CLINICAL TECHNIQUE

Oblique Dorsiflexion Osteotomy of the Distal Tibia for Fixed Ankle Equinus: Surgical Technique

Ramiro Olleac[1], Fernando Farfan[2], Lucas Acosta[3], Sabrina Campero[4], Mohan V Belthur[5]

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Abstract

Aim: There are significant challenges in the treatment of a severe rigid ankle equinus caused by a flat-topped talus, arthrogryposis, burn sequelae, or extensive scarring. Conventional approaches, such as soft tissue releases, often fail due to joint incongruence or compromised soft tissues, thereby necessitating supramalleolar osteotomies. The classic transverse supramalleolar osteotomy (TSO) of the distal tibia can lead to secondary anterior translation of the centre of rotation of the ankle and alters mechanical and anatomical axes. An alternative technique involves an oblique closing wedge osteotomy of the distal tibia, with a fulcrum near the ankle joint. This technical note delineates the planning parameters and procedural steps for the oblique dorsiflexion osteotomy of the distal tibia (ODODT).

Method: Using an anterior approach to the distal tibia, the "alpha angle," which determines the size of the closing wedge required for the foot to be plantigrade, is resected with a fulcrum at the most posterior part of the ankle joint, ensuring that the posterior cortex remains intact. The inclination of this resected wedge is planned preoperatively and is referred to as the "beta angle." This aims to equalise the lengths on both sides of the osteotomy. For osteotomy fixation, 2 or 3 cannulated screws in lag mode are employed. Postoperatively, a short cast boot is used for 6 weeks.

Results: The ODODT is a salvage solution for severe rigid ankle equinus when first-line foot and ankle procedures are impractical due to tibiotalar incongruence or poor soft tissues. Advantages include minimal translation of the centre of rotation of the ankle, excellent stability when the posterior cortex remains intact, avoidance of large internal fixation devices, and cost-effectiveness, making it suitable for low-resource settings.

Keywords: Burns, Equinus deformity, Flat topped talus, Oblique osteotomy, Supramalleolar osteotomy.

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Introduction

The treatment of severe rigid ankle equinus from a flat topped talus, arthrogryposis, burn sequelae, or deep scarring from multiple previous surgeries is a challenge.[1–6] When conventional procedures for treating equinus are not practical due to incongruence at the tibiotalar joint or poor soft tissue conditions, supramalleolar osteotomies are used. The classic approach is the transverse supramalleolar osteotomy (TSO) of the tibia which is performed parallel to the ankle with a fulcrum in the posterior cortex of the tibia.[2,5–10] As this procedure is not at the level of the apex of the deformity [centre of rotation of angulation (CORA)], it results in a secondary anterior translation of the centre of rotation of the ankle with a significant modification of the mechanical and anatomical axis of the tibia.[11–13] This which may lead to abnormal biomechanics, a poor cosmetic result, and potential premature ankle arthritis (Fig. 1).[13,14]

A possible alternative to mitigate such translation is to perform an oblique closing osteotomy shaped like an isosceles triangle with a fulcrum close to the ankle joint. This approach is commonly used for the correction of coronal plane deformities near joints such as cubitus varus, ankle valgus, and knee varus.[14–17] The geometric design and planning parameters for the oblique dorsiflexion osteotomy of the distal tibia (ODODT) are not well described in the literature. The aim of this technical note is to explain the parameters in planning and to describe the sequence of steps to perform this surgical procedure.

Method

The ODODT is a second-line treatment for fixed ankle equinus deformity in patients with closed physes. This means that posterior soft tissue releases, anterior hemiepiphysiodesis of the distal tibia, and foot osteotomies have to be considered before this option. Candidates for ODODT have a rigid equinus at the ankle joint associated with flat top talus, incongruent ankle joint, burns, or severe adhered scar tissue in the posterior region of the ankle.[15] Contraindications are advanced degenerative conditions with less than 50% of the tibiotalar joint surface remaining and active infections of the bone.[13] Relative contraindications are severe tibial

[1,4]Pediatrics Orthopeadics Division, N. Avellaneda Hospital, San Miguel de Tucumán, Tucumán, Argentina

[2,3]Bioengineering Department, Faculty of Exact Sciences and Technology (FACET), Neuroscience and Applied Technologies Laboratory (LINTEC), National University of Tucuman, Instituto Superior de Investigaciones Biológicas (INSIBIO), National Scientific and Technical Research Council (CONICET), San Miguel de Tucumán, Tucumán, Argentina

