Calcaneus osteotomy

Joshua N. Tennant · Michael Carmont · Phinit Phisitkul

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Abstract Calcaneal osteotomy is an extra-articular, joint-sparing procedure that is used in the correction of cavovarus and planovalgus foot deformity. Careful indications and contraindications for the procedure, with meticulous surgical technique, should be followed to avoid complications and to achieve optimal outcomes. Multiple options of osteotomies exist, including translational (medializing and lateralizing calcaneal osteotomy, with ability to slide proximally or distally, closing wedge (Dwyer), and rotational type osteotomies (Evans, Z-osteotomy). Future directions for innovation include developments of both implants and surgical techniques.

Keywords Calcaneus · Osteotomy · Realignment

Introduction

As part of the “tripod” of the foot, the position of the calcaneus is of critical importance to the alignment of the foot during weight bearing. Although this theory has largely been

superseded by a greater understanding of foot and ankle biomechanics the general concept remains true. In the presence of symptomatic foot and ankle malalignment, an osteotomy of the calcaneus is an important component in either restoration of hind foot biomechanics. Osteotomies through the calcaneus body not only realign the tuberosity but also redirect the pull of the Achilles tendon making it a corrective rather than a deforming force [1]. The many options for calcaneal osteotomy allow surgical planning of both planovalgus and cavovarus deformity correction.

Dwyer popularized calcaneal osteotomy for the correction of cavovarus foot alignment in the 1950s. The original description was that of a removal of a laterally-based wedge to produce a neutral or valgus position of the heel. The wedge is taken proximally to the posterior articular facet. A plantar fascia release in all patients and a dorsal closing wedge in the tarsometatarsal area in adults complete the correction [1]. Prior to the Dwyer calcaneal osteotomy, Steindler in 1921 had described a lateral closing wedge through the neck of the talus, anterior process of the calcaneus, and cuboid, in addition to a plantar fascia release [2]. High rates of talar avascular necrosis led to reduced favor [3].

Pes planovalgus correction by calcaneal osteotomy was first described in 1893 by Gleich [4], in 1923 by Lord [5], and in 1960 by Dwyer [6] with a medial translational osteotomy. In 1959 Evans described a lateral column lengthening calcaneal osteotomy procedure as an additional alternative to arthrodesis procedures for pes planovalgus deformity [7].

Indications/Contraindications

The primary indication for a corrective osteotomy of the calcaneus is a cavovarus or planovalgus foot deformity that is driven, at least in part, by a malaligned calcaneus with a

J. N. Tennant
Department of Orthopedics, University of North Carolina School of
Medicine, Chapel Hill, NC 27599, USA

M. Carmont
Shrewsbury and Telford NHS Trust, Princess Royal Hospital,
Telford, UK

M. Carmont
Sheffield Teaching Hospitals NHS Foundation Trust, Northern
General Hospital, Sheffield, UK

P. Phisitkul (✉)
Department of Orthopaedic Surgery and Rehabilitation, University of
Iowa Hospitals and Clinics, 200 Hawkins Drive, 0102X JPP, Iowa
City, IA 52242-1088, USA
e-mail: phinit-phisitkul@uiowa.edu

supple subtalar joint. An initial attempt should be made a nonoperative management, using corrective foot and ankle orthoses. “Over the counter” orthotics are frequently attempted with little success. Bespoke or custom made orthotics are recommended with inclusion of forefoot posts as well as heel cups and support for the arch. Medial forefoot posting should be used for a flexible planovalgus deformity; lateral forefoot posting with a flexible cavovarus deformity.

If nonoperative treatment is unsuccessful in alleviating the patient’s symptoms surgical correction may be considered, to address the bony alignment and soft tissue tension of the hind, mid, and forefoot. A calcaneal osteotomy is a key bony component of this correction. Contraindications to calcaneal osteotomy include pre-existing subtalar arthritis. In the presence of subtalar arthritis, subtalar arthrodesis alleviates pain and an extra-articular osteotomy is required. Attempted realignment at the site of fusion may lead to nonunion and failure of fusion. Relative contraindications include patient medical comorbidities such as smoking, obesity, diabetes, peripheral vascular disease, peripheral edema, and skin conditions. Many patients find that the incidence and severity of these complications unacceptable risks for elective surgery in addition to the prolonged period of immobilization required.

