CLINICAL TECHNIQUE

Anterior Hemiepiphysiodesis of the Distal Tibia: A Step-by-step Surgical Technique Guide

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Received on: 09 November 2023; *Accepted on:* 04 December 2023; *Published on:* 17 January 2024

Abstract

Aim: This paper aims to serve as a guide for surgeons to prepare, execute, and perfect anterior hemiepiphysiodesis of the distal tibia (AHDT).

Background: Treatment of persistent or recurrent equinus deformity following multiple conservative and surgical interventions in patients with idiopathic clubfoot or neuromuscular conditions can be challenging, and multiple surgical options are presented in the existing literature. Anterior hemiepiphysiodesis of the distal tibia is an option that seems to be safe and efficient in treating this entity. To the best of our knowledge, there is not yet any detailed description of this surgical technique in the English literature.

Technique: The AHDT detailed surgical technique includes patient positioning, careful distal anterior tibial approach, placement of guided growth plates, fixation with epiphyseal and metaphyseal screws under fluoroscopic guidance, meticulous closure, and postoperative measures.

Conclusion: This guide can be used pre-operatively to plan the surgery, intra-operatively to aid in smooth and safe step progression, and post-operatively to assist in critical critiquing.

Clinical significance: By understanding the various stages of the surgery as well as the anatomy, pitfalls can be avoided and AHDT can be performed efficiently.

Keywords: Ankle, Clubfoot, Equines, Guided growth, Surgical anatomy, Tibia.

Strategies in Trauma and Limb Reconstruction (2023): 10.5005/jp-journals-10080-1596

Background

Persistent or recurrent equinus deformity in idiopathic clubfoot or in neuromuscular conditions following multiple conservative and/or surgical interventions is one of the most challenging obstacles for pediatric orthopedists. The ultimate goal of treatment is to have a functional, pain-free, plantigrade, mobile, and shoeable foot. Numerous surgical options have been presented in the literature, including revision of extensive posterior release, supra-malleolar osteotomy, talectomy, triple arthrodesis, and correction by external fixators. These options can have limited results, be technically challenging, or may carry significant risks. Additionally, some of these surgical interventions are associated with an increased risk of perioperative complications and prolonged recovery.[1,2]

Anterior hemiepiphysiodesis of the distal tibia (AHDT) is a newer option that improves dorsiflexion and has demonstrated positive results.[3–5] It is indicated for pediatric clubfoot and neuromuscular condition patients with residual or recurrent equinus, open physeal plates, and who have substantial growth remaining. The principle behind AHDT originated from the extrapolation of treatment for flexion contracture of the knee.[3,6–8] Little has been written on the topic and to the best of our knowledge, there is not yet any detailed description of this surgical technique in the English literature. We believe AHDT can be performed in a safe manner and be a very powerful tool in the arsenal of options for treating persistent or recurrent equinus.

This surgical technique article aims to describe the step-by-step procedure of AHDT. The relevant ankle anatomy encountered during AHDT is detailed and all steps are accompanied by clinical intraoperative photos and radiographs. The technique is written in a style based on a description of a recent case at our institution. This article will guide surgeons in a clear and precise fashion, with all the surgical specifics beginning from patient position and concluding with hospital discharge.

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How to cite this article: Katz A, Dumas É, Hamdy R. Anterior Hemiepiphysiodesis of the Distal Tibia: A Step-by-step Surgical Technique Guide. Strategies Trauma Limb Reconstr 2023;18(3):174–180.

