Supramalleolar Osteotomy

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KEYWORDS

• Ankle deformity • Malunion • Osteotomy • Correction

Realignment osteotomy of the distal tibia is a valuable surgical procedure for the treatment of distal tibial malalignment resulting from posttraumatic malunion, physeal disturbances, congenital and metabolic diseases, and degenerative arthritis.[1–11] The purpose of supramalleolar osteotomy (SMO) is to preserve the ankle and foot from articular degeneration and biomechanical dysfunction by restoring the joint orientation and axial alignment of the ankle and hind foot. Juxta-articular malalignment of the distal tibia often results in hind foot and forefoot compensation, which, over time, creates predictable patterns of joint degeneration and pain. Gait disturbances can have detrimental effects on the ipsilateral hip, knee, and spine. Small degrees of malalignment are well tolerated, given that there is no concomitant stiffness or arthritis in the adjacent hind foot joints.[12,13] Heywood[10] described SMO in patients who had rheumatoid arthritis and secondary deformity to restore a plantargrade foot and preserve hind foot motion. Takakura and collegues[8,9] described SMO for the treatment of posttraumatic arthritis and malunion. These researchers were able to demonstrate the restorative influence that SMO has on the articular cartilage. In a small series of hemophilic ankle valgus deformity resulting from recurring hemarthrosis, Pearce and colleagues[11] demonstrated that realignment osteotomy preserved function and eliminated the need for need for secondary reconstructive surgery at 9 years of follow-up.

In addition, limb length inequality, restriction of normal joint motion, soft tissue contracture, and compensatory adaptation in the foot are all potential surgical considerations that require evaluation when planning an osteotomy near the ankle joint. Severe scarring, previous soft tissue transfer, or skin grafting may alter the surgical approach and influence the type or location of osteotomy. The clinical and radiographic evaluation of deformity and execution of corrective osteotomy have been described in a comprehensive way by Paley[14,15] and Paley and Lamm.[14–16] Using concepts of vector trigonometry, corrective SMO can be evaluated and treated with predictable results. A thorough clinical evaluation, including physical examination,

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Clin Podiatr Med Surg 26 (2009) 245–257
doi:10.1016/j.cpm.2008.12.008 **podiatric.theclinics.com**

stance and gait evaluation, radiographic planning, and, in some instances, manual stress views of the ankle and subtalar joint, is necessary.[16]

INDICATIONS

The most frequently encountered indication for SMO in the author's practice is for posttraumatic malunion and secondary degenerative arthritis. Often, only a portion of the articular surface of the joint is involved, and corrective osteotomy can salvage the remaining articular surface by redistribution of pathologic wear patterns on the joint. Takakura and colleagues[8] demonstrated that focal degenerative wear patterns could be positively affected with regeneration of fibrocartilage by arthroscopic debridement and SMO. The importance of restoring axis alignment and joint orientation is critical for eliminating abnormal degenerative wear patterns on the articular surface and diminishing secondary subtalar and forefoot compensation.[17,18] Chronic lateral ankle instability resulting from ankle varus is difficult to correct with calcaneal osteotomy and lateral ankle ligament reconstruction. Varus chondral wear patterns often lead to a recurrence of varus instability. Calcaneal osteotomy often fails to realign the mechanical axis of the limb adequately, leading to failure of the reconstruction. Valgus corrective osteotomy can more appropriately address the varus joint orientation of the tibiotalar joint (**Fig. 1**). Valgus SMO is also indicated in the cavovarus foot. Hind foot osteotomy and midfoot correction are often inadequate to correct the intrinsic varus ankle joint orientation. These adaptive wear patterns develop over many years and may not be as obvious as the foot deformity, although they are just as important to adequate deformity correction. Valgus corrective osteotomy can be a helpful adjunctive procedure to achieve rectus alignment (**Fig. 2**).

Malpositioned ankle arthrodeses can lead to significant degenerative changes in the subtalar and midtarsal joints with alteration in the ground reactive forces (GRFs) generated in the limb. Sagittal plane malalignment can lead to degeneration of the midtarsal joint and generate recurvatum thrust on the knee. Corrective osteotomy for ankle arthrodesis malunion is directed at restoring a plantargrade foot and realigning the tibiocalcaneal axis (**Fig. 3**). Growth plate disturbances from fracture or infection can result in significant secondary deformity. Often, limb length inequality is an additional consideration in these cases, and planning must take excessive shortening into account. McNicol and colleagues[5] and Scheffer and Peterson[6] demonstrated the use of SMO for congenital deformity in children. McNicol and colleagues[5] used a derotational osteotomy in children with complex equinovarus deformity and external tibial torsion. Scheffer and Peterson[6] described an opening wedge osteotomy to correct deformity and restore length. Best and Daniels[18] treated a small series of four patients who had five opening wedge osteotomies with a Puddu plate (Arthex Inc., Naples, Florida). Autogenous bone was used in all cases, and all osteotomies had healed by 3 months.

