Technical Note

Low-Flow Ankle Arthroscopy for Gunshot Wounds With Retained Intra-Articular Ballistic

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Abstract: Gunshot injuries to the foot and ankle can cause unique and challenging situations for orthopaedic surgeons. The foot and ankle have limited soft-tissue coverage and highly congruent joint spaces, leading to injuries that are often intra-articular with substantial tissue loss. These injuries are often confounded by feet shod in footwear that is pulled into the path of the missile and corresponding tissue. Thus, we report our experience of using low-flow arthroscopy for extraction of retained ballistics, while irrigating and debriding the path of the missile.

Gunshot wounds (GSWs) to the foot and ankle can be devastating, with long-lasting functional impairments. The rate at which foot and ankle GSWs are sustained is also significant, outnumbering upper extremity, abdomen, and chest.[1] The morbidity of these injuries can cause severe impairment due to minimal soft-tissue coverage and highly congruent joints, which leads to the development of an underlying fracture nearly 80% of the time and retained intra-articular ballistics.[2] Further complicating surgical decisions is the fact that low-velocity GSWs are considered sterile but patients often have sock and shoe debris within the wound, leading to greater infection rates compared with GSWs to other locations.[3]

GSWs typically are classified by the velocity of the projectile, which is correlated with the amount of soft-tissue damage present. Low-velocity GSWs are attributed to projectiles with a velocity of <350 m/s and generally cause less severe injuries compared with greater-velocity weapons.[4] Low-velocity GSWs typically are caused by handguns and are more common in the civilian population. In addition to the velocity of the projectile, other factors that are involved in determining the severity of the injury include total kinetic injury possessed by the projectile at the time of impact, stability and entrance profile of the projectile, caliber, construction, and configuration of the bullet as well as depth and path traveled by the projectile within the body.[5]

Retained bullet fragments are conventionally removed when located within an intra-articular space due to the risk of mechanical trauma leading to cartilage damage and eventual loss of function as well as the risk of lead toxicity or plumbism.[6] While retained lead fragments from the projectile often are covered by avascular scar tissue when imbedded within soft tissue, projectiles within joint spaces are at increased risk of leading to plumbism as lead is soluble in synovial fluid. Plumbism can lead to synovitis, local destruction of intra-articular cartilage, and even cause systemic effects such as neurotoxicity, anemia, and nausea with emesis.[7]

To date, there are limited reports on the use of low-flow arthroscopy for treatment of GSWs with retained intra-articular fragments within the ankle. Previous studies have shown that arthroscopy can be used for treatment of wounds to both the hip and knee with risks of the procedure being greater when done by

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physicians with less arthroscopic experience and in patients with underlying fracture.[8,9] Our aim is to illustrate a technique using low-flow arthroscopy for extraction of retained ballistics, while fully irrigating and debriding the path of the missile.

Surgical Technique (With Video Illustration)

Preoperative planning is essential before the completion of the operative procedure. Plain radiographs should be obtained after GSW to the lower extremity to evaluate for the presence of underlying fracture and retained ballistic fragment(s). Advanced imaging in the form of computed tomography is then obtained to confirm the location of the ballistic fragments within the joint space and for further characterization of underlying fracture if present. Examples of patient radiographs and associated computed tomography scan after GSW to the lower extremity are demonstrated in Figure 1.

The patient can be positioned either supine or prone for completion of the procedure depending on the location of the retained fragments within the ankle joint. In a stepwise fashion, our surgical team performs the following steps for our prone position ankle arthroscopies. A tourniquet is applied to the proximal thigh before the patient being flipped on the operative table. Two gel foam bumps are placed underneath the patients' shoulders and lateral rib cage to allow for space for the abdomen (Fig 2). The shoulders are abducted, and elbows are flexed to 90° to allow for the arms to be positioned on each side of the patient. A safety strap is placed around the patient's waist and a