[5]Department of Orthopedic Surgery, Phoenix Children's Hospital, Phoenix, Arizona, United States of America

Corresponding Author: Ramiro Olleac, Pediatrics Orthopeadics Division, N. Avellaneda Hospital, San Miguel de Tucumán, Tucumán, Argentina, Phone: +54 901160070955, e-mail: ramiroolleac@hotmail.com

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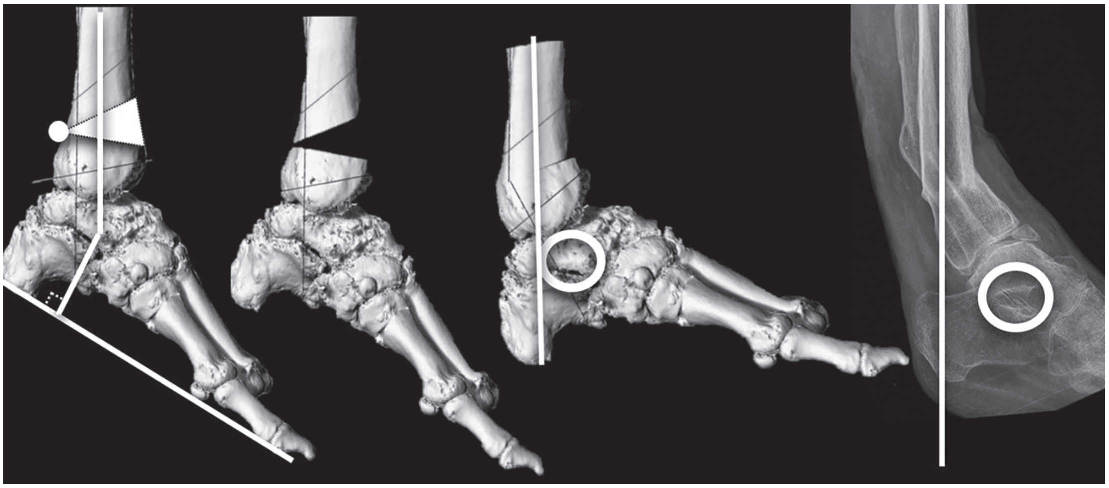


Fig. 1: Anterior translation of the centre of rotation of the ankle in relation to the mechanical axis of the tibia after TSO

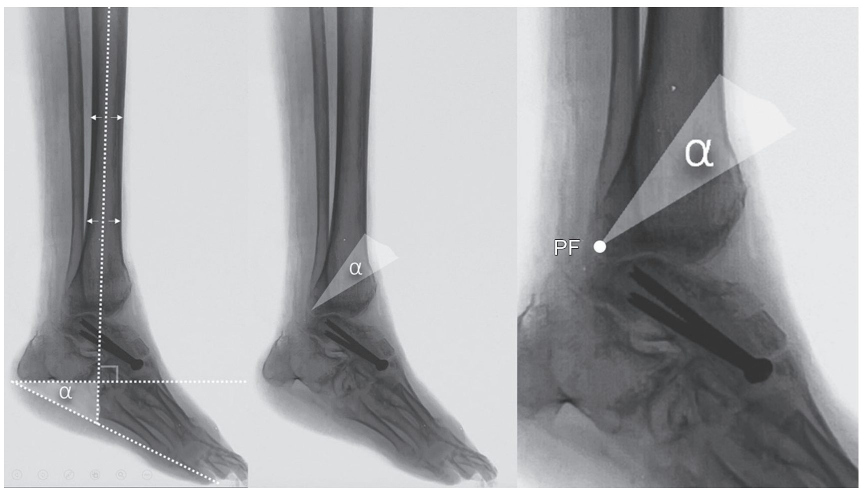


Fig. 2: Alpha angle (bony wedge to resect) and point of fulcrum (PF)

torsion and valgus-varus deformity as this osteotomy corrects only in the sagittal plane.

Pre-operative Planning

A full weight-bearing lateral radiograph of the whole tibia including the whole foot is mandatory (to confirm that the dimensions measured on the screen can correspond to the patient's size, some calibration marker is required).[12]

The first step is to define the "alpha angle." This is the angle of correction that is needed for the ankle to achieve a 90º plantigrade foot (angle between the surface of contact of the weight-bearing foot and tibial anatomic axis in the lateral view).[18] This angle represents the size of the anterior bony wedge that will be resected and the value will vary with the size of each deformity (Fig. 2).