BIOMECHANICAL RATIONALE FOR SUPRAMALLEOLAR OSTEOTOMY

Articular cartilage can be adversely affected by malalignment, and chondral wear patterns can develop rapidly with deformity.[17,19] The degree to which the deformity influences clinical symptoms and function depends on several factors, including the degree of motion in the subtalar and midtarsal joint, size of the individual, severity of the index injury, intra-articular fracture patterns, articular incongruity, and age. The available amount of motion in the subtalar joint is not precisely understood and can vary considerably among patients.[20,21] Paley[14] believes that 30° of ankle valgus and 15° of ankle varus can be compensated for with a normal functioning subtalar joint

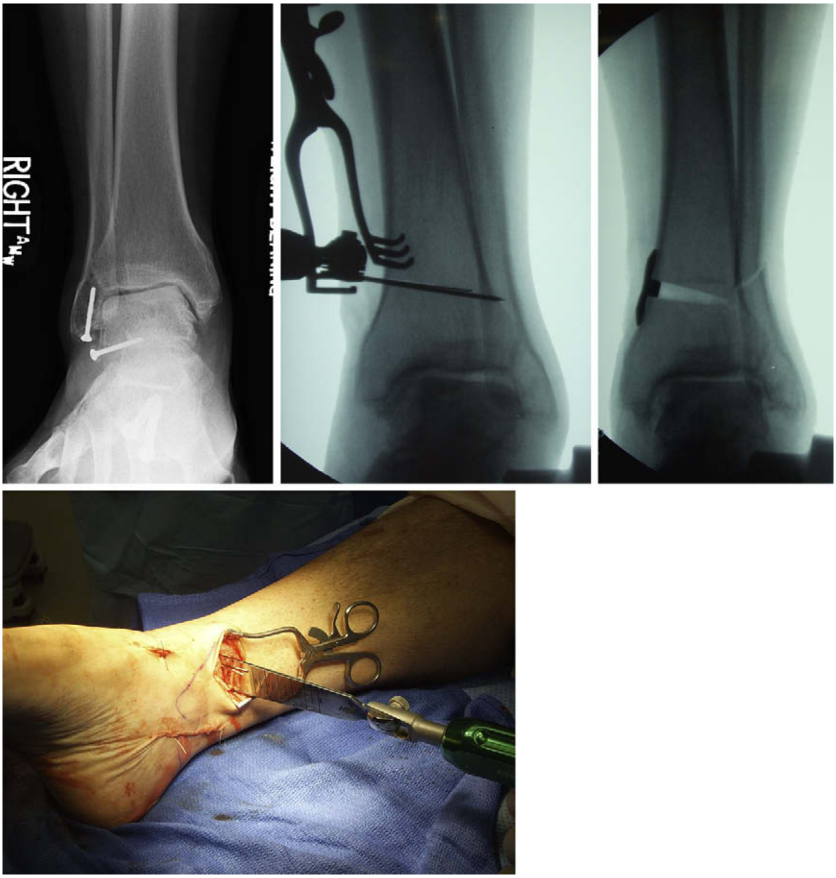

Fig. 1. Chronic lateral ankle instability unsuccessfully treated with calcaneal osteotomy and lateral ligament reconstruction. Unrecognized ankle varus was the underlying cause of recurrent instability. The patient was treated with a metaphyseal opening wedge osteotomy and Puddu plate. The wedge back was filled with ipsilateral calcaneal autograft.