Source of support: Nil

Conflict of interest: None

Technique

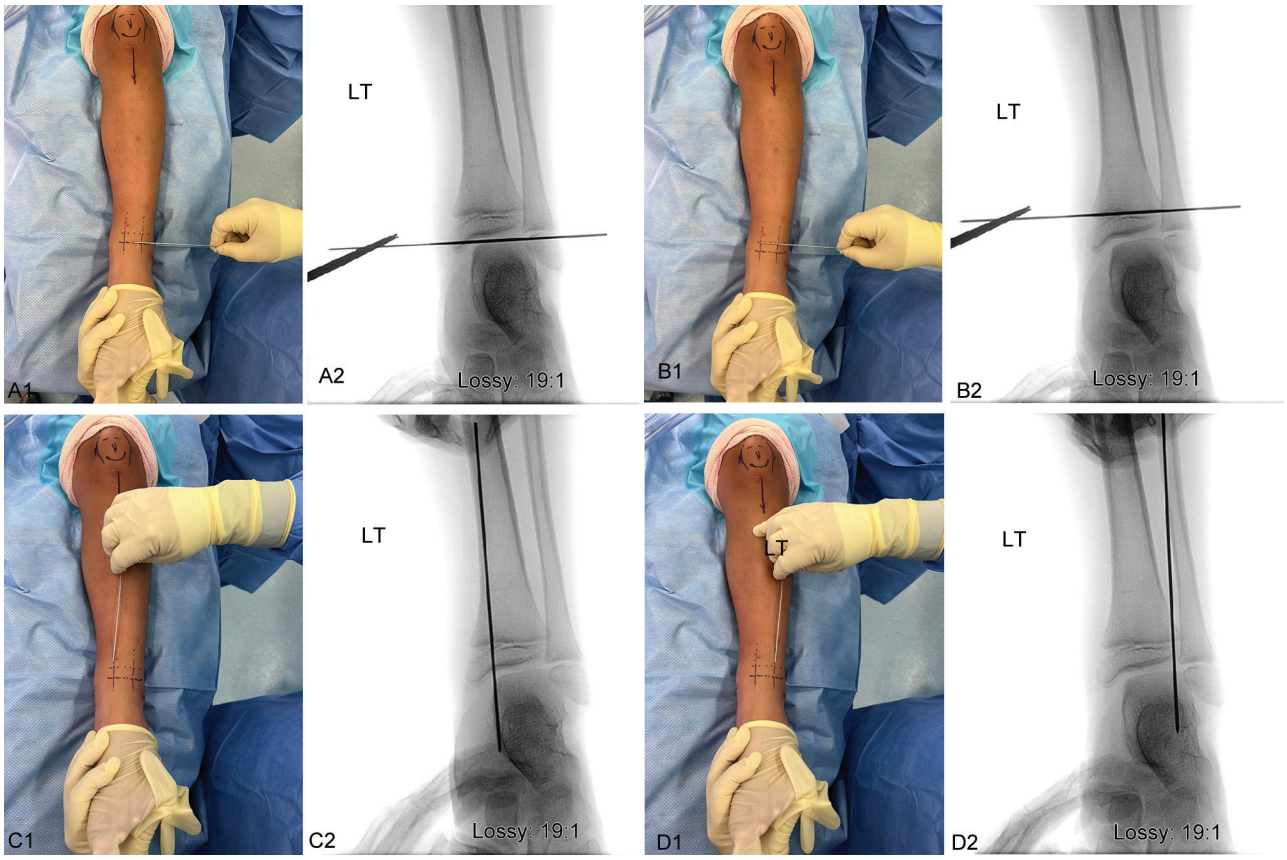
1. Preparation
   a. The patient is placed in the supine position on the radiolucent operative table and preoperative prophylactic antibiotics were given.
   b. A "bump" is placed under the ipsilateral upper thigh and buttock and a leg elevator (example: bone foam) is placed under the surgical leg (Fig. 1).
   c. The fluoroscopic C-arm is positioned on the side of the surgical leg.
   d. A tourniquet is placed on the upper thigh.
   e. The patient is cleaned and draped in a sterile manner (Fig. 2).

Fig. 1: Patient's leg positioning, including leg elevator and tourniquet

Fig. 2: Sterile draping

f. Under fluoroscopy, the anatomical landmarks are identified and labelled with a surgical skin marker (the malleoli, the joint line, the physis, and the medial and lateral borders of the distal tibia) (Fig. 3).
g. The incision is marked, the midline between the medial and lateral borders of the distal tibia, centred on the physis, approximately 2.5 cm above and below the physis (Fig. 4).
h. The tourniquet is inflated after exsanguination of the limb with an esmark bandage.