The second step is to locate the point of fulcrum of the closing wedge. For this technique, this is constant and is located in the most posterior and distal aspect of the articular surface of the ankle (posterior malleoli). This is where the osteotomy hinges so the osteotomy cut should be incomplete leaving the posterior cortex intact (Figs 2 and 3). The third step is the determination of the beta angle, which is referred to as the "attacking angle," the inclination used to create the alpha bone wedge. This is the only parameter where the surgeon must make estimations. With the alpha angle already fixed and with the apex of this wedge fixed at the point of fulcrum, the surgeon must attempt simulations by altering the inclination of the alpha angle clockwise or counterclockwise in relation to the joint surface. The optimum "beta angle" is the one that closest equalises the length of both surfaces of the osteotomy distance 1 (D1, proximal) and distance 2 (D2, distal) leaving at least 2 cm of bone distal to the osteotomy to ensure appropriate fixation with two or three 4.5 mm cannulated partially threaded lag screws with a washer (Fig. 4).

The fourth and final step, after having determined the alpha angle and the chosen inclination (beta angle), is to measure with a ruler on the radiograph the distance between the articular surface (joint mark) and the entrance point of most distal cut (D2), then measure the distance between the articular surface and the entrance of the most proximal cut (D1). This establishes the entry points of the osteotomy cuts and with both cuts directed to the fulcrum point on the posterior part of the ankle joint (Fig. 5).

Surgical Technique

The operation is performed under anaesthesia in the supine position. A skin incision is performed following the conventional

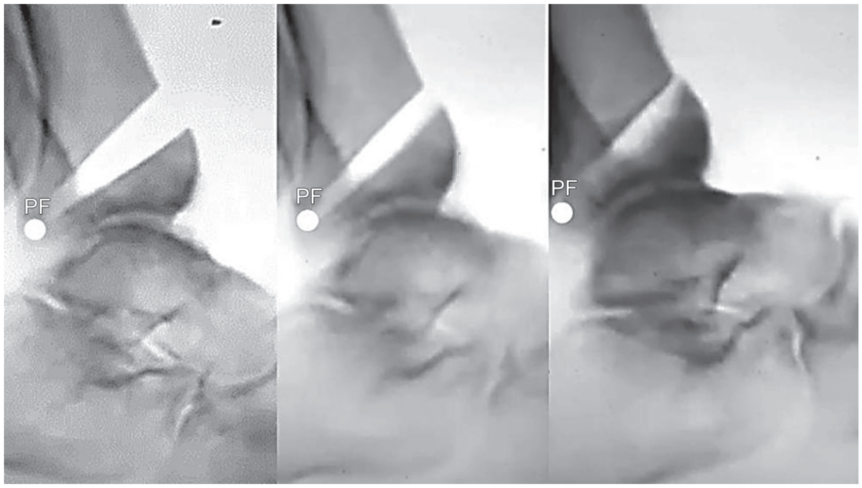
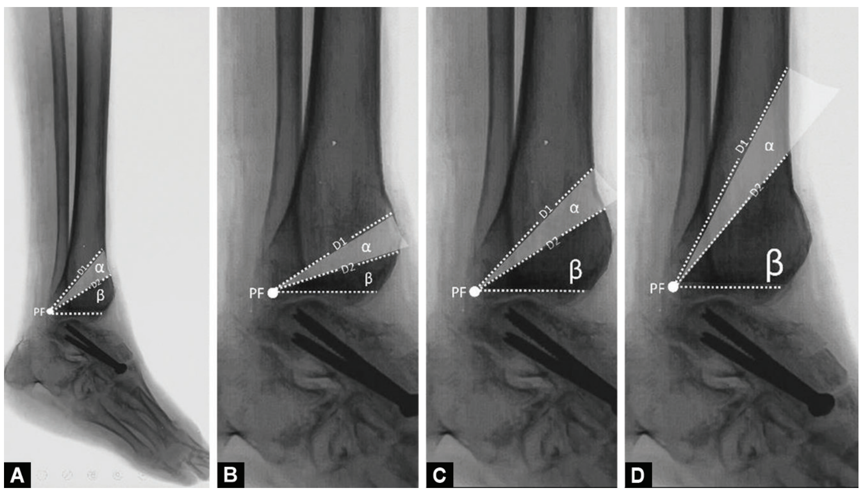