(**Fig. 4**). Distal tibial valgus deformity is better compensated for than distal tibial varus deformity, because twice as much inversion exists in the subtalar joint than eversion. When the distal tibial deformity exceeds the available frontal plane compensation in the subtalar joint, several clinical scenarios develop. When the amount of ankle varus deformity exceeds the available subtalar eversion, a residual hind foot varus deformity results. This condition creates additional forefoot pronation to maintain a plantargrade foot. The opposite occurs when a distal tibial valgus deformity is incompletely compensated for. Complicating this condition is the progressive development of degenerative stiffness in the subtalar joint, with the inability to compensate for distal tibial deformity. Further, joint axis malalignment causes degenerative articular wear patterns. Tarr and colleagues[19] showed that distal tibial deformity significantly altered the contact location, shape, and magnitude of the tibiotalar contact pressures. Sagittal plane malalignment created the most significant alterations in contact characteristics. Recurvatum (shear deformity) and procurvatum (impingement deformity) of 15° resulted in changes in contact biomechanics of greater than 40%. These cadaver studies showed how deformity near the joint can focus contact pressure to small areas

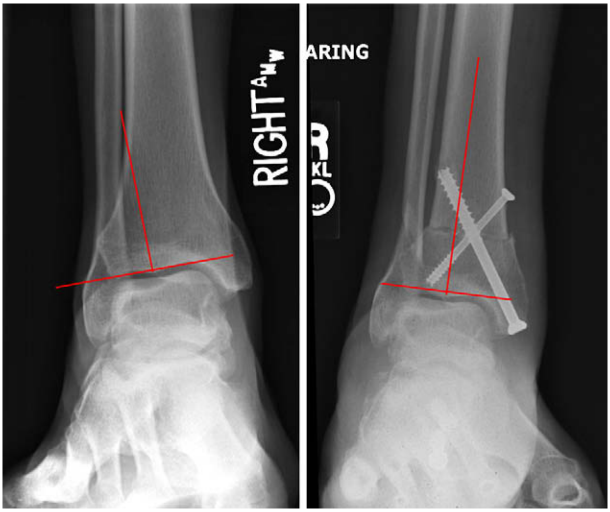

Fig. 2. Cavovarus deformity secondary to Charcot-Marie-Tooth neuropathy. The patient was treated with a lateral calcaneal closing wedge and lateral tibial closing wedge osteotomy.

of the articular surface. This could explain why patients tolerate distal tibial deformity initially and often present only later when painful degenerative articular wear patterns begin in the ankle and subtalar joint. These cadaver studies are difficult to extend into the clinical situation but do correlate with the clinical patterns of articular wear observed. Steffensmeier and colleagues[22,23] demonstrated that the focal areas of the talar dome could be offloaded with shifts in the center of pressure of 1 mm and 1.58 mm with lateral and medial displacement osteotomies of 1 cm, respectively. This shift in the GRF demonstrates the ability to manipulate the GRF acting on the hind foot and ankle with corrective osteotomy. Normally, the GRF passes through the heel and lateral aspect of the ankle joint, creating a valgus torque in the hind foot.[14] The lateral position of the calcaneal axis with respect to the tibial axis explains this mechanical principle. Additionally, abnormal lateral translation (greater than 1 cm) of the calcaneus can cause detrimental hind foot valgus forces. Often, the surgeon encounters a dysfunctional flatfoot with hind foot valgus associated with ankle valgus deformity. This poorly compensated ankle and hind foot valgus predictably leads to posterior tibial tendon dysfunction and deltoid ligament failure over time. Understanding the effects of malalignment of the distal tibia and hind foot is critical to understanding the importance of realignment osteotomy. The foot and ankle surgeon can use these techniques to restore axis alignment and joint orientation and, secondarily, to offload focal degenerative areas of the ankle. The clinical consequence of realignment osteotomy in preserving the tibiotalar joint in the long term is not well documented, although skeletal malalignment must be corrected before arthrodesis or implant arthroplasty.

CLINICAL EVALUATION

A thorough examination of the extremity must include accurate weight-bearing orthogonal radiographs of the ankle and foot, hind foot alignment, and long-leg calcaneal axial views. For conditions that are not attributable to the obvious fracture malunion or physeal injury, full-length standing films are indicated. Close attention