2. Approach
   a. A scalpel (#15 blade) is used to cut the skin in the midline of the distal anterior tibia according to the planned skin-marked incision (about 3–5 cm).
   b. Careful dissection of the subcutaneous soft tissues is carried out, taking care to protect the superficial peroneal nerve, passing from lateral to medial on the dorsal aspect of the foot.
   c. Exposure of the extensor retinaculum and anterior compartment fascia is performed, and a longitudinal incision in line with the skin incision, lateral to the anterior tibialis tendon, is made (Fig. 5).
   d. Relevant anatomy is then identified; tibialis anterior, the extensor hallucis longus, the extensor digitorum longus, as well as the neurovascular bundle lying between the extensor hallucis longus and extensor digitorum longus (Fig. 6).
   e. With the use of retractors, the extensor hallucis longus and the neurovascular bundle are pulled laterally and the tibialis anterior medially.
   f. Incision of the fascia deep to the tibialis anterior tendon is made, to expose the distal tibia surface (Fig. 7A).
   g. The surface of the distal tibia is gently cleared with a Cobb elevator, taking care not to enter the ankle joint or injure the periosteum (Fig. 7B).
3. Plate placement
   a. Under fluoroscopic guidance, the guided growth plate on the distal anterior surface of the tibia is placed. The distal hole of the plate sits on the epiphysis, the proximal hole on the metaphysis, and the centred hole for the guiding pin lays over the physis. Attention is paid to being well-centred medial-lateral on the tibia (Fig. 8). [We use two 12 mm 2-holed plates side by side, as discussed in the "Discussion" section. We start first with the lateral plate and then the medial (Fig. 9).]
   b. The plate is secured with non-threaded K-wires in the centre of the plate going in the physis (Fig. 10).
   c. Under fluoroscopic guidance, k-wires are placed in the screw holes of the plate in the desired future screw location using the pin guide. A ball-tipped-wire-guide is used in the hole of the plate to aid in K-wire trajectory and placement. The proximal wire in metaphysis aims a little proximal to avoid the distal tibial physis that is oriented in a dome-like fashion. The distal wire in the epiphysis aims straight posteriorly, to avoid violating the physis proximal and the joint distal (Fig. 11).
   d. The anterior cortex of the distal tibia is drilled in preparation for the screws, drilling only to breach the anterior cortex.
   e. Placement of the screws (3.5 mm cannulated) over the k-wires, slowly and alternately tightening in a balanced fashion (Fig. 12).
   f. Attention to making sure that the screws do not violate the joint or the physis and that the plate is not compressed too tight on the periphery on the physis.
   g. The screws are placed in a parallel fashion and have strong purchase.
   h. (If a 2nd plate is used, as in our case) The same steps above are now repeated for the 2nd plate placement and fixation, with the k-wires placed parallel to the screws of the first plate (Figs 13 and 14).
   i. Live view fluoroscopy is used to verify in full plantar flexion and full dorsiflexion that there is no impingement of the plate on the dorsal aspect of the talus (Fig. 15).
   j. A final fluoroscopy is performed (Fig. 16).
4. Closure
   a. Washout and irrigation are performed with saline.
   b. The fascia deep to the tibialis anterior tendon is sutured with size 0 absorbable sutures (Vicryl) over the plates to allow smooth gliding of the tendons over the anterior surface of the tibia (Fig. 17).
   c. Extensor retinaculum is closed over the tendons with size 0 absorbable sutures (Fig. 18).
   d. Closure of the skin is performed with inverted deep subcutaneous simple stitches with 2-0 absorbable sutures and 4-0 absorbable subcuticular running stitches over it (Fig. 19).
   e. Steri-strips are placed on the wound.
   f. Local anaesthetic is given.
   g. The tourniquet is deflated and removed.
   h. Sterile bandages are placed on top of the Steri-strips.