Fig. 3: Point of fulcrum and how the osteotomy hinges on that point



Figs 4A to D: (A) The planning parameters for ODODT; (B) Small beta angles generate a small segment of bone distal to the osteotomy making fixation difficult; (C) Medium-sized beta angles adequately equalise both sides of the osteotomy (D1 and D2); (D) Large beta angles generate a discrepancy between D1 and D2 with an incongruency in the lengths of both sides of the osteotomy

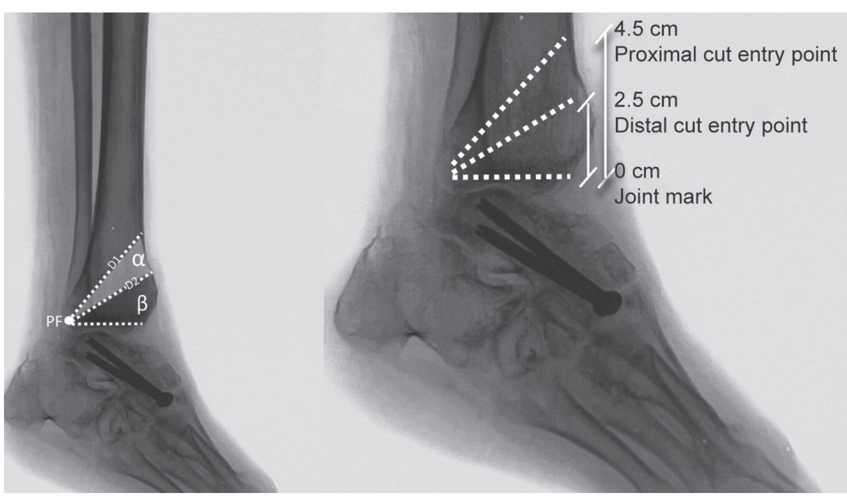
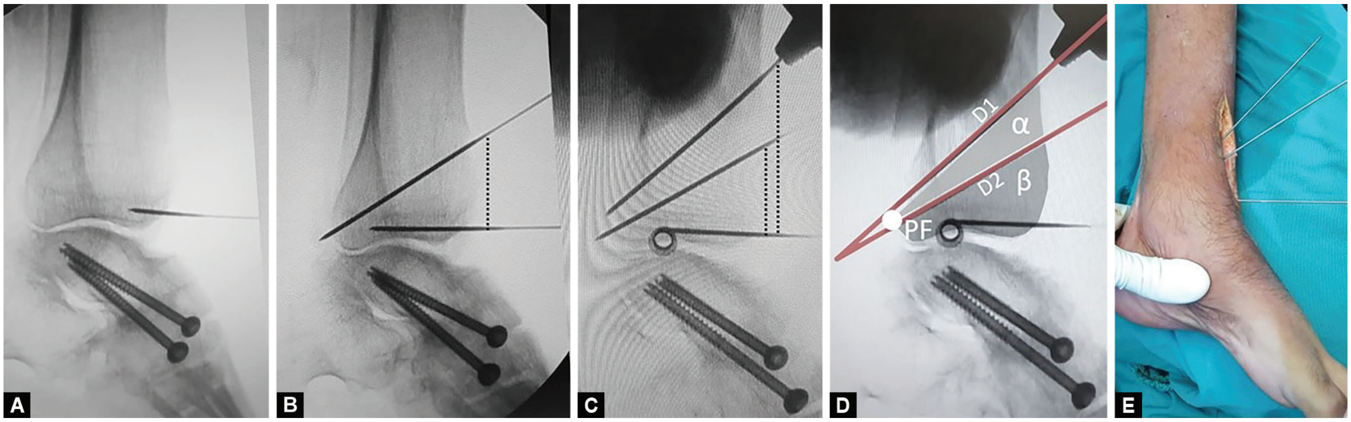


Fig. 5: Measurement of the distances between the joint line (0 cm) and the point of entrance of the K-wires that will guide the proximal and distal cuts (distances depicted in this radiograph are examples)



Figs 6A to E: (A) First K-wire marking the joint surface; (B) Second K-wire respecting the distance marked for the distal cut entry point in the planning and aiming to the point of fulcrum; (C) Third K-wire respecting the distance marked for the proximal cut entry point in the planning and aiming to the point of fulcrum; (D) Measuring that the alpha angle is the adequate; (E) Clinical image prior to starting the osteotomy