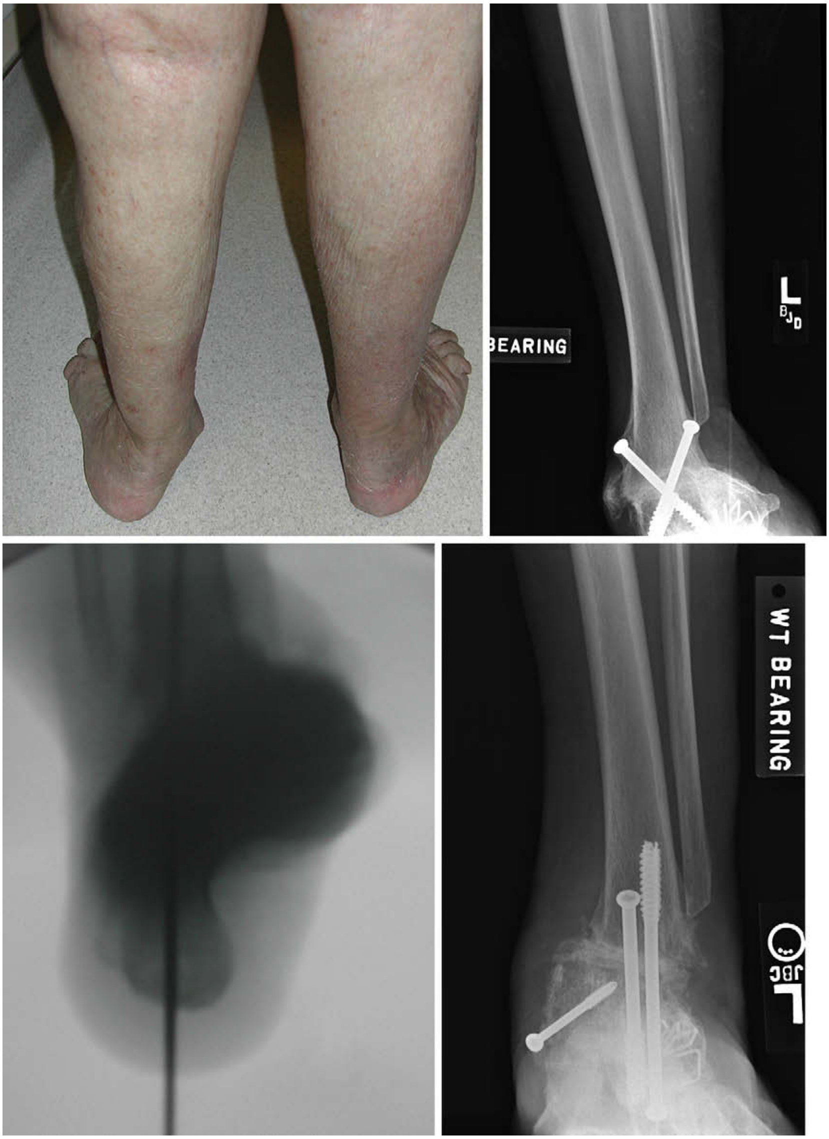

Fig. 3. Valgus ankle arthrodesis malunion. The patient was treated with a medial closing wedge osteotomy through the fusion mass to realign the calcaneal axis to the axis of the tibia. A derotational midfoot osteotomy also was required to maintain a plantargrade forefoot.

must be given to the subtalar joint when planning a correctional osteotomy. Adaptive compensation for a distal tibial deformity may result in stiffness or degenerative arthrosis in the hind foot. Frontal plane corrective osteotomies may realign the ankle joint but unmask adaptive deformity in the subtalar joint, which may be poorly tolerated because of stiffness or arthrosis. Rotational alignment can be assessed on examination with the femoral foot angle. Joint stiffness and arthrosis, which is less objective and often more subtle than radiographic parameters, must be evaluated and included

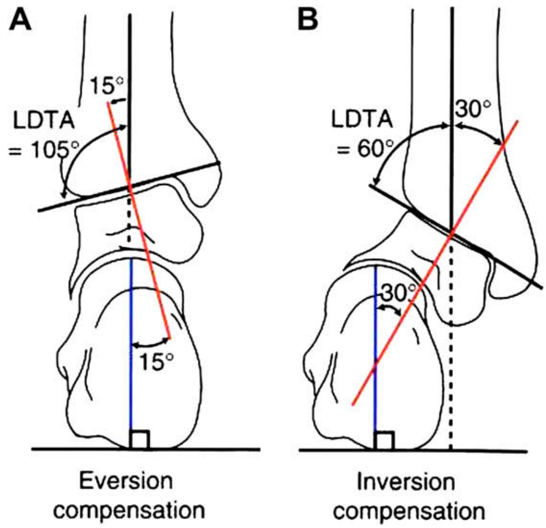

Fig. 4. (*A*) Distal tibial varus of 15° is compensated for with subtalar eversion. (*B*) Distal tibial valgus of 30° is compensated for with subtalar inversion. Note the lateral translation of the calcaneus with respect to the tibial axis in valgus deformity. (*From* Paley D. Principles of deformity correction. Berlin: Springer-Verlag; 2003, p. 574; with permission.)

in the planning process. Diagnostic injections are often useful to confirm painful arthrosis.