Figs 3A1 to D2: (A1 and A2) Marking the joint line. (A1) Clinical photo; (A2) Under fluoroscopy; (B1 and B2) Marking the physis. (B1) Clinical photo; (B2) Under fluoroscopy; (C1 and C2) Marking the medial border of the distal tibia. (C1) Clinical photo; (C2) Under fluoroscopy; (D1 and D2) Marking the lateral border of the distal tibia. (D1) Clinical photo; (D2) Under fluoroscopy

Fig. 4: Marking the incision

Fig. 5: Extensor retinaculum incision in line with skin incision, lateral to tibialis anterior tendon. Tibialis anterior tendon is exposed

i. The patient's ankle and foot are cast in a three-sided posterior cast.
j. The patient is transferred to the PACU (Post-anaesthesia care Unit) in stable condition.

5. Post-operation
   a. Patient is discharged the same day.
   b. Patient is informed of weight-bearing as tolerated.
   c. Follow up in the clinic at 1–2 weeks post-operation for wound check and removal of the cast.
   d. Follow up with X-rays at 3 months and then 6 months after to monitor the guided growth.

Discussion

Anterior hemiepiphysiodesis of the distal tibia is a simple but powerful tool in addressing persistent or recurrent equinus. A review of the literature was conducted, however, we were unable to

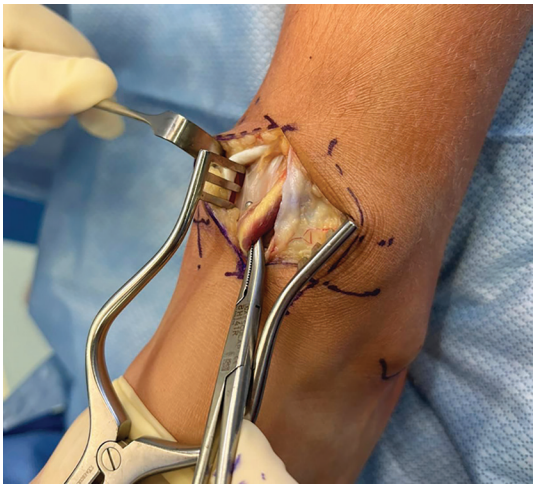
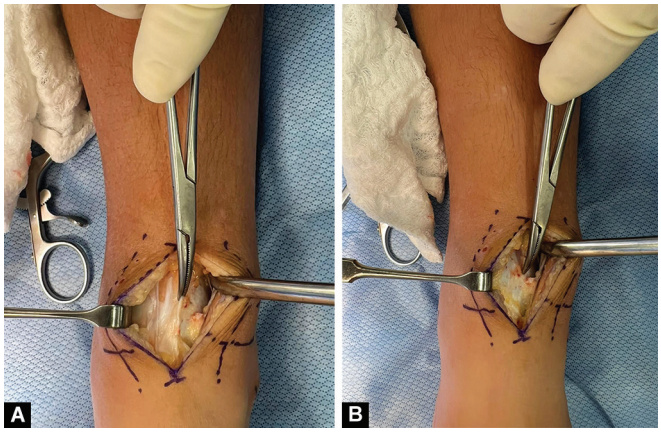


Fig. 6: Identification of tibialis anterior in self-retaining retractor and extensor hallucis longus (EHL) in hemostat. (Neurovascular bundle is lateral to EHL)



Figs 7A and B: (A) Incision of the fascia deep to the tibialis anterior tendon; (B) Exposure of the anterior surface of distal tibia

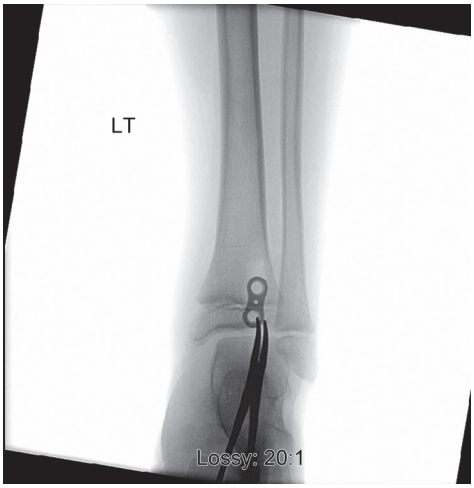


Fig. 8: Positioning of the first 2-holed plate on the more lateral side of anterior distal tibia under fluoroscopy guidance. Note that the epiphyseal hole is entirely in the epiphysis, neither violating the joint nor the physis