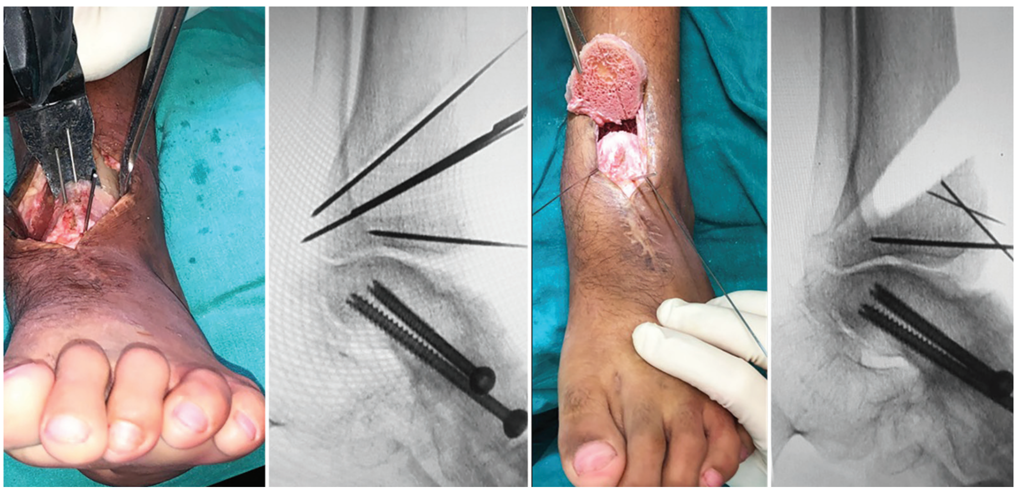


Fig. 7: Performing the osteotomy

anterior approach to the distal tibia. The extensor retinaculum is divided, and care taken of the tibialis anterior neurovascular bundle. The anterior part of the ankle joint capsule is not opened. The anterior periosteum is divided and a subperiosteal exposure towards the posterior malleoli developed. Two Hohmann retractors are placed on the medial and lateral aspects of the distal tibia, with the prongs pointing to the fulcrum of the osteotomy. At this point, a lateral approach to the fibula and an osteotomy of the fibula in the sagittal plane is made. This osteotomy is at a proximal level in relation to the level of the tibial osteotomy.

A reference for the joint surface orientation is made by passing a 2 mm K-wire parallel to the ankle joint from anterior to posterior place at the level of the epiphysis of the distal tibia (Fig. 6). Next, a reference for the entrance point of the distal cut is made. Using a sterile ruler, this distance (as indicated from preoperative planning) is measured from the joint surface. This is marked by inserting a 2 mm K-wire from that level towards the point of fulcrum (most posterior aspect of the ankle joint). It is useful to have an assistant draw on the fluoroscopy monitor the line from the point of entry of the distal osteotomy cut to the fulcrum as this then allows the surgeon to follow this line (Fig. 6).

The next reference is for the entrance point of the proximal cut. This is measured with a sterile ruler at the distance planned from the joint margin and marked with a 2 mm K-wire which is inserted towards the point of fulcrum (Fig. 6). The proximal and distal cut reference K-wires should be strictly aligned in the axial plane to avoid introducing malrotation (Fig. 6).

The distal segment of tibia should now be prepared for fixation. This is done by inserting 2 or 3 guide wires from a cannulated lag screw fixation set. These wires are directed from the distal tibial segment pointing perpendicular to the slope of the distal cut so when the wedge is resected and the osteotomy is closed, these wires act as temporary fixation until the screws are placed through them (Fig. 7). By using a goniometer or angle measurement app, check on the fluoroscopy monitor that the alpha and beta angles are outlined as planned.

The cuts are made under fluoroscopy, slowly with oscillating saw and guided by the K-wires, ensuring sterile saline solution