Soft tissue adaptation is usually the rule with long-standing deformity. For optimal correction and joint motion after correctional osteotomy, soft tissue releases are usually required. Achilles tendon lengthening or gastrocnemius is the most common adjunctive procedure used, especially with sagittal plane deformity correction. Hind foot tendon rebalancing, such as flexor digitorum longus augmentation of the posterior tibial tendon and peroneus longus–to–peroneus brevis augmentation, can help to stabilize and restore motor function to the hind foot. It is important to record a complete muscle inventory to ensure that previous trauma or periarticular fibrosis has not diminished motor function to any significant degree.

Neural structures, most notably the tibial nerve, are at risk for traction or compression neuropraxic injuries with certain SMOs. Correction of varus, procurvatum, equinus, or internal rotation places the tibial nerve at risk for traction or compression. Prophylactic tarsal tunnel release is generally recommended for any significant degree of correction.[14,16] Care should be taken with release of the tarsal tunnel and porta pedis to decompress the medial and lateral plantar nerves adequately as they pass beneath the abductor hallucis muscle.

Clinical stress examination of the lateral collateral and deltoid complex is a helpful adjunct to determine ligamentous stability. It is common to encounter lateral collateral instability in long-standing varus deformity. Often, secondary soft tissue reconstruction is warranted, which is decided on a case-by-case basis. Manual stress radiographs can guide the surgeon to the appropriate procedure.

Advanced imaging, such as MRI or CT, may also be helpful to evaluate focal articular damage and periarticular pathologic conditions. Arthroscopic debridement of articular injuries and soft tissue impingement should always accompany SMO if clinically warranted. Periarticular spurring is common in long-standing deformity and is as much an adaptation to abnormal joint mechanics as it is degenerative. Lateral plafond spurring in valgus malalignment and medial talar neck spurring in varus malalignment can be addressed with arthroscopic debridement or arthrotomy.

DEFORMITY EVALUATION AND OSTEOTOMY PLANNING

Accurate and reproducible weight-bearing radiographs are important to proper deformity evaluation and deformity planning. Anteroposterior and lateral radiographs of the ankle are the most important films in deformity planning for SMO. The center of the ankle joint and the middiaphyseal line extended to the joint are important parameters to be familiar with. In a rectus angle, the middiaphyseal line should pass through the center of the talus and lateral talar process on the anteroposterior and lateral views, respectively. These landmarks form joint orientation angles, and the lateral orientation angles have been determined. The lateral distal tibial angle (LDTA). ($89^\circ \pm 3^\circ$) and anterior distal tibial angle (ADTA) ($80^\circ \pm 2^\circ$) (**Fig. 5**) are established joint orientation angles.[14] The absolute magnitude of necessary deformity to indicate SMO is not clear and must be taken in the context of clinical condition.

The talocrural angle ($82^\circ \pm 3.6^\circ$)[14] is the angle formed by a line connecting the tip of the medial and lateral malleolus and middiaphyseal line. Deformity in the distal tibia influences this angle, and it is not reliable in such instances. The plafond malleolar ($9^\circ \pm 4^\circ$) angle[14] is the angle formed by the tip of the malleoli and the tibial plafond. This angle is more reliable in the presence of distal tibial deformity (**Fig. 6**).

Long-leg calcaneal axial and hind foot alignment views allow for evaluation of the hind foot and subtalar joint[14] Long-leg calcaneal axial views allow assessment of the subtalar joint and the relation of the calcaneus to the anatomic axis of the tibia. The hind foot alignment view allows evaluation of the calcaneus with respect to the ankle and distal tibia. The calcaneus has a normal lateral translation of 1 cm with respect to the middiaphyseal line.[14] The amount of translation of the calcaneus relative

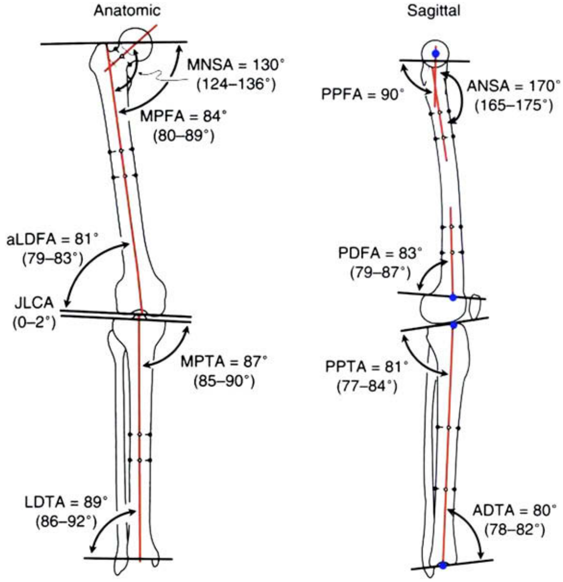

Fig. 5. Normal joint orientation angles and anatomic axes in the frontal and sagittal planes. (*From* Paley D. Principles of deformity correction. Berlin: Springer-Verlag; 2003, p. 9; with permission.)