Calcaneal osteotomy techniques

The patient may be positioned in either the lateral or supine position. Placing a sandbag beneath the ipsilateral hip tilts the pelvis and access is allowed with the hip adducted and the knee flexed and the foot held on a second sandbag. This position allows simulated weight bearing to be performed under fluoroscopic control without difficulty but screw placement can be difficult. For proximal calcaneal osteotomies an oblique incision at 45° to the sole of the foot may be used. This minimizes sural nerve injury and is proximal to the peroneal tendons. An L shaped mini extensile lateral incision may be used to elevate a full thickness skin flap. This preserves the integrity of the lateral calcaneal artery reducing the risk of edge ischemia, infection, and wound breakdown. Distal calcaneal osteotomies can be performed through a 5 cm longitudinal incision. Recently, an omega style incision has been described for fixation of fifth metatarsal base fractures to minimize iatrogenic injury to branches of the sural nerve [8]. Using a small Hohmann retractor, the peroneal tendons can be retracted inferiorly and a second retractor placed over the anterior process of the calcaneus.

Single plane translational osteotomies

Translational osteotomies of the calcaneus aimed to realign the posterior part of the foot tripod through a simple transverse

osteotomy at the body of the calcaneus. The tuberosity can then be translated medially, laterally, proximally, distally, or combined depending on the type of deformities (Fig. 1A). Generally, medial translation is used for the correction of planovalgus deformity commonly associated with tibialis posterior dysfunction while the lateral translation is used for the correction of cavovarus deformity. Medial translation has been shown to unload the lateral aspect of the tibiotalar joint and decrease strain of the deltoid and spring ligaments [9, 10]. The calcaneal pitch can be corrected for either condition by allowing the tuberosity to migrate proximally or distally. The osteotomy is performed in line with the skin incision using a power saw. Great care is needed to avoid over-penetration of the saw blade toward medial neurovascular structures. Alternatively, the medial corticotomy can be completed using an AO chisel in a more controlled manner. The osteotomy is then gently distracted with a laminar spreader. The calcaneal tuberosity is manually translated while the ankle is in full plantarflexion to relax the Achilles tendon. The osteotomy is usually stabilized with 1 or 2 cancellous screws placed retrograde from the tuberosity or recently developed lateral based plate and screw constructs.

A translational uniplanar osteotomy may be performed using a percutaneous technique. The key here is that the Gilgi saw is tunneled close to the medial wall of the calcaneus, deep to neurovascular structures, through stab incisions medially. Either end of the Gilgi saw is then passed superior and inferior to the calcaneus and to the skin on the medial side. The sawing action requires careful technique to avoid damaging the lateral stab incisions using an up/down action rather than side to side.

Lateral column lengthening osteotomy (Evans)

Evans described a lengthening opening wedge osteotomy of the calcaneal neck for correction of an overcorrected clubfoot deformity [7] (Fig. 1A). It provides an effective restoration of the arch of foot by the lengthening of the lateral column and, thereby, rotating forefoot and hindfoot medially. The restoration of foot tripod is through a 3-dimensional modification of foot alignment. It can be performed in combination with medial translational osteotomy of the calcaneal tuberosity in patients with severe flatfoot deformity [11]. The lengthening osteotomy secondarily leads to varus alignment of the forefoot and accentuates equinus deformity because of the presence of a tight heel cord. As a result, the lateral column lengthening osteotomy is commonly performed in conjunction with a plantar flexion osteotomy of the medial cuneiform (Cotton) to correct forefoot varus and with a lengthening gastrocsoleus recession to correct ankle equinus. The procedure is performed through a longitudinal incision on the lateral aspect of the calcaneal neck. The peroneal tendons are identified and retracted plantarly. Two Hohmann retractors are placed

Figure 1 **A**, Single plane translational osteotomy (*solid arrow*) and Evans osteotomy (*arrow head*); **B**, Closing wedge osteotomy; **C**, Z-osteotomy.

around the calcaneal neck and the osteotomy is made at 10–15 mm posterior to the calcaneocuboid joint with a power saw. A Hintermann distractor is then used to fine-tune the amount of lengthening required. A wedge-shaped tricortical iliac crest allograft is then inserted into the osteotomy site. Fixation is not necessary but may be performed using a plate and screws or staples.