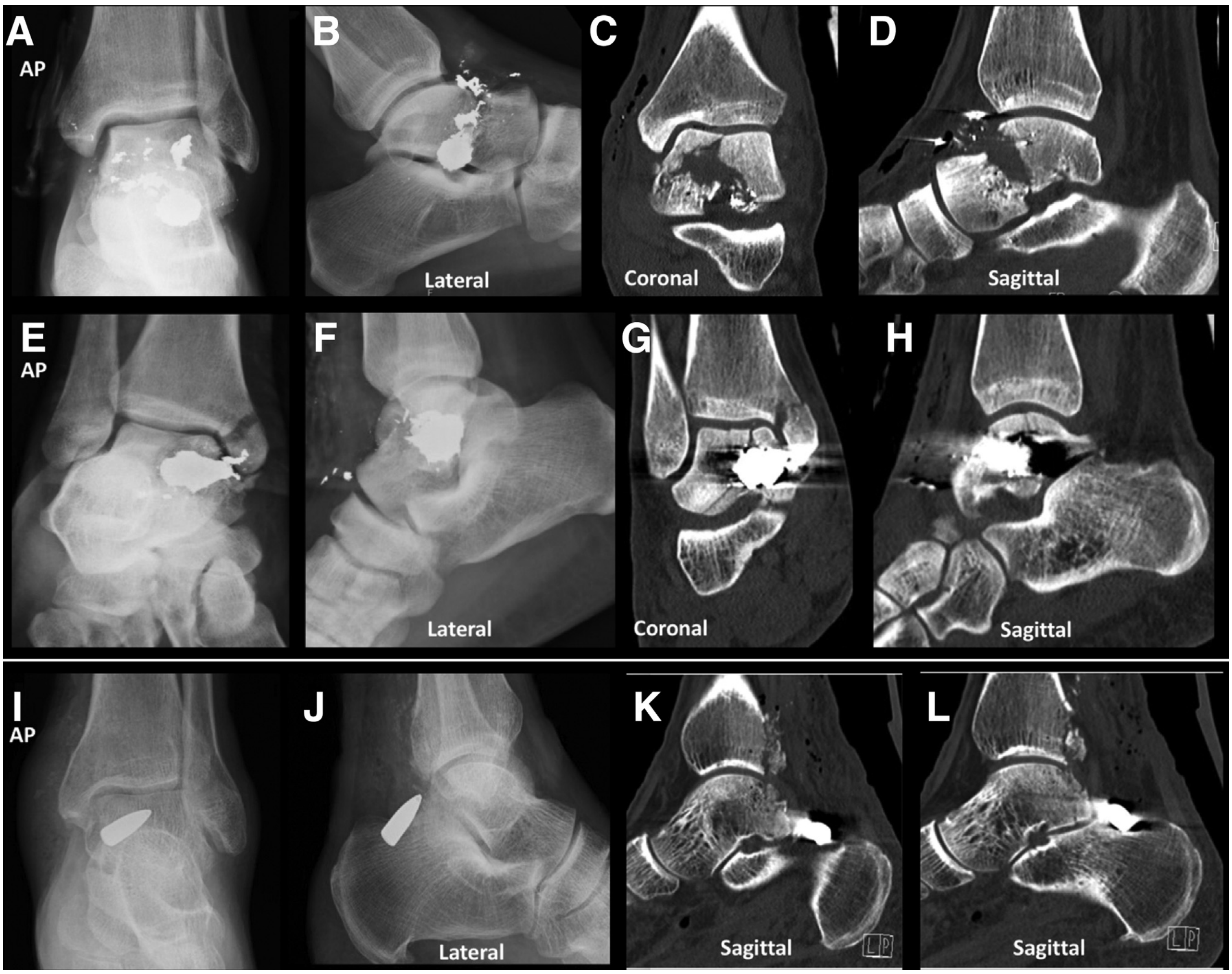

Fig 1. (A-D) Anteroposterior (AP) and lateral radiographs and associated coronal and sagittal computed tomography (CT) images of the ankle demonstrating evidence of an intra-articular ballistic missile with underlying talar neck fracture. Intra-articular ballistic foreign bodies are appreciated within the ankle and subtalar joints. (E-H) AP and lateral radiographs and associated coronal and sagittal CT images of the ankle demonstrating evidence of an intra-articular ballistic missile with underlying talar neck, talar body and medial malleolus fractures. (I-L) AP and lateral radiographs and associated sagittal CT images of the ankle demonstrating evidence of an intra-articular ballistic missile with underlying posterior talar body and posterior malleolus fractures.

