 6).
- Patient needs to be compliant with postoperative weight-bearing status and should be counseled on smoking cessation.

Surgical Techniques
Arthroscopic arthrodesis: typically for patients with little or no deformity of the ankle and good bone stock and density. Fixation can only be performed with screws.

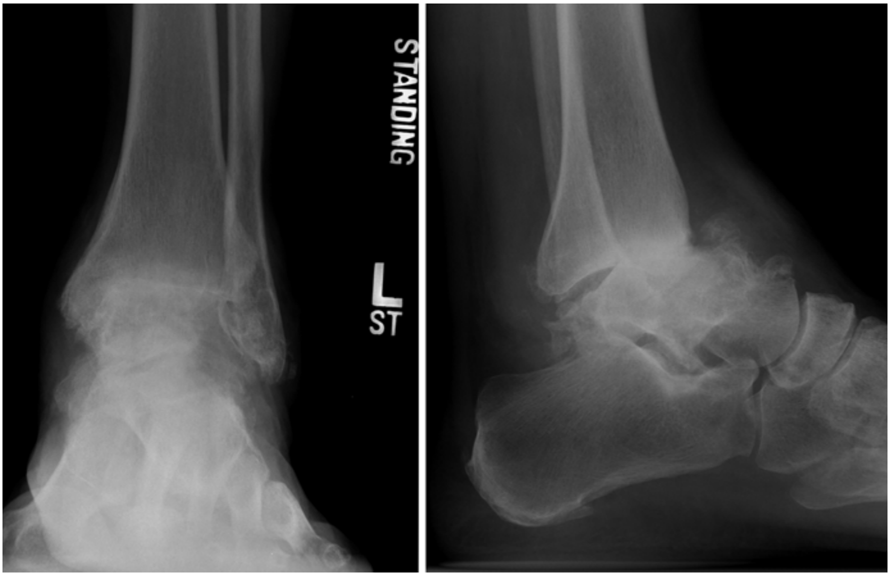

Fig. 6 AP and lateral WB views of a patient with end-stage ankle arthritis. Note the significant anterior subluxation of the talus on the lateral radiograph which must be addressed intraoperatively

Open arthrodesis: particularly useful for patients with severe ankle joint deformity. Better visualization of joint, correction of deformity, and allows use of plate fixation.

- Approaches: Options include lateral exposure where the fibula is either resected or osteotomized and replaced or an anterior approach (between the tibialis anterior and the extensor hallucis longus tendons), and least commonly performed is the posterior approach (in setting of compromised tissues).
- After achieving operative exposure of the joint to be fused → remove remaining cartilage and subchondral bone from the arthritis joint surfaces (Fig. 7).
- Obtain good bony apposition and reduction with compression of the joint surfaces.
- Then use rigid internal fixation (multiple 6.5 mm screws or a plate and screw construct) or external fixation for preexisting septic joint and those with severe osteopenia. Both isolated screw and plate and screw constructs have demonstrated a similarly high union rate that approaches 95–100 % with modern techniques (Fig. 8).

Optimal position of ankle joint: neutral dorsiflexion, 5–10° of external rotation, 5° hindfoot valgus (in order to keep hindfoot unlocked for accommodative hindfoot motion) (Fig. 9).

Tibiotalocalcaneal arthrodesis: can be performed with retrograde nail or a plate for concomitant subtalar and tibiotalar arthrodesis. Use of screws in isolation for a TTC fusion has demonstrated a higher nonunion rate compared to the other constructs.