Closing wedge osteotomy (Dwyer)

A lateral closing wedge osteotomy, originally described by Dwyer in 1959, is generally used for the correction of mild cavovarus deformity (Fig. 1B). It is performed through the same approach as the translational osteotomies as described above. In addition, an 8–12 mm lateral-based wedge of bone is removed prior to the osseous stabilization. It, theoretically, displaces the weight-bearing portion of the heel laterally while redirecting the plantar surface into more valgus. This technique is advantageous when there is overloading on the lateral edge of the heel. Although the medial cortex must be broken, this osteotomy does not require a complete corticotomy of the medial cortex with the saw blade, thus, minimizing potential injury to the neurovascular structures. A modification of lateral closing wedge technique has been described combined with lateral translation to minimize the amount of shortening from wedge resection [12•].

Complex osteotomy

Similarly to osteotomies of the first metatarsal a scarf joint has the ability to be moved in all 3 planes and yet still preserve stability [13] (Fig. 1C). This Z osteotomy starts supero-proximally, posteriorly to the posterior articular facet, then extends distally and finally a distal plantar cut. The obliquity of the superior and inferior cuts provides bone on bone apposition for healing [14]. A wedge may be placed into the distal inferior cut in a manner similar to the Evans osteotomy permitting lengthening of the lateral column as well as medial translation of the posterior of the calcaneus.

Outcomes

Planus correction

The literature reporting on the outcome of the operative treatment of pes planus and hindfoot valgus reveals outcomes of both sliding osteotomies, Evans distal calcaneal opening wedge osteotomies together with either medial column arthrodesis or soft tissue reconstruction.

In 1995 Mosca reported on a series of 31 feet producing severe symptomatic valgus hindfoot deformities in which Evans osteotomies were performed. After a 2–3.5 year follow-up, 29 out of 31 patients reported satisfactory outcome and radiographically the lateral talar-first metatarsal head angle was reduced from 31° to 5° postoperatively [15].

Hintermann has reported the outcome of calcaneal osteotomies together with tendon transfer, deltoid ligament repair, or spring ligament repair in patients with type II and III tibialis posterior dysfunction. For those in whom a medial translational osteotomy was performed, the American Orthopedic Foot and Ankle Score (AOFAS) improved from 49 to 91 and all patients were satisfied with the result [16]. In those who were treated with a lengthening of the lateral column 17 out of 19 patients had excellent or good corrections. One patient had future loss of correction and another required subsequent calcaneocuboid joint surgery [17]. Both procedures seem to produce good results.

Iaquinto performed an Evans opening wedge osteotomy, which led to double the calcaneocuboid contact pressures in a cadaveric model. A medializing calcaneal osteotomy was found to shift plantar forefoot loads from lateral to medial [18].

Recently Cao performed medial displacement calcaneal osteotomies and tendon transfers for flexible flat foot. All 16 patients were satisfied and pain free at 6 months. AOFAS increased from 53 to 91 [19].

A retrospective study of patients with adult flat foot ($n=41$) treated with a medial column arthrodesis together with a calcaneal osteotomy. Radiographic parameters of talonavicular coverage, the calcaneal inclination and the

lateral talometatarsal angle were all improved. There were however, 4 nonunions at the naviculocunieiform joint and 1 at the tarsometatarsal joint [20]. A case example is illustrated in Fig. 2.

Cavus correction

Similarly corrections for cavovarus feet report on the use of a lateral sliding osteotomy, lateral closing wedge osteotomies together with medial soft tissue releases.