Fig 2. Operative table setup for completion of prone ankle arthroscopic procedures demonstrating 2 gel foam bumps positioned underneath the patient's shoulders, foam padding for the patient's knees, and a small gel foam bump for positioning of the ankle. Gel foam bumps and foam padding is placed to ensure all boney prominences are well padded. The gel foam bump at the end of the table allows for the ankle to be manipulated during the course of the procedure.

4-inch strip of silk tape is applied around the contralateral leg to reduce overall movement of the body, as well as prevent the contralateral leg from moving during the procedure. Next, the operative extremity is positioned so that the ankle rests in neutral position off of the end of the operative table. The patient is then prepped and draped in typical sterile fashion. All the toes are wrapped together with Ioban (3M St. Paul, MN) to maintain complete sterility of the surgical field. Once completed and the patient is fully draped, the patent's pertinent structures are marked with a surgical skin marker. First, the borders of the medial and lateral malleolus are marked; then, the edges of the calcaneal tuberosity and medial and lateral edge of the Achilles tendon is marked (Fig 3). Depending on the position of the object and the soft-tissue injury, the portals can be adjusted, but in our experience standard anterior or posterior portals work well. Accessory portals should be used as needed keeping anatomic structures and locations in mind.

A low flow 1.9-mm mini-arthroscope (NanoScope; Arthrex, Naples FL) with a blunt plastic tip is inserted via a small stab incision (Fig 4). A low-flow arthroscope is used to reduce fluid extravasation into the damaged tissue and to mitigate any potential compartment pressurization. We then use a 20-gauge spinal needle to verify the position of the working portal, then create a small portal with the nick-and-spread technique. The joint is often hemorrhagic with damaged soft-tissue and foreign material noted. Establishing clear visualization is paramount before extensive debridement as landmarks will be difficult to appreciate. Next, a 3.5-mm shaver is introduced, and damaged tissue and hematoma is evacuated. Foreign body material from footwear, socks, and pants must be removed but can quickly clog shavers; therefore, we recommend using graspers for most objects.[10] Also, to prevent hydrojetting of the objects away from the arthroscope, we turn off the inflow before attempted retrieval. This will also help reduce hydrojetting objects over the dome of the talus to the opposing gutter preventing extraction or necessitating creation of additional portals. Retained ballistic fragments will vary, hollow points or soft-point ammunition expands and takes an irregular shape, whereas some ball tip may retain its missile shape. For extraction of missile-shaped rounds we arthroscopically rotate the round so the tip points out the portal to reduce soft-tissue impingement (Fig 5). Depending on the size of the foreign body, the established portal may need to be enlarged. An aggressive debridement of loose osteochondral fragments is performed to prevent

Fig 3. Before initiating a prone ankle arthroscopy, pertinent anatomical structures are marked, including the borders of the medial and lateral malleolus, edges of the calcaneal tuberosity, medial and lateral edge of the Achilles tendon, and path of the sural nerve. When being viewed from the lateral side, the borders of the fibula (F), approximate course of the sural nerve (S), and borders of the Achilles tendon should be marked to determine appropriate portal placement.

