The Use of Osteotomies in the Treatment of Asymmetric Ankle Joint Arthritis

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Introduction

Osteoarthrosis (OA) of the ankle joint is common and found in 1% of the world’s population. In contrast to OA of the hip or knee (mainly primary arthritis), the etiology at the ankle is posttraumatic in a large majority of patients. As a result, they become symptomatic 12 to 15 years earlier than arthritic hip or knee patients. This underlines the importance of long-lasting treatment options for this patient group. Surgical treatments for ankle joint arthritis are divided into 2 categories: procedures that preserve the joint and those that do not.

Although ankle arthrodesis and total ankle replacement (TAR) show good short- and mid-term results, several complications have been reported in long-term data. For arthrodesis, this may include OA of adjacent joints. The overall survival rate after TAR is around 80% after 10 years, and therefore ankle replacement in many cases does not present a lifelong solution.

Two-thirds of the patients with ankle joint arthritis present with an asymmetric wear pattern, for example, more wear on either the medial or the lateral side of their tibiotalar joint. As the ankle is part of a kinematic chain, the intra-articular load distribution is not only influenced by the alignment of the tibiotalar joint itself but is highly dependent on extrinsic forces that are present because of the alignment of the subtalar (ST) joint, the medial column of the foot, and soft tissue balance.

The present review provides an overview of the joint-preserving possibilities to balance the forces in the ankle joint by performing osteotomies around the ankle joint.

Anatomic and Biomechanical Background

The load distribution within the joint is influenced by the alignment (static component) and the joint-crossing tendons (dynamic component). While standing, the center of force transmission is medialized in a varus deformity and lateralized in a valgus deformity. The forces within the joint are amplified by the activation of the triceps surae; the Achilles tendon acts as an additional deforming force on the hindfoot, specifically as an inverter in varus deformities and an evertor in valgus deformities respectively.

Location of the deformity

As the hindfoot is composed of 4 bones (fibula, tibia, talus, calcaneus), localization of the apex may be difficult, even more if there is a multiplanar deformity. In a large majority, the apex of a supramalleolar deformity lies close to the ankle joint or even within the joint. Therefore, correction through the apex may not be possible in all cases, particularly with opening or closing wedge osteotomies. If the correction is not performed at the level of the apex, translation of the distal fragment occurs (Figure 1). Wedge osteotomies proximal to the apex lead to medialization of the ankle joint if a valgus ankle is corrected (Figure 1) and to lateralization of the ankle if a varus ankle is corrected. This may maintain a lateral overload in valgus arthritic ankles and a medial overload in varus arthritic ankles. Therefore, a corrective translation should be added (lateral transfer in valgus ankles and medial transfer in varus ankles) in the correction of large deformities. Alternatively, a dome-shaped osteotomy may allow correcting the deformity even if the apex does not lie in the preferred metaphyseal area of the tibia (Figure 1).

Assessment of an inframalleolar deformity usually is even more of a challenge and can make the preoperative planning very difficult. The reason lies in the limited imaging modalities of the subtalar joint. The newer generation of weight-bearing computed tomographic scans may serve as a valuable tool to define the location and nature of the deformity.

References 1, 4-6, 31, 40, 48, 56, 64.
Supramalleolar osteotomy

Type of joint presentation. For prognostic reasons and for the planning of the type of osteotomy, 2 different types of malaligned ankles need to be distinguished. In the first group, the talus is not tilted within the mortise (congruent type; Figure 2A) whereas in the second group a tilt of the talus is present (incongruent type; Figure 2B). This distinction may help to determine the type of supramalleolar osteotomy (dome-shaped vs wedge). Dome-shaped osteotomies are technically more demanding (surgical technique and planning of the correction) but may preserve joint congruity better than wedge osteotomies. Therefore, congruent types may be easier to correct with a dome-shaped osteotomy, whereas an incongruent ankle may be more easily addressed by a wedge osteotomy.

Role of the fibula. Biomechanical testing has shown that maintaining or restoring ankle joint congruity in supramalleolar osteotomies is very important to achieve reliable changes of the intra-articular forces with corrective osteotomies. These findings are in accordance with earlier discussions in ankle fractures: if the fibula is shortened, the talus tends to lateralize. Placing the talus adequately under the pilon therefore requires adjusting the length and position of the fibula in addition to the potential of osteotomy of the tibia or hindfoot. In supramalleolar osteotomies, this is particularly true in congruent ankles (Figure 2A). Solely correcting the angle of the distal tibia on its own may not redistribute the intra-articular forces enough, an additional correction of the position and length of the fibula should be considered in every single case (Figure 3).

Sagittal plane deformity. In the sagittal plane, procurvatum and recurvatum deformities are additional anatomic features of the tibia to consider in the treatment of OA of the ankle via osteotomy. Procurvatum of the distal tibia is better tolerated than recurvatum. Recurvatum is more joint destructive because the articular surface is not as covered leading to higher peak pressures in the ankle joint because of the anterior displacement of the center of rotation of the ankle joint. Procurvatum may be more painful for the patients as a result of anterior impingement, but usually the joint is spared from deterioration as the talar dome is well covered in the mortise.
Inframalleolar Corrections

Several underlying causes may lead to an asymmetric wear pattern in the ankle joint. Traditionally, deformities of the lower leg and knee joint, ligamentous laxity, tendon dysfunction, and neurologic disorders have been noted to lead to an altered intra-articular load distribution. Lately, it has been proposed that the ST joint may have a major influence on this process.