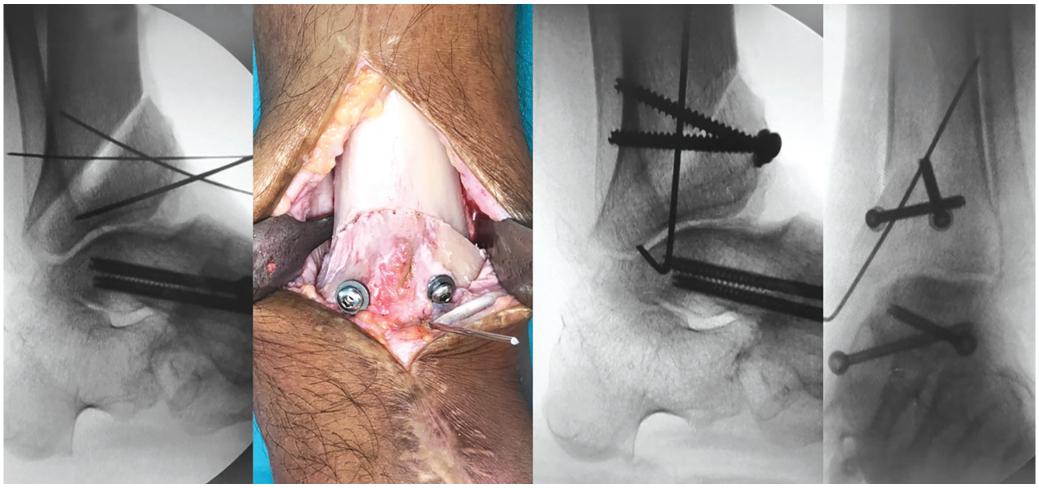


Fig. 8: Fixation of the osteotomy with 2 screws with a washer and a lateral K-wire for coronal stability during the fixation manoeuvre

is used liberally to avoid high temperatures as the cuts may go through thick cortical bone. It is recommended at first to start with smaller cuts and, if necessary, to take out more bone. The posterior parts of the osteotomy tend to be more difficult to remove and this may be accomplished using a thin rongeur (Fig. 7).

After removal of the wedge, the osteotomy is closed and the guide wires for cannulated screws advanced across. A third K-wire from the medial malleolus crossing the osteotomy is helpful to avoid movement in the coronal plane (varus-valgus) when the ankle is being handled for imaging to confirm the corrections. Measure the correction to ensure the plantigrade position, as was planned, is achieved. The fixation of the osteotomy is then completed with two or three 4.5 mm partially threaded cannulated lag screws with washers placed over the previously inserted guide wires after pre-drilling. If the equinus correction is not adequate, more bone will need removing from the tibia until a plantigrade angle of 90° is achieved (Fig. 8). The surgical wound is then closed in layers.

Postoperatively, patients are instructed to remain non-weight bearing and fitted with a split short cast boot to avoid swelling complications. At 15 days postoperatively, the boot is converted to a short leg cast and patients start physical therapy with passive and active mobilisation of the hip and knee. After 6 weeks, radiographs are taken to assess the status of osteotomy healing. The patients are placed then in an ankle and foot orthosis (AFO) to allow full weight bearing (Fig. 9).

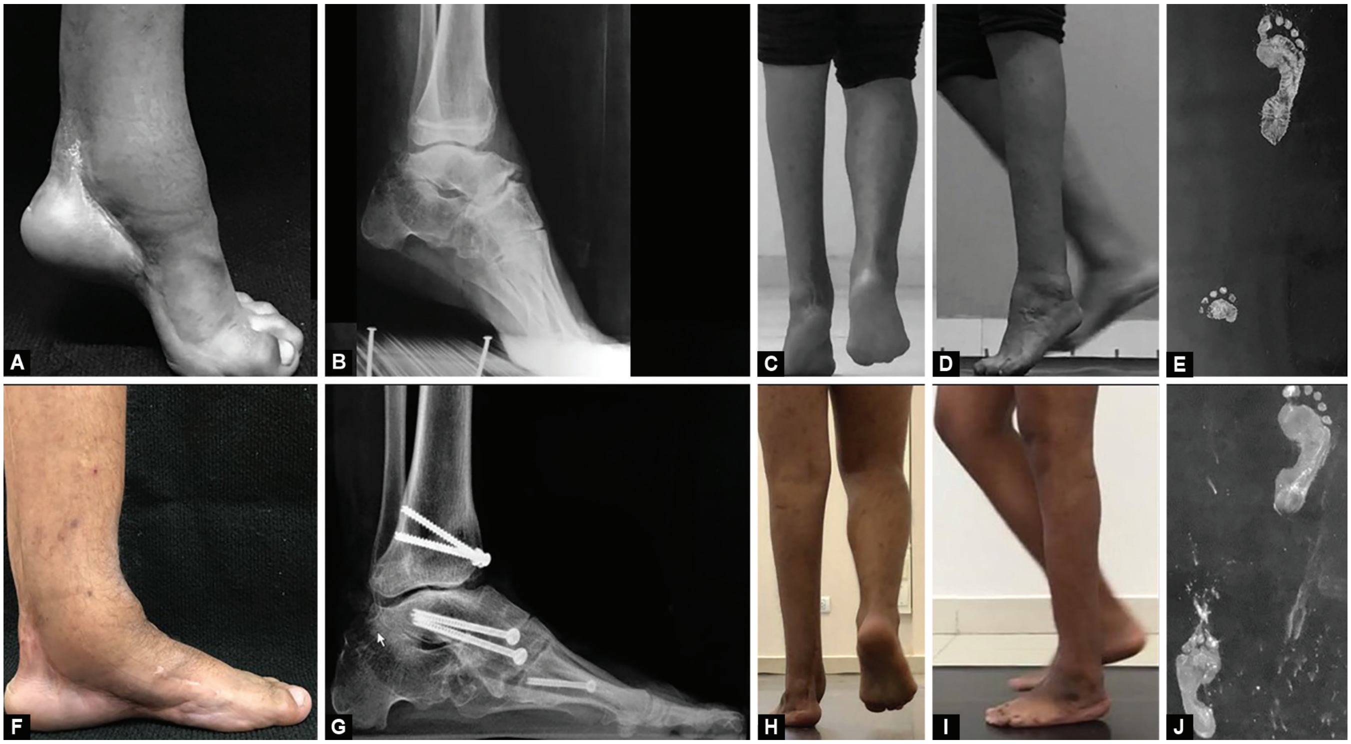
There are several potential pitfalls in this technique which can be avoided:

