Calcaneal osteotomies

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Contributions: (I) Conception and design: DC Farber; (II) Administrative support: DC Farber; (III) Provision of study materials or patients: D Prat; (IV) Collection and assembly of data: D Prat; (V) Data analysis and interpretation: D Prat; (VI) Manuscript writing: All authors; (VII) Final approval of manuscript: All authors.

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Abstract: Alteration of hindfoot alignment is a cornerstone of orthopaedic foot and ankle deformity correction. Hindfoot and forefoot loading are influenced by the alignment of the hindfoot and by the calcaneus configuration. Calcaneal osteotomies allow multi plane modification of the calcaneal axis and deformity correction, which results in improved biomechanics of the foot. Multiple calcaneal osteotomies incorporating numerous techniques, have been described to address the varied pathologies that produce varus and valgus hindfoot deformity. Although no clear evidence supports the superiority of one calcaneal osteotomy over the other, recent studies compare the biomechanical properties of different osteotomies. The aim of this review is to outline the of history and current concepts of calcaneal osteotomies.

Keywords: Calcaneal osteotomies; Dwyer; Evans; medial displacement calcaneal osteotomy (MDCO); lateral column lengthening (LCL)

Received: 11 November 2019; Accepted: 22 January 2020; Published: 15 July 2020.
doi: 10.21037/aoj.2020.02.02
View this article at: http://dx.doi.org/10.21037/aoj.2020.02.02

Introduction

Alteration of hindfoot alignment is a cornerstone of orthopaedic foot and ankle deformity correction. Hindfoot and forefoot loading are influenced by the alignment of the hindfoot and by the calcaneus configuration. Calcaneal osteotomies allow multi plane modification of the calcaneal axis and deformity correction, which results in improved biomechanics of the foot. Multiple calcaneal osteotomies have been described to address foot malalignment incorporating numerous techniques to address the varied pathologies that produce varus and valgus hindfoot deformity. Although no clear evidence supports the superiority of one calcaneal osteotomy over the other, recent studies compare the biomechanical properties of different osteotomies. The aim of this review is to outline the of history and current concepts of calcaneal osteotomies.

Calcaneal osteotomy for the correction of planovalgus foot

Gleich, in 1893 (1), first described an inferomedial shift of the tuberosity through oblique medial closing wedge osteotomy. Lord in 1923 (2) proposed a lateral opening wedge osteotomy. Dwyer in 1960 (3) performed medial wedge subtraction and lateral bone graft insertion to correct valgus malalignment. This technique was further modified by Silver (4) who used allograft wedges. Koutsogiannis (5) described a medial and plantar translation through an oblique osteotomy of the calcaneal tuberosity. His technique has evolved to what is recognized today as the medial displacement calcaneal osteotomy (MDCO).

The concept of modifying the "external column" was presented by Evans (6), who suggested a lateral column reducing osteotomy in relapsed cases of residual club foot. Evans described the effect of lateral column length alteration on the control of forefoot abduction and adduction, and presented the lateral column lengthening (LCL) osteotomy, now known as the Evans osteotomy (7). Later, Mosca (8) added the use of a trapezoid graft to the LCL, adjusting the center of rotation of the osteotomy to match more closely the center of the talus head.

Over the years, two key techniques of single coronal plane osteotomies remain the workhorse of hindfoot valgus correction: The MDCO and the LCL. The classic surgical approach to MDCO is through an oblique lateral incision posterior and inferior to the peroneal tendons. The calcaneal tuberosity is exposed with protection of the sural nerve. An oblique osteotomy and 8 to 10 mm medial shift of the calcaneal tuberosity are performed (9). The approach for the calcaneal neck in LCL is in the internervous plane between the superficial peroneal nerve and the sural nerve. The peroneal tendons are retracted plantarly. A vertical osteotomy is made 1.5-cm proximal to the calcaneocuboid joint (7). A bone graft or a metal wedge is inserted after adequate displacement is achieved (10).