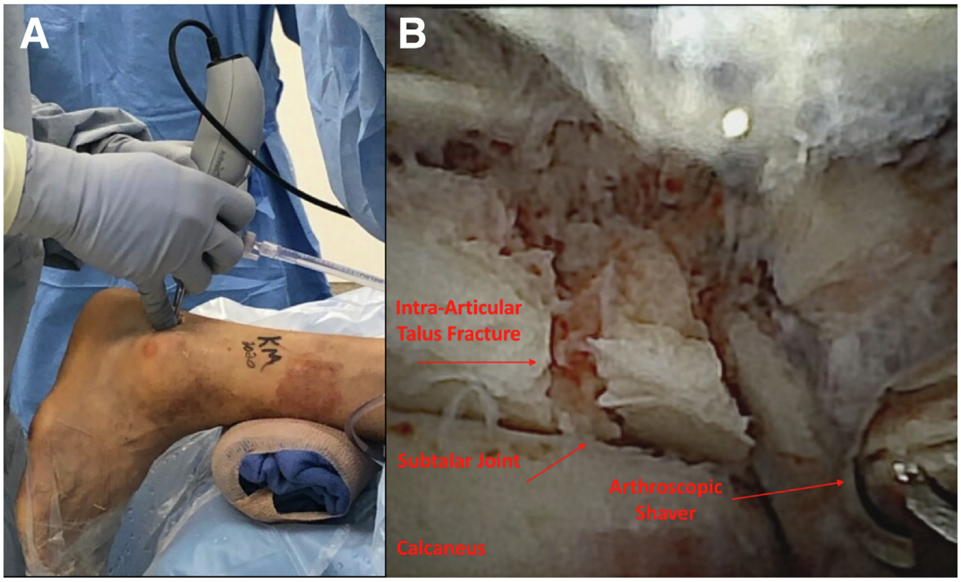

Fig 4. This particular patient was positioned prone for completion of the procedure based on the location of their intra-articular ballistic fragment. The standard nick-and-spread technique is used for creation of each portal on the medial and lateral side of the Achilles tendon. (A) The NanoScope (Arthrex, Naples FL) is inserted within the posteromedial portal for complete visualization of the ankle joint. A probe can be visualized within the posterolateral portal, which is used to evaluate intra-articular structures arthroscopically. (B) Arthroscopic view from the posteromedial portal demonstrating evidence of intra-articular talus fracture involving the subtalar joint. An arthroscopic shaver is placed within the posterolateral portal to debride loose osteochondral fragments and hemorrhagic tissue.

loose bodies in the future. A dynamic examination is then performed assessing joint stability, varus/valgus stress, flexion/extension, any instability should be investigated further. We also flex and extend the toes; posteriorly, the flexor hallucis longus tendon sheath is a large potential space that should be examined.

The bullet path or cavitation is then evaluated with placement of the arthroscope within the entrance wound and along its path. The path of the missile is thoroughly evaluated with direct endoscopic visualization (Fig 6). NanoScope (Arthrex) is uniquely suited to follow the path of a ballistic missile as it has a 120° straight forward field of view and is malleable allowing it to be bend along the path. We then place a shaver or grasper in the exit wound or accessory portal and perform an aggressive debridement of any residual foreign material or devitalized bone which must be removed to prevent sequestration and infection. The irrigation and debridement are nearly completely performed arthroscopic/endoscopically but standard

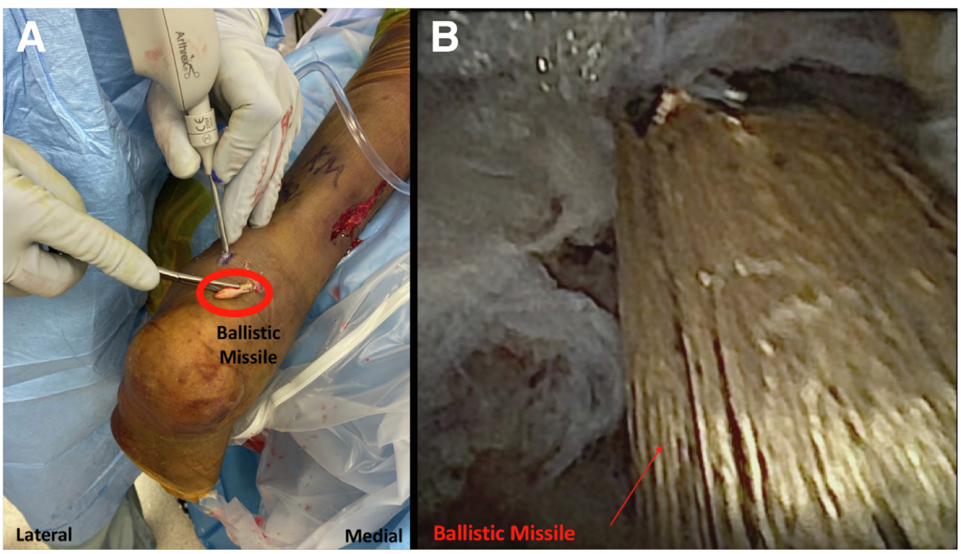

Fig 5. This patient is positioned prone for completion of the procedure based on the location of their intra-articular ballistic fragment. (A) The NanoScope (Arthrex, Naples FL) is shown within the posteromedial portal. The intra-articular projectile was removed successfully from the ankle joint using a retriever with the tip pointed toward the posterolateral portal. The projectile is shown outside of the patient's ankle. The NanoScope (Arthrex) is then used to perform irrigation and debridement of the path of the missile. (B) Intra-articular ballistic missile being extracted from the joint space with the tip facing the portal entry site.