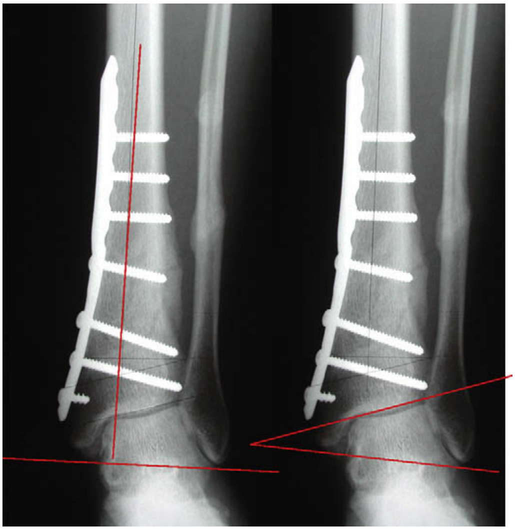

Fig. 6. Determining the relative length of the malleoli can be misleading with distal tibial deformity. The talocrural angle ($82^\circ \pm 3.6^\circ$) is changed with a distal tibial deformity. The plafond malleolar angle ($9^\circ \pm 4^\circ$) is a more accurate way to assess the relative length of the malleoli.

to the tibial axis and the angulation of the calcaneus with respect to the tibia are two important criteria to evaluate. The translational deformity is the most often overlooked residual deformity when performing SMO. Translational or wedge osteotomy can be used to align the calcaneus to the tibial axis properly.

CENTER OF ROTATION OF ANGULATION ANALYSIS

Every deformity has a geometric center that defines the apex of the deformity. This apex is referred to as the center of rotation of angulation (CORA) and serves as an important reference point in osteotomy planning. Generally, the diaphyseal bisection on each side of the deformity defines the location of the CORA. For juxta-articular deformity, a distal middiaphyseal line cannot be drawn accurately. A reference joint orientation angle must be used. The LDTA (89°) and the ADTA (80°) are determined and extended proximally to intersect with the middiaphyseal line proximal to the deformity. The intersection of these lines is the CORA. Often, the level of the CORA is different on anteroposterior and lateral films. This is the result of translation in a different plane from the plane of angulation deformity. Translation is common in fracture malunion deformity of the distal tibia after spiral oblique fractures (**Fig. 7**).

Paley[14] has described a scientific and systematic formula for deformity planning and osteotomy execution. He has described three osteotomy rules that accurately predict the appropriate level of osteotomy and the expected result of the osteotomy based on the location relative to the CORA. Osteotomy rule 1 states that when the osteotomy and axis of correction of angulation (ACA) pass through the CORA, pure angulation correction occurs without translation. Osteotomy rule 2 states that when the ACA is through the CORA but the osteotomy is at a different level, the deformity realigns by angulation and translation at the osteotomy site. Osteotomy rule 3 states that when the osteotomy and ACA are at a level away from the CORA, a translation deformity results. Violation of these principles by improper osteotomy planning may

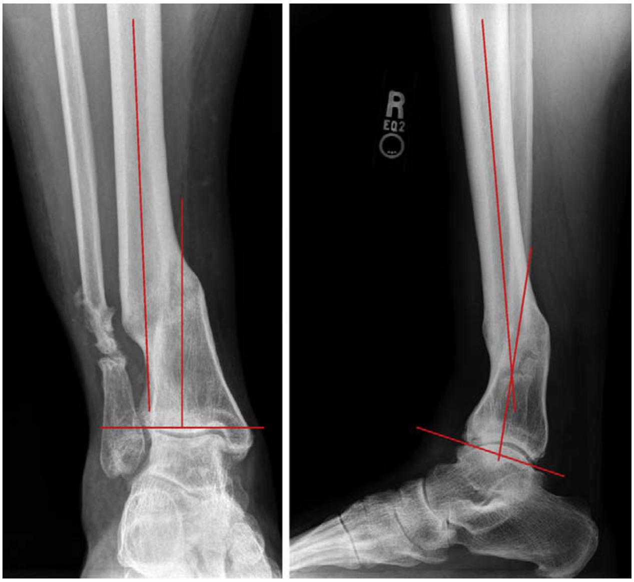

Fig. 7. Recurvatum deformity with medial translation after malunion of a spiral distal tibial fracture. When translation occurs in a plane other than the deformity, the CORA does not correspond on the anteroposterior and lateral films. An osteotomy must correct the recurvatum and medial translation.