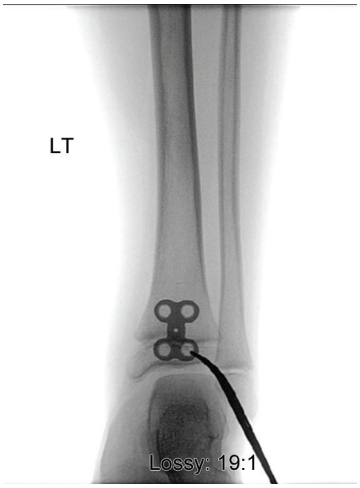
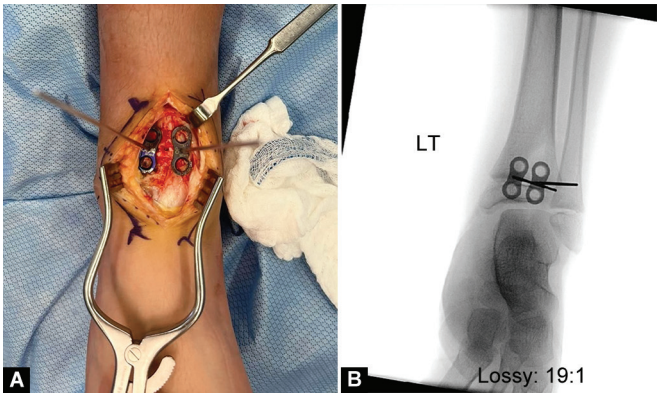


Fig. 9: Example of the "I" plate (4-holed) that is too large for this patient, with the screw hole overlapping with the physis



Figs 10A and B: (A) Securing plates with central k-wires in the physis; (B) Under fluoroscopic guidance making sure to be centred on the AP

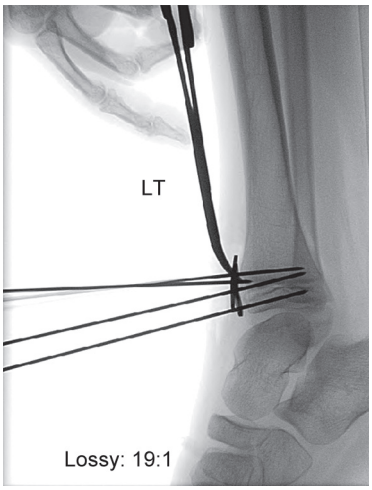
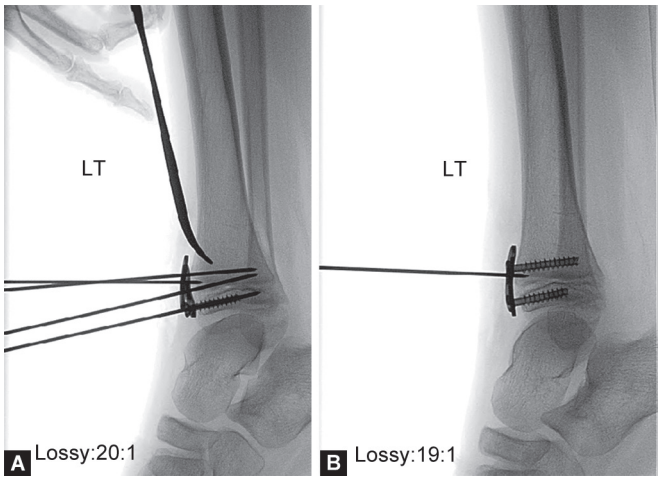


Fig. 11: Placing k-wires in plate holes guiding for screw placement. Note the plate is distalised to assure distal screw is entirely in the epiphysis, avoiding the physis

find a detailed surgical (with pictures and fluoroscopy) description of this procedure. The technique has steps that are crucial to the guided growth of the distal tibia, but also vital nuances that are