The lack of sustainable correction and consistent outcomes with various osteotomies has triggered further research in hindfoot correction in adult pes planovalgus deformity (11). Three-plane osteotomies were introduced with the aim of increasing the power and stability of the osteotomy (12). Griend (9), highlighted the advantage of his modification of the Evans procedure, utilizing a three-plane osteotomy that medially rotates the midfoot and hindfoot while reducing unwanted effects of altering the lateral column length, such as lateral column pain, calcaneocuboid joint arthritis, and increased lateral plantar pressures (13). Furthermore, his technique maintains calcaneocuboid and subtalar joint motion, and reduces dependence on bone to graft healing by creating an axial plane area of primary bone contact (9,14). Favorable clinical results of this techniques have been recently reported (11,15).

In 2019, Ebaugh and colleagues (11) proposed a conceptually similar "extended Z-cut osteotomy" that couples LCL and MDCO, by using reverse vertical cuts compared to the Griend osteotomy. In their short-term series, they demonstrated that the extended z-cut technique maintains improvement in radiographic parameters with minimal complications and complete union rate.

Further extending the indications, Xu and colleagues (16) suggested that a Z-osteotomy of the calcaneus in combination with talocalcaneal arthroereisis for adolescents with severe flatfoot deformity provided satisfactory results.

Mechanics

Several cadaveric studies analyzed foot and ankle joint pressure dynamics after osteotomies of the calcaneus. Nyska and colleagues (17) demonstrated the deforming effect of the Achilles tendon in pes planovalgus. MDCO decreased the effect of the Achilles pull on the flattening of the arch, and by that achieved direct correction of the malalignment and influenced the natural history of the deformity. Hadfield and colleagues (18) presented that MDCO shifted plantar pressures from medial forefoot to the lateral heel. Steffensmeier and colleagues (19) analyzed pressure alteration in the ankle joint following calcaneal osteotomies. They concluded that 1-cm medial or lateral translation created a significant change in pressures in the ankle joint; Medial displacements unloaded the lateral joint and increased the load of the medial joint; and vice versa in lateral calcaneal displacements.

LCL principally influences midfoot abduction in flatfoot deformity with secondary influence on hindfoot valgus, in addition to improvement in calcaneal pitch (20). LCL has been indicated to provide better correction ability than MDCO alone (21,22).

Limitations

MDCO and flexor digitorum longus transfer provide deformity correction that may not be maintainable radiographically at longer follow-up. The need for further reconstruction has been suggested (23-26). Though considered to have robust reduction properties, LCL has been linked to increased lateral foot pressures in cadaveric and in case-control studies (13), higher rates of nonunion, reoperation and adjacent joint arthritis when compared to MDCO (23).

Calcaneal Osteotomies for the treatment of cavovarus foot

Multiple calcaneal osteotomies have been described for the treatment of cavovarus, primarily to address the residual deformity of poliomyelitis (27,28). Dwyer osteotomy is considered as the classic valgus shifting osteotomy of the calcaneus, achieved by a lateral closing wedge osteotomy of the tuberosity. The approach to the calcaneus is through a lateral oblique incision posterior and inferior to the peroneal tendons, directly to the calcaneal tuberosity. The sural nerve must be acknowledged and protected in this approach (28). Later, it was suggested that the Dwyer osteotomy may have limited correction power in severe cases, and by shortening the calcaneus, may contribute to weakening of the Achilles tendon (29).

Lateralizing calcaneal osteotomy is another frequently used osteotomy performed through the same lateral approach. A concurrent superior translation of the tuberosity can aid in the correction of cavus (30). A maximal displacement of about 1 cm is considered appropriate in order to decrease the risk of nerve impingement, tarsal tunnel syndrome (TTS) and wound complications. Preventive release of the tarsal tunnel has been suggested (31). A recent retrospective study concerning the neurologic deficit after lateralizing calcaneal osteotomy demonstrated no protective effect for the addition of a tarsal tunnel release (32).