introduce iatrogenic deformity, usually in the form of translation. Conversely, knowing that translation can be introduced into the osteotomy, the osteotomy principles can be used in the surgeon's favor when planning deformity correction. For example, a distal tibial malunion with angulation and translation cannot be fully corrected with pure angulation osteotomy. An osteotomy that allows for angulation and translation correction should be used.

The most logical way to approach deformity correction planning is first to understand normal lower limb alignment and joint orientation. It is necessary to define the anatomic axis of the tibia on the anteroposterior and lateral views, to define the middiaphyseal line, and then to extend these distally to the ankle. It is then necessary to draw the LDTA and ADTA, which, when extended proximally, define the CORA. Evaluation of the hind foot alignment with respect to the tibial axis and ankle joint is required. This exercise should define the deformity, level of the CORA, and hind foot position. Clinical examination can determine rotation (femoral foot angle), soft tissue contracture, and ligament instability. This information can then be used to plan the appropriate operation and combination of procedures.

FOCAL DOME OSTEOTOMY

The focal dome osteotomy (FDO) is an osteotomy performed for deformity at or near the ankle joint. The indication for the osteotomy is a deformity that requires angulation correction. The osteotomy describes a portion of the circumference of a circle. Mendicino and collegues[1] described a percutaneous minimally invasive technique that spares periarticular soft tissue dissection and preserves blood supply. The technique is done with the aid of intraoperative imaging. The osteotomy is most appropriate for frontal or sagittal plane correction located at or near the ankle joint. The osteotomy allows for pure angulation correction. No translational correction can be obtained with this technique. In addition, no rotation correction can be achieved.

The surgical technique involves an axis pin at the center of the arc, which is usually placed in the talus or distal tibia near the joint. The center of the pin is ideally placed at the CORA, thereby not introducing any secondary deformity. A Rancho cube placed over the pin allows for circular rotation of the Rancho cube. This rotation describes an arc. The holes in the Rancho cube can be used as a drill guide. Several drill holes placed through the tibia are connected with an osteotome, completing the osteotomy. The fibula also requires an osteotomy, which is performed in an oblique orientation in the same plane and level as the planned osteotomy and allows for fibular translation along the osteotomy. Fixation of the tibial osteotomy can be done in several ways. Given the interdigitation of the osteotomy, percutaneous screws are the most logical method of stabilization (**Fig. 8**). The fibular osteotomy is inherently stable and can be fixed with screws or a lateral plate. Often, the fibula can be left without fixation.

SUPRAMALLEOLAR WEDGE OSTEOTOMY

Opening and closing an osteotomy of the distal tibia is a straightforward technique that affords several advantages. For juxta-articular deformity with the CORA near the joint, the osteotomy can be performed at the CORA. This allows for pure angular correction. The transverse nature of the osteotomy allows small amounts of translation through the osteotomy to restore axis alignment. The transverse design of the osteotomy is inherently stable, and the metaphyseal location of the osteotomy encourages rapid healing. The osteotomy is performed in a limited open fashion with exposure of the base of the osteotomy to be performed. Preoperative templates determine the placement and size of the osteotomy. Osteotomy guide pins can be placed for the desired amount of bone to be removed. The distal pin is placed parallel to the tibial plafond, and the proximal pin is placed perpendicular to the tibial axis. When removed, the area between the converging wires corrects the deformity. Small adjustments in blade orientation result in multiple plane correction. The fibular osteotomy is performed in the same plane as the correction, similar to the FDO. Intraoperative assessment of axial alignment to assess the center of the talus, with respect to the axis of the tibia, in the frontal and sagittal planes is important before definitive fixation. The author prefers intraoperative plain film radiographs to assess alignment better.

Fig. 8. Anterior ankle impingement resulting from clubfoot surgery. Hypoplastic talus and loss of height in the mortise lead to anterior plafond impingement. The patient was treated with FDO in the sagittal plane.