Figs 12A and B: Screw placement over the k-wires. (A) Epiphyseal screw placement first, over k-wire; (B) Plate fixation with screws and k-wires out

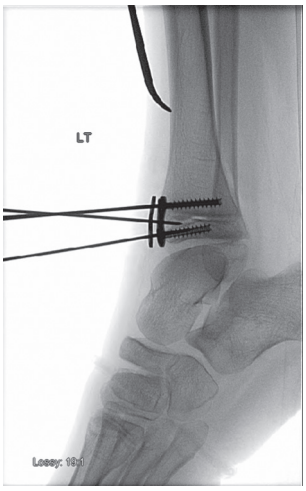


Fig. 13: K-wires placement for the second plate, parallel to the screws of the first plate

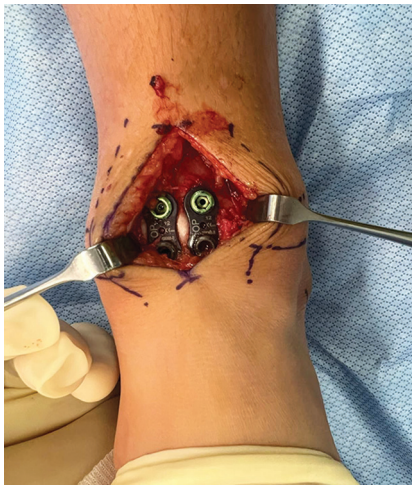
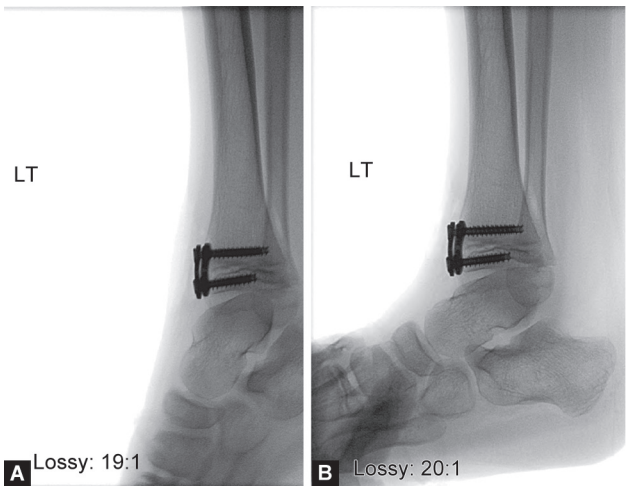
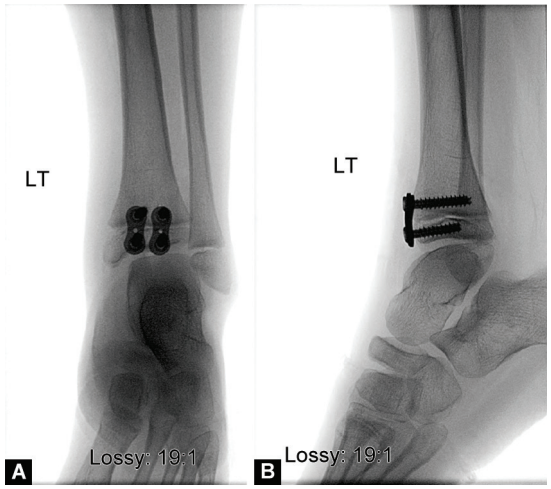


Fig. 14: Plates fixated with screws

employed to decrease potential pitfalls and complications. It is of utmost importance to know the surgical site anatomy to ensure a smooth and complication-free procedure. The reasoning, rationale,



Figs 15A and B: (A) Fluoroscopy in full plantar flexion; (B) Full dorsiflexion, making sure the plate does not impinge with full ROM