- In cutting the posterior cortex, try to maintain the point of fulcrum intact. If this is not possible, try at least to keep the posterior soft tissues intact. The posterior ankle capsule, the posterior talofibular ligament, and the interosseous ligament may provide some elastic stability.
- If D1 and D2 are not equal in length, this creates an anterior overhang of bone when we close the osteotomy due to discrepancy in the lengths of the sides of the cut (Fig. 10).
- Positioning the cannulated screws too close to the osteotomy may compromise the fixation. Also, placing the screws too vertically and close to the ankle joint could cause impingement between the talar dome and the screws (Fig. 10).
- Fixing the osteotomy with undesired residual varus, valgus, or rotation. To avoid this, place a K-wire in the proximal tibia aligned with the K-wire in the epiphysis distal to the cut. After the cut, both K-wires should remain aligned (Fig. 10).

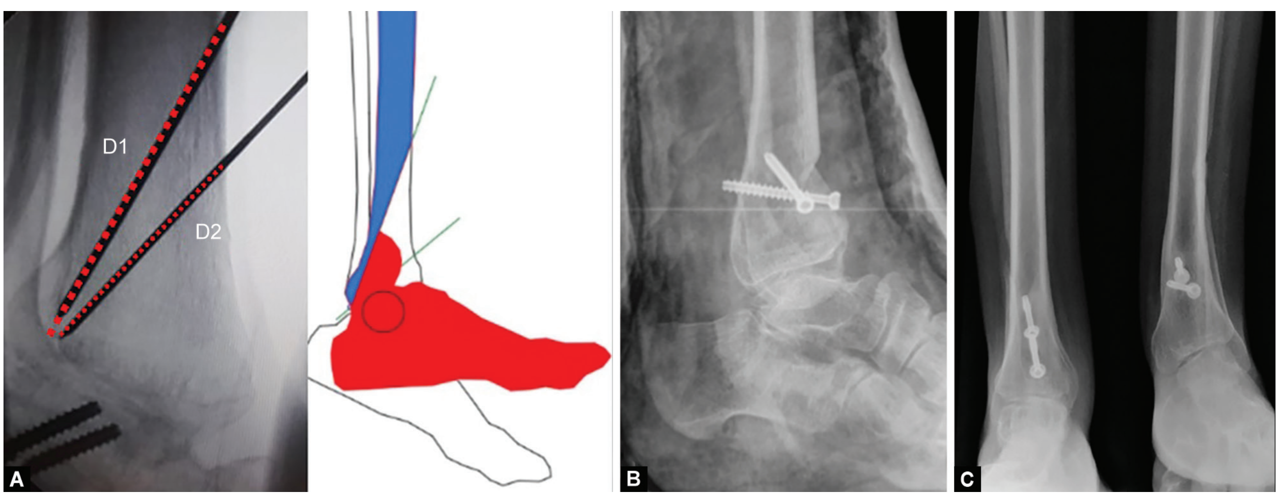
Discussion

Supramalleolar osteotomies are techniques for the correction of rigid ankle equinus in the context of a flat topped talus, severe scarring, or burns sequelae.[5,8,9] However, the classic transverse distal tibia osteotomy may create a secondary translational deformity that may compromise the mechanical axis as it is performed away from the apex of the deformity (CORA) and without being on the transverse bisector line (TBL).[11,19] The ODODT with the fulcrum at the posterior part of the ankle joint performs the correction closer to the apex of the deformity. This adjustment resembling the TBL inclination, produces less translation of the centre of rotation of the ankle in relation to the mechanical axis of the tibia.[11] One possible consequence of modifying the inclination of the anterior distal tibial angle is the creation of shear forces across the ankle joint. However, a flat talus or incongruent ankles already have abnormal biomechanics and limited mobility, therefore, this technique aims to achieve a plantigrade non-painful foot, despite altering conventional relation between the tibia and the talus.[19]