Lamm reported radiographic outcomes following Dwyer osteotomies ($n=17$) at a mean of 2.5 years. There were reductions in calcaneal varus of 18° , the calcaneal inclination angle of 5° , and a medial calcaneal translation of 10 mm [21]. The pressures in the ankle joint have been compared following different types of calcaneal osteotomy in a model of a cavovarus foot. The center of force observed moved laterally 2.3 mm with a lateral closing Z osteotomy, 3.4 mm with a lateral sliding osteotomy, and 4.9 mm with a lateral closing and sliding osteotomy. Peak pressures were similarly reduced by 0.41 MPa, 0.58 MPa and 0.53 MPa, respectively, (Krause) [12•].

Zhou has recently reported that 94 % of patients with rigid pes cavus were satisfied with an extra-articular midfoot osteotomy. Additionally, Meary's angle, calcaneal pitch, and

the tibiotalar angle reduced from 26° to 5.5° , 44.5° to 28° , and 135° to 100° , respectively [22].

Complications

Complications with calcaneal osteotomies include over and under correction, the lack of appreciation of heel cord tightness, and those of all osteotomies such as nonunion and local complications to the sural nerve and skin. Nerve injury from lateral surgical approaches to the calcaneus has been well studied in the anatomy and trauma literature, and can result in temporary or permanent irritation along the course of the sural nerve at the heel with neuroma formation and distal dysesthesia [23, 24•]. A painful scar, with or without identifiable nerve injury, may also be associated with a surgical approach to the calcaneus.

Tarsal tunnel syndrome has been associated with lateralizing calcaneal osteotomy. Higher risk of tarsal tunnel syndrome is associated with greater translation of the osteotomy and osteotomies performed more anteriorly on the tuberosity [25]. This is presumably because of irritation of the nerve passing through the tarsal tunnel and the sinus tarsi.

Overcorrection is an uncommon complication that demonstrates the power of the calcaneal osteotomy, and has been reported in a single case for a planovalgus foot overcorrected into varus by medial slide osteotomy [26].

Painful hardware is relatively common for calcaneal osteotomy. Screw heads that are placed in the posteroinferior tuberosity or a lateral plate for a translational or Evans osteotomy are potential sources of hardware related pain [27, 28]. Patients should be counselled for this and the potential requirement for hardware removal in the future.

Future directions

Some relatively new approaches to calcaneal osteotomy have been developed recently, both with implant and technique development. Trabecular metal wedges have been used instead of bone graft or lateral plate fixation for Evans osteotomy with reported success [29]. Medial calcaneal displacement osteotomy plates have been developed, with biomechanical studies noting greater relative strength of the construct [30]. Last, a percutaneous technique using endoscopic assistance has been developed for performing translational calcaneal osteotomies [31•]. None of these newer techniques have published comparative clinical evidence or long-term follow-up reporting the efficacy of the procedures. Cost effectiveness for all new implants and technology must be borne in mind with careful evaluation of new procedures.

Figure 2 Preoperative (A) and postoperative (B) weight-bearing lateral radiographs of a patient with severe pes planus that underwent a combination of medial translational osteotomy, Evans osteotomy, medial column stabilization, and soft tissue repair. Improvement in alignment is shown using Meary's lines.

Conclusions

Calcaneal osteotomies are powerful, reliable, joint-preserving surgical procedures that are common components of the correction of planovalgus and cavovarus foot deformities. While its historical roots lie in the late 19th century, the procedure continues to evolve in the present day with the development of technique modifications and implant and technology advances. Clinical research studies show good results of calcaneal osteotomies, most of which include the procedure with other procedures. Continued research and development for surgical techniques and outcomes are indicated, as calcaneal osteotomy will foreseeably remain an important reconstructive option in the correction of foot deformity.

Compliance with Ethics Guidelines

Conflict of Interest Joshua N. Tennant and Michael Carmont declare that they have no conflict of interest. Phinit Phisitkul owns stock in MTP solutions, and receives personal fees from Arthrex and from Smith & Nephew.

Human and Animal Rights and Informed Consent No human or animal studies performed by the authors:

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