A posterior and superior displacement osteotomy is another technique to address cavovarus feet, if cavus and impaired Achilles power are the dominant contributors to malalignment. It was suggested that this osteotomy improves the moment arm of the Achilles (33). A crescentic osteotomy of the calcaneus has also been described (34).

The advocates of multi-plane osteotomies for pes cavovarus have postulated that single-plane osteotomies may not be able to provide adequate correction in severe deformities (35). Pisani (36) suggested a wedge resection osteotomy that complements the valgus of a Dwyer osteotomy with lateralization. Similarly, Malerba and De Marchi (37) described a scarf like Z-osteotomy with a wedge resection, with supposedly less risk to the subtalar joint. Aiming to provide further coronal plane correction, Knupp and colleagues (35) further modified the Z-osteotomy to include lateralization of the calcaneal tuberosity (30). These multiplane osteotomies may require a larger exposure and may be more technically demanding than single plane osteotomies, theoretically increasing the perioperative risk. The greater correction potential of these osteotomies may be associated with inadvertent overcorrection (38). Furthermore, Kaplan and colleagues (39) and Saxby and Myerson (40) advocated that an oblique osteotomy that combines a lateral closing wedge osteotomy and lateralization of the tuberosity, allows multiplanar correction without the risks of the more aggressive Z-osteotomy.

In comparison to the previously described lateral approach, a medial approach has been studied by Jaffe and colleagues (41). The occurrence of tibial nerve injury or TTS in their case-series of 24 patients who underwent lateralizing calcaneal osteotomy utilizing a medial approach, was zero. In their surgical technique, they emphasized diligent dissection and mobilization of the adjacent neurovascular structures.

Mechanics

By changing the mechanical axis of the heel, calcaneal osteotomies affect the alignment and the forces transferred through the ankle joint and forefoot (30). Krause and colleagues (42) compared three types of calcaneal osteotomies (Dwyer, lateralizing, and Z-type osteotomies) in a cadaveric model, and concluded that all three types improved tibiotalar contact pressures. An and colleagues (43) showed that combining Dwyer with lateralizing and coronal plane internal rotation, attained the best correction of varus heel.

A second study from the same group, Pfeffer and colleagues (44) compared three dimensional printed models of Dwyer, a more oblique modified lateral closing wedge osteotomy, and a step-cut osteotomy. They demonstrated that the step-cut osteotomy provided higher coronal correction and postulated that better re-alignment of cavovarus can be achieved by adding rotation and translation to all three osteotomies. They concluded that Dwyer and oblique osteotomy should be coupled with milder deformity and the step-cut osteotomy should be coupled with more significant deformity. Furthermore, they highlighted that unlike the step-cut osteotomy, Dwyer and oblique osteotomy shortened the calcaneus.

Limitations

The risk of tarsal tunnel compromise and tibial nerve injury following large lateral shifts of the calcaneus in severe deformities have been investigated and the need of preventive tarsal tunnel release have been questioned. In a cadaveric study by Bruce and colleagues (45), MRI scans were performed after lateralizing and medializing osteotomies. They found decreased tarsal tunnel volumes after lateralizing osteotomies, potentially compromising the tibial nerve. VanValkenburg and colleagues (32) investigated clinical symptoms of TTS after a lateralizing osteotomy. The incidence of injury to a branch (one or more of the three) of the tibial nerve following lateral calcaneal osteotomy was 34%. During 19 months of follow-up in average, 59% resolved fully by 3 months, 33% demonstrated no recovery, and the rest demonstrated partial recovery. They found a correlation between the location of the osteotomy, middle or posterior thirds of the calcaneus tuberosity, and nerve injury. Middle third osteotomies were found to be more prone to nerve damage, but osteotomy configuration, amount of translation, or a preventive decompression of the tarsal tunnel had no effect on the incidence of nerve damage. Krause and colleagues (31) suggested that the tibial neurovascular structures may be compressed by the osteotomy itself.