If there is residual translational deformity, the distal tibia can be translated to realign the talus beneath the tibial axis. Fixation can be delivered by means of a percutaneous method. In some circumstances, a medial plate can be used, but there is often a cortical stepoff at the level of the osteotomy that makes plating impractical.

An opening wedge osteotomy is planned and executed in the same way as the closing wedge osteotomy. Indications include osteotomy of the distal tibia requiring angulation and small amounts of length. This type of osteotomy is usually used to treat physeal disturbances and malunion resulting in varus deformity. There is little additional translation correction after the opening wedge is completed. The technique involves a linear incision over the base of the opening wedge. A guide wire is placed in the metaphyseal bone as an osteotomy guide. The periosteal sleeve is lifted in a circumferential fashion at the level of the osteotomy. The bone cut is made leaving a cortical hinge to improve stability,[8] and a Weinraub distractor or similar distractor is used to dial in the amount of desired correction. Intraoperative films verify the correction. Fixation is placed, and the void is filled with bone. The periosteal sleeve keeps the bone graft in place. Best and Daniels[18] described a technique with a platform (Puddu) plate placed inside the cortex of the osteotomy. Autogenous bone graft was used to fill the open wedge. Healing and incorporation of the graft were seen in all osteotomies at 12 weeks. A potential problem with opening wedge osteotomy is the tensioning of the medial soft tissues with varus correction. Sanders and colleagues[24] used neuromonitoring for any lengthening procedures to void iatrogenic nerve injury with deformity correction.

A modification of this technique involves a combined opening and closing wedge osteotomy (**Fig. 9**). This technique allows for maintenance of length while improving the degree of angular correction. The transverse nature of the closing wedge allows for additional translation with angulation correction.

TRIPLANE OSTEOTOMY

The triplane osteotomy (TO) is a technique that allows for deformity correction in all three planes. The osteotomy is based on the principle that any deformity has one axis of rotation around which the deformity can be corrected. Sangeorzan and colleagues[25] described a mathematic model for deformity planning and correction

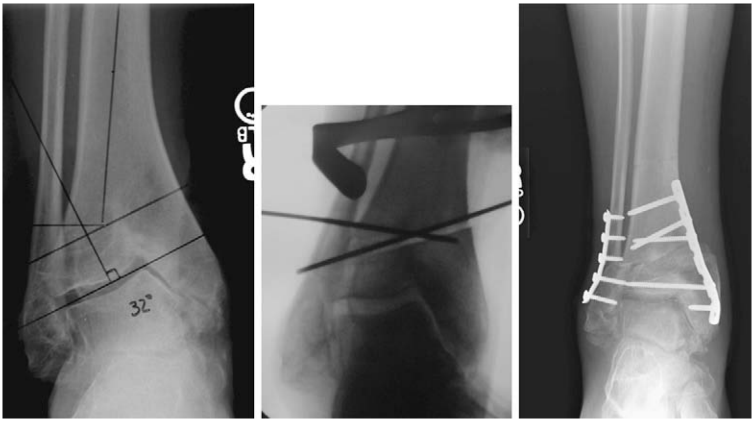

Fig. 9. Distal tibial varus resulting from physeal injury. A combined medial opening wedge and lateral closing wedge allows for correction near the CORA and maintains length.

Fig. 10. Distal tibial malunion with valgus and recurvatum. The patient was treated with an oblique TO to correct valgus and recurvatum. Lateral tension plate fixation was used. A subtalar arthrodesis was required to realign the hind foot.

based on vector trigonometry. A carefully planned and executed osteotomy can realign the deformity in all three planes. The TO is ideally centered at the level of the CORA. The degree of correction in any plane is proportional to the amount of deviation from that plane. For example, a long oblique osteotomy made in the frontal plane affords frontal plane correction with little transverse or sagittal plane correction. In contrast an osteotomy of 45° with respect to all three planes affords equal correction in all three planes. This osteotomy is only useful for tibial malunion above the metaphysis. The author prefers fixation with lateral tension plating using standard internal fixation techniques (**Fig. 10**).

SUMMARY

SMO for posttraumatic malunion, developmental or physeal deformities, congenital malalignment, or focal articular degenerative problems in the ankle is a useful surgical technique. Accurate evaluation of the distal tibial deformity, weight-bearing radiographs, and soft tissue examination for contractures and instability ensure proper decision making. Osteotomy planning must involve all components of the deformity, including the foot, and respect osteotomy principles.

FURTHER READINGS

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