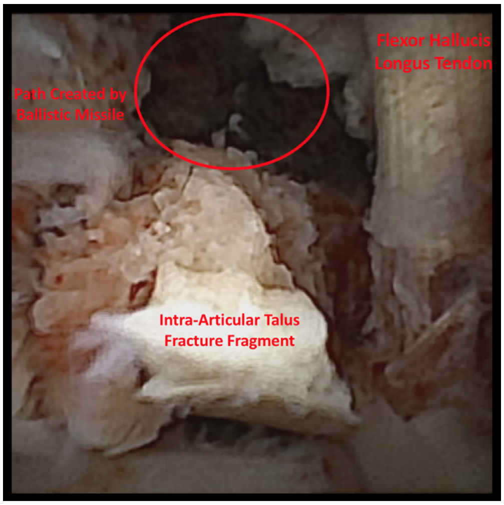

Fig 6. Arthroscopic view of the ankle from the posterolateral portal after extraction of the intra-articular ballistic missile. The flexor hallucis tendon can be viewed just medial to the path created by the projectile. Intra-articular osteochondral fragments with surrounding hemorrhagic tissue can be appreciated.

principals remain with a meticulous ordered pattern. We prefer to evaluate on the way in, then debride form deep to superficial, lastly sharply ellipse the skin back to a stable base.

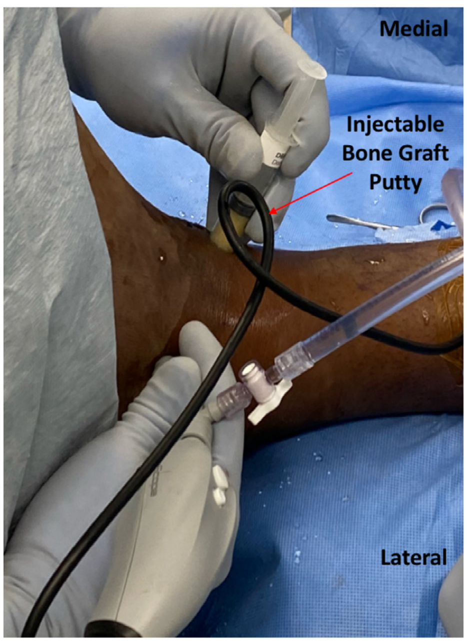

Fig 7. This patient was positioned supine for completion of the procedure based on the location of their intra-articular ballistic fragment. While performing arthroscopic removal of the projectile, a large amount of bone loss was appreciated within the talar body. The residual bone loss is being addressed acutely with primary grafting with arthroscopically injectable putty through a standard anteromedial portal under direct visualization using the nanoscope within the anterolateral portal (Arthrex, Naples FL).

Associated fractures and soft-tissue deficits must be critically evaluated determining the extent of contamination and surrounding injury. Larger more contaminated wounds may require multiple debridements and soft-tissue flaps. For clean low-caliber fractures amenable to fixation, we prefer immediately/early fixation with arthroscopically placed, cannulated fully threaded headless compression screws, which can be countersunk to preserve the articular surfaces while preventing long-term collapse.[11,12] We prefer these screws to be titanium, which reduces artifacts on magnetic resonance imaging if avascular necrosis of the talus is suspected postoperatively.[13] Residual bone loss is addressed acutely with primary grafting with arthroscopically injectable putty verse larger talar osteoperiostic grafting from the iliac crest (TOPIC) for larger defects needing structural support (Figs 6 and 7).[14,15] Final fluoroscopic images using the mini C-arm are then obtained to confirm successful removal of all retained intra-articular missiles (Fig 8).

Smaller wounds are left open with twice-daily dressing changes, but, in most cases, we prefer a bridging (entry and exit) negative pressure dressing set at 125 mm Hg constant pressure. A removable splint or boot is applied for soft-tissue rest and to prevent equines contractures. The patient's weight bearing status is dependent on the degree of soft-tissue pathology and if there is presence of underlying fracture and the method of fixation. A demonstration of successful removal of an intra-articular ballistic missile and evaluation of the residual ballistic missile path using our low flow arthroscopic technique can be found in Video 1.