Malalignment of the hindfoot distal to the ankle joint (inframalleolar deformities) results from anatomic variations of the calcaneal shape and the orientation and position of the subtalar joint or the result of forefoot deformity. As for the anatomic variations of the shape of the calcaneal body, there are only limited studies—mainly on posttraumatic deformities and patients with clubfoot. When it comes to the influence of the ST joint, this has been investigated intensively in the last decade. The ST joint allows for movement in the frontal plane (inversion and eversion) and may therefore compensate for varus and valgus deformities of the lower extremity. Takakura et al speculated that the subtalar joint has a compensatory function in that it prevents the progression of osteoarthritis: the varus deformity of the ankle is thought to be compensated by the valgus inclination of the subtalar joint, and osteoarthritis begins to progress when the compensatory function is inoperative. This has been confirmed in subsequent clinical studies. Hayashi et al described with plain radiographic images a more pronounced valgus inclination of the ST joint in the coronal plane at the intermediate stage of primary varus osteoarthritis, whereas in advanced stages the ST joint seemed to “tip over” and increase the overall hindfoot deformity (Figure 4). On the basis of his observations, he suggested that the mechanism of primary varus type OA is as follows: the varus inclinations of the tibial plafond and the talar dome trigger the disorder (stage 1); the varus inclination of the ankle progresses and the compensatory function (valgus inclination) of the subtalar joint increases so as not to concentrate the weight-bearing stress too medially in the ankle (stages 2 and 3a); the breakdown of the compensatory function leads to the varus inclination of the subtalar joint, the medial stress concentration in the ankle increases, and the disorder progresses to the terminal stage (stages 3b and 4; Table 1).

Figure 4. Illustration of the “tip over” effect on plain radiographs. The varus of the ankle joint is compensated by the subtalar joint in early stages (A-C). In advanced stages the subtalar joint tips over and increases the overall varus deformity of the hindfoot (D, E). Reprinted with permission from the American Orthopaedic Foot & Ankle Society.
Limitations for this theory include the highly variable anatomic presentation of the subtalar joint and the lack of intrinsic stability of this joint in the frontal plane. The ST joint varies significantly in shape and frontal plane orientation. The posterior facet is concave in 88% of the healthy population and flat in 12%. The latter group probably does not allow for much motion in the frontal plane, and these patients therefore may not be able to compensate varus and valgus deformities through their subtalar joint. This is also the case in patients with an arthritic ST joint and patients with coalitions.

The effect of the ST joint orientation has been investigated for both the ankle joint and the foot distal to the ST joint. Patients with varus-type ankle joint arthritis have varus inclination of the posterior facet, and those with valgus-type arthritis have valgus inclination of the posterior facet. Furthermore, valgus tilt of the ST joint has been described to be a risk factor for the development of tibialis posterior tendon dysfunction and subsequent flatfoot deformity. Finally, the ability to compensate deformities in the frontal plane implies that the ST joint provides limited intrinsic stability in the frontal plane, and therefore a normal hindfoot alignment does not automatically guarantee normal load distribution as a zig-zag deformity may be present (Figure 5).

Suggested Algorithm

The following algorithm is a modification of an earlier suggestion and does not include soft tissue balancing, which may be an important part of the reconstructive procedures.

1. Arthroscopy

Ankle joint arthroscopy can be used to complete the preoperative diagnostics and to exclude intra-articular risk factors for progression of ankle joint arthritis (loose bodies, instability). Although there is controversy on the benefit for the arthritic joint, it allows for intraoperative functional testing of the stability, debridement, and removal of loose bodies. In case of anterior ankle impingement, scar tissue is debrided and if required, a talar neck plasty added.

Caution should be taken in removing distal tibia osteophytes anteriorly, as they may function as a strut to prevent collapse of the tibiotalar joint, and removing them may allow accelerated cartilage wear and subsequent increasingly painful arthritis.

2. Deformity Above the Ankle Joint: Supramalleolar Correction

2.1. Frontal plane correction. The first step is a supramalleolar osteotomy (SMOT). The angle to be corrected in the frontal plane is the distal tibial joint surface (TAS; normal value for the Caucasian population 91 to 93 degrees, eg, slight valgus). The type of osteotomy is determined by the level of the deformity, the type of fixation (eg, the hardware used to secure the correction), the condition of the soft tissues and the type of the joint presentation (congruent vs incongruent joints). Ideally, the correction is carried out at the apex of the deformity (see also section “Location of the Deformity” and Figure 1). Congruent joints (type I) are preferably corrected with dome-shaped osteotomies in order to preserve joint congruity (Figure 6). Tilted ankles (type II) are corrected with wedge osteotomies unless the CORA lies within the joint or very close to it (Figure 7). The latter are preferably corrected with dome-shaped osteotomies to avoid medial or lateral translation of the ankle joint (Figure 1).

Varus ankles. Varus ankles that qualify for a wedge osteotomy are addressed with a medial opening wedge osteotomy or a lateral closing wedge osteotomy. Dome-shaped
Osteotomies are used in congruent types, large deformities, and deformities that cannot be addressed by a wedge-shaped osteotomy at the level of the deformity (Figure 6).

**Valgus ankles.** The type of osteotomy is chosen similar to that for the varus ankles. In case of a wedge osteotomy, a medial closing wedge (large majority) or a lateral opening osteotomy (rare) is used (Figure 7).  

**Fibula osteotomy.** After all supramalleolar corrections of the tibia, the length and position of the fibula must be reassessed and if required adjusted (see below).

**Amount of correction.** Overcorrection has been reported to lead to better results than undercorrection, particularly in advanced stages of OA. 19 The ideal amount of overcorrection is still a matter of