Although Handelsman and Weinberg reported that the benefits of the TSO correction exceed the problems from anterior translation.[8] Mosca and Paley emphasised that the anterior translation of the centre of rotation is a pitfall and should be avoided by making a complete osteotomy of the posterior cortex of the tibia and translating posteriorly the distal segment to maintain alignment of the mechanical and anatomical axis of the tibia with the centre of rotation of the ankle.[6,7,11] We believe that a complete osteotomy of the distal tibia should be stabilised with a plate, which is appropriate for patients with intact anterior soft tissues but may complicate hardware placement in patients with poor-quality soft tissues.[18] Conversely, the conservation of the posterior cortex for hinge in the ODODT, although technically challenging, allows the use of only lag screws avoiding problems in patients with severe scarring and soft tissue coverage issues.[4]



Figs 9A to J: Clinical case: A 16-year-old boy, with a sequela a multiple relapsed congenital talipes equinovarus, he was a community ambulator experiencing daily pain and difficulty wearing shoes. He has had 9 previous surgeries at another institution. (A) Severe deep scar in the posteromedial region, with a Tinel sign over the scar and hypoesthesia over the medial aspect of the heel and medial arch; (B) Radiograph showing flat topped talus and an arthritic midfoot joint; (C and D) Still images captured from the clinical videos, showing ankle equinus at midstance; (E) Foot print during gait shows limited forefoot contact during midstance; (F and G) 3 years post-surgery after midfoot arthrodesis, dorsiflexion osteotomy of the 1st metatarsal and ODODT; (H and I) Still images captured from the 3 years post-surgery follow-up, showing a plantigrade foot at midstance; (J) Improvement of the footprint at the 3-year follow-up evaluation



Figs 10A to C: (A) Discrepancy between both sides of the osteotomy (D1 and D2); (B) Screws placed too proximal to the osteotomy; (C) Undesirable valgus in the left ankle

In patients with an open physis, an anterior distal tibia hemiepiphysiodesis is a viable option depending on the age of the patient. However, the amount of correction of the anterior distal tibial angle due to the slow rate of growth of the distal tibia is moderate only and reports of changes in the slope vary from a mean of 17.3° for the series of Zargarbashi et al. to 11.7° in the series of Ebert et al. Also, it is important to emphasise that this growth modulation technique does not correlate linearly to improvement in clinical dorsiflexion.[2–4,20]

Nelman et al. reported positive outcomes with multiplanar corrections at the supramalleolar level in 18 children with severe, rigid equinus and previously operated feet, with an average age at the surgery of 5.6 years. However, the planning and execution sequence of this technique are not clearly detailed.[5] Warnock et al. developed a mathematical model for planning a supramalleolar osteotomy to correct mild arthritic ankles with varus and anterior impingement. Since the deformity corrections were mild, their model did not account for the translation of the centre of rotation. We were unable to derive a universal geometric equation because each ankle has its own alpha angle and metaphysis–diaphysis relationship, and the equalization of D1 and D2 varies for each patient.[21]

Gradual correction using circular external fixation is also a viable choice, with some authors seeing it as a potential option in patients with burn contractures and poor soft tissue coverage.[6,22,23] Other options for these patients may include talectomy, ankle arthrodesis, or triple arthrodesis, which are procedures with limited contingency options available if they fail. Hence, we consider these procedures as a third-line option for treatment.[4,5,10]

Conclusion

We present a detailed overview of the ODODT emphasizing pre-operative planning and the critical steps for executing the procedure. The described technique has shown potential in addressing stiff equinus as a second-line treatment option and may be the optimal choice in conditions with established incongruence at the tibiotalar joint or have poor soft tissue conditions.

Orcid

Ramiro Olleac https://orcid.org/0000-0003-3311-8171
Mohan V Belthur https://orcid.org/0000-0001-5279-0591

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