Minimally invasive techniques

Minimally invasive surgery (MIS) have been suggested to decrease complications of traditional open procedures (46). DiDomenico and colleagues (47) described an osteotomy technique performed through four skin incisions with a Gigli-saw. In his cadaver study, the neurovascular structures were dissected and found intact after the percutaneous osteotomy, concluding that the percutaneous osteotomy minimized trauma to soft tissue and neurovascular structures. Tennant and colleagues (48) modified this technique by arthroscopically passing a suture through the subperiosteal tunnel before "shuttling" a Gigli saw. In their series, one patient had persistent numbness in the sural nerve but no vascular injuries have been recorded. Veljkovic and colleagues (49) in another cadaver study, modified this procedure and showed results of percutaneous endoscopically assisted calcaneal osteotomy. They studied the risk of injury to the lateral calcaneal nerve branches of the sural nerve and found that the risk of nerve injury in the MIS technique was significantly reduced compared to open oblique surgical incisions. The use of a Shannon burr for MIS osteotomies has been developed and popularized by Walker and Redfern (50) and Vernois (51). Durston and colleagues (52) performed a chevron calcaneal osteotomy using a Shannon burr by way of a lateral percutaneous approach under fluoroscopic guidance and found no evidence of significant neurovascular injury. Kheir and colleagues (53) retrospectively reviewed 30 cases of MIS MDCO in which no cases of nerve, vascular or wound complications were found. All patients had clinical union and proper correction of the alignment of the foot. Furthermore, they mentioned that since the burr removes about 3 mm of bone, the shift can be readily achieved. In a retrospective review of 15 patient, Mourkus and Prem (54) described their techniques of a MIS double osteotomy. They performed MDCO and LCL with tricortical trapezoid autologous iliac bone graft, transfixed with a K-wire through the calcaneocuboid joint. Kendal and colleagues (55) compared 31 patients who underwent MIS calcaneal osteotomy of cavovarus and planovalgus deformities with 50 patients who underwent open calcaneal osteotomies. They reported significantly fewer wound complications in the MIS group with similar mean displacement of the osteotomy. Talusan and colleagues (56) provided fluoroscopic landmarks of a safe zone in MIS calcaneal osteotomy to avoid sural nerve injury. They defined a safe zone extending 11.2-mm anterior to the apex of the calcaneus. Gutteck and colleagues (46) compared 58 patients that underwent open calcaneal osteotomy with 64 patients that underwent MIS. They reported similar clinical and radiologic outcome between the groups at 6 weeks and 1 year postoperatively. No non-unions occurred in both groups. The percutaneous group had less wound problems and shorter hospitalization time.

Conclusions

Calcaneal osteotomies provide a robust surgical tool for the correction of foot malalignment. Several techniques have evolved over the years. Most commonly, MDCO and LCL are used for the treatment of pes planovalgus, while a lateral closing wedge, or Dwyer osteotomy, are used for the treatment of pes cavovarus. Newer approaches exploit step-cut techniques for 3-dimentional corrections. Future directions, such as MIS calcaneal osteotomies, may decrease wound complications and the risk for neurovascular injury.

Acknowledgments

Other than the authors of this study, to which I thank for their expertise and assistance throughout all aspects of our study and for their help in writing the manuscript, no other contributor is to be acknowledged.
Funding: None.

Footnote

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at http://dx.doi.org/10.21037/aoj.2020.02.02). DCF reports grants from Arthrex, grants from AOFAS / Wright Medical, personal fees and other from Treace Medical, outside the submitted work. The other authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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doi: 10.21037/aoj.2020.02.02
Cite this article as: Prat D, Lee W, Farber DC. Calcaneal osteotomies. Ann Joint 2020;5:29.