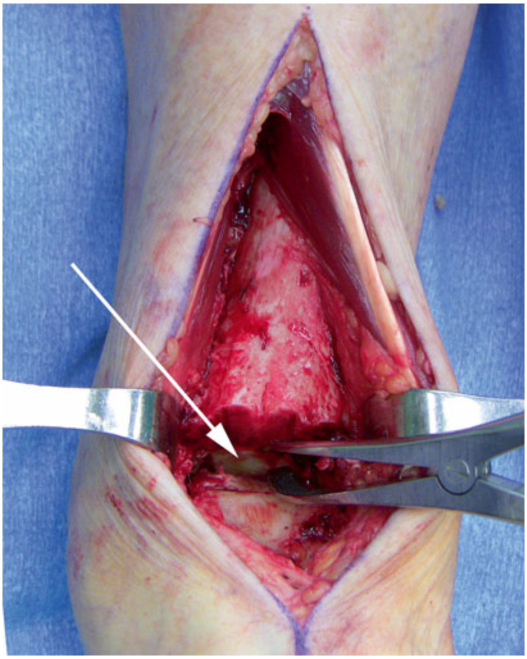

Fig. 7 The use of a lamina spreader allows visualization of the tibial articular surface (*arrow*) and facilitates cartilage removal and bony preparation. Alternating the lamina spreader medially and laterally will provide access to the entire joint

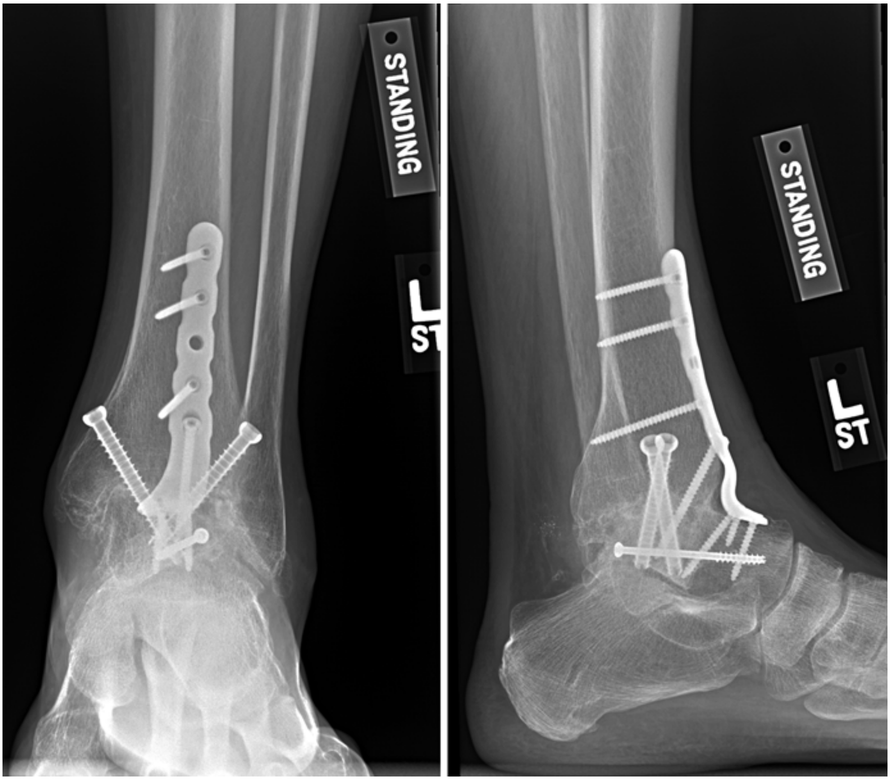

Fig. 8 AP and lateral WB views of a patient who is 1 year s/p an open ankle arthrodesis. Note the neutral position of the ankle with bony union at the tibiotalar joint

Fig. 9 Intraoperative view of the ankle demonstrating a neutral (90°) position of the arthrodesis

Results

- Patient satisfaction has been reported as 90 % following successful arthrodesis, with decreased pain and improved function.
- Gait studies demonstrate alterations in normal gait, but these changes are often clinically subtle with shoewear. A clear contrast has been demonstrated with barefoot walking with a longer stride length and decreased velocity compared to the normal population and total ankle arthroplasty.

Complications

- Adjacent joint arthritis (most common): usually considered an expected sequel of the subtalar joint
- Nonunion: rates range from 0 to 5 % in a recent meta-analysis to 40 %, elevated in tobacco users
- Malunion, wound healing, infection, and nerve injury

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