Discussion

There is limited research describing the use of low-flow arthroscopy/endoscopy for the management of GSWs with retained intra-articular ballistic missiles within the foot and ankle. While it is recommended that retained intra-articular fragments are surgical removed, this is commonly completed using an open

Table 1. Advantages and Disadvantages of an Arthroscopic Approach to Surgical Removal of Intra-Articular Ballistic Missiles When Compared With an Open Arthrotomy

Advantages	Disadvantages
Minimizes soft-tissue striping	Operating room setup, requiring appropriate arthroscopic equipment
Maximizes intra-articular visualization	Prolonged operative time
Provides visualization of ballistic track and retained nonradiolucent fragments	Need for surgeon familiarity with arthroscopy

Table 2. Technical Pearls and Pitfalls of an Arthroscopic Approach for Surgical Removal of Intra-Articular Ballistic Missiles

Pearls	Pitfalls
Use of low-flow arthroscopy or gravity flow	Use of high-flow 4.0 arthroscopy with pressure greater than 40 mm Hg
Use of fluoroscopy in combination with arthroscopy to identify foreign bodies	Poor portal placement near neurovascular structures
Uses small joint arthroscopy equipment with minimal damage to surrounding soft tissues	Fail to obtain preoperative computed tomography scan to identify foreign body location and possible underlying fractures
Allows for removal of all devitalized tissue in an organized fashion	

arthrotomy when within the ankle joint.[4] There are many advantages of an arthroscopic approach to surgical removal of intra-articular ballistic missiles when compared with an open arthrotomy (Table 1). When compared with an open arthrotomy without arthroscopy, which uses blind sweeps for debridement, an advantage of a low-flow arthroscopic technique allows for direct visualized debridement of the tract of the ballistic missile, which can decrease the risk of infection and retained intra-articular foreign bodies. If no underlying fracture is present, our patients are allowed early progressive protected weight-bearing, limited by soft-tissue maturation. Given the congruency and talus geometry, the preoperative radiographs and computed tomography scan must be evaluated thoroughly to determine the trajectory of the ballistic missile and allow for debridement of the path during the operative procedure. Our portals and patient positioning are highly dependent on the location of the missile and the wounds.

An additional advantage of an arthroscopic technique for bullet removal when compared with an open arthrotomy technique is that it allows for a quicker postoperative recovery because of its minimally invasive nature to a joint that has sustained a traumatic insult.[16] Using the described arthroscopic surgical technique also may decrease the amount of postoperative pain, stiffness, scar formation, and soft-tissue morbidity associated with the procedure. Arthroscopic evaluation of the joint allows for clear visualization of the articular surface and opportunity for interventions at the time of the operative procedure if needed which can include removal of foreign bodies, chondroplasty, grafting of areas with significant bone loss or fixation of underlying fracture.

While low-velocity GSWs with retained intra-articular missiles are attempted to first be treated arthroscopically within our practice, the surgeon has the opportunity to convert the case to an open procedure if needed, based on their findings. Based on the nature of the wound, low-velocity GSWs with minimal contamination and soft-tissue disruption may require open debridement, which can also be supplemented by our arthroscopic technique to allow for a more thorough debridement. Before implementation of an arthroscopic technique for treatment of intra-articular ballistic missiles within one's practice, it is important understand some of the technical pitfalls, which include use of appropriate arthroscopic technique, instrumentation, and preoperative planning (Table 2). More research regarding the use of low-flow arthroscopy in management of GSW with retained intra-articular ballistic missiles within the ankle joint is needed but is difficult due to the uncommon nature of these injuries.

The potentially decreased risk profile, faster patient recovery, successful irrigation, and debridement of the path of the ballistic missile and decreased fluoroscopy time are all benefits of the described technique. In conclusion, using low-flow arthroscopy can allow for foot and ankle surgeons to safely and effectively perform successful bullet removal and irrigation and debridement of the intra-articular surface after GSW, which is often confounded by feet shod in footwear that is pulled into the path of the missile and corresponding tissue.

Fig 8. Mini C-arm fluoroscopic image of the lateral ankle demonstrating no evidence of any radio-opaque foreign bodies within the ankle joint after successful removal of the intra-articular ballistic missile using low-flow arthroscopy.

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