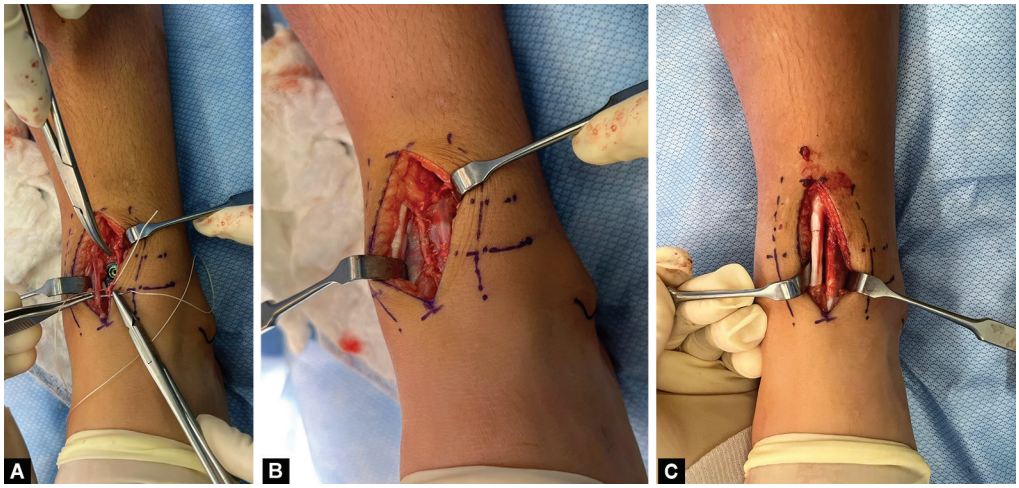


Figs 16A and B: Final fluoroscopy (A) AP; (B) Lateral

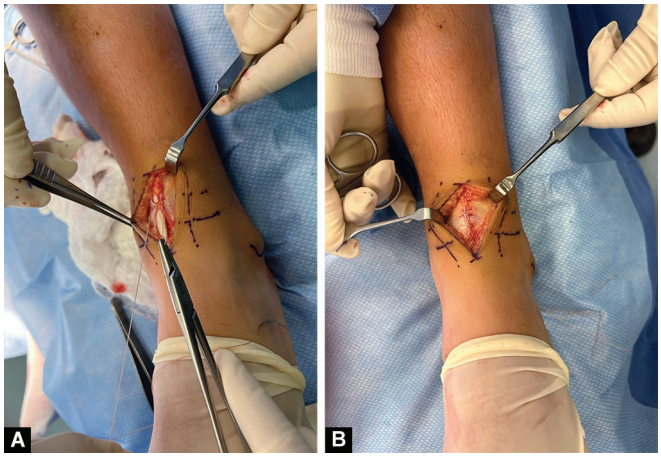
and elaboration behind some of the technical pearls are explained below.

In the "Preparation" section, in step "1 (b)," a "bump" is utilised under the ipsilateral posterior thigh and buttock to hold the surgical leg in a neutral position. A "bump" can be any radiolucent placeholder, for example, a gel roll, a rolled sheet, or folded bed pads. The "bump" prevents positional external rotation of the leg in the supine position and helps keep the patella facing skyward. These steps maintain the anterior ankle facing the surgeon and ensure the AHDT is placed correctly. A bone foam leg elevator is used to assist the C-arm fluoroscopy to obtain easy lateral X-rays during the operation without the 2nd leg obscuring the image. In step "1 (f)," the joint and physis are marked to aid in the initial incision location, the surgical approach, and plate placement. It also allows a clean and tension-free skin closure at the end of the surgery.

In the "Approach" section, in steps "2 (b–d)," the soft tissue is slowly dissected and anatomy is identified. This simple stage of the procedure permits clean closure according to the anatomical layer at the end of the surgery, adequate coverage of the plate with soft tissue, and prevents iatrogenic injury to the neurovascular bundle during retraction or closure. In step "2 (g)" it's important not to injure or dissect the periosteum as good blood supply is important



Figs 17A to C: (A) Closure of the fascia deep to the tibialis anterior tendon over the plates; (B) The fascia closed; (C) Tendons in normal anatomical position over the deep fascia



Figs 18A and B: (A) Closure of extensor retinaculum over the tendons; (B) Extensor retinaculum closed

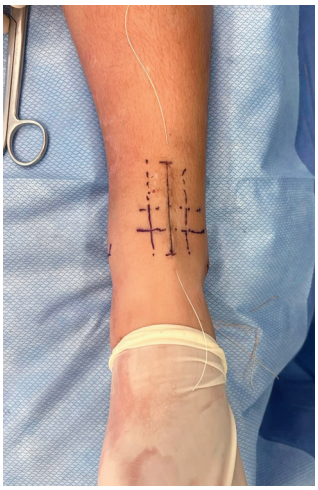


Fig. 19: Closure of the skin

to bony health and in case the plate is removed in the future, it's important to ensure balanced ankle growth.

In the "Plate placement" section, in step "3 (a)" it is vital to choose the appropriate plate size. The epiphyseal screw should be centred between the physis and joint, in the proximal-distal axis, without violating these two structures, and without causing impingement. If the plate is too large or placed too distal, it can cause limitation on ankle dorsiflexion. The plate size can be planned pre-operation but also verified under vision, as well as, fluoroscopically intra-operatively (Fig. 8).

Anterior hemiepiphysiodesis of the distal tibia can be achieved with a different size, brand, style, or shape-guided growth plates. In our institution, it has been found that two side-by-side "8-shaped plates" achieve the desired goal without risking injury to the physis or joint. An "I" (butterfly shaped) plate can be utilised, but sometimes they are too large (centred over the physis, the distal screw can violate the articular joint surface or injure the physis) (Fig. 9). We use two 2-holed 12 mm eight-plates because we want a stronger and wider hemiepiphysiodesis and believe that only placing one plate could possibly be insufficient for a balanced guided growth (if the plate wasn't exactly placed at centre anterior, it could result in valgus-varus malalignment). Therefore, two plates side-by-side are used to restrict a wide anterior-sided distal tibia growth.

In step "3 (b)" the plate is temporarily fixated with a non-threaded K-wire to avoid physis disturbance. The dome shape of the distal tibial physis and ankle joint must be taken into consideration, and therefore in step "3 (c)", the K-wires and subsequent screws are carefully (under fluoroscopy) aimed and positioned to provide maximum guided growth with the lowest risk for physis or joint injury. A ball-tipped guide is used to aid in K-wire placement as it allows for a wide trajectory while maintaining the K-wire and subsequent screw to be centred in the plate hole.

In step "3 (e)" the plate screws are alternately tightened to ensure a balanced placement of the plate. Also, in step "3 (f)" the screws and plate are not over-tightened in order to avoid periosteum injury or bone necrosis. Healthy bone is vital in case the plate needs to be removed in the future and growth is desired from the anterior distal tibia.

In step "3 (g)" the screws are placed in a parallel fashion to optimise the guided growth correction.[9–11] While the length of the screws has proven to be of little importance, their anatomical placement and avoidance of physis injury are vital.[12]

At the end of plate placement and fixation with screws, step "3 (i)," the foot is passively dorsiflexed and plantarflexed under live fluoroscopy to verify free movement of the ankle joint and lack of impingement of the newly placed hardware.

In the "Closure" section, steps "4 (b–c)," the soft tissue is meticulously closed in an anatomical fashion. The clean and precise approach allows for an easy closure. The plate is well covered and the tendons are able to glide freely without any plate irritation.

At the end of the surgery, step "4 (i)," the patient's lower leg is placed in a supportive cast purely for pain management and soft tissue rest. The patient may bear weight on the operated leg, in the cast, as tolerated.

Clinical Significance

The purpose of this article is to serve as a guide for surgeons to prepare, execute, and perfect AHDT. This clinical technique detailed above can be used pre-operatively to plan the surgery, intra-operatively to aid in smooth and safe step progression, and post-operatively to assist in critical critiquing. By understanding the stages of the surgery as well as the anatomy, pitfalls can be avoided and AHDT can be performed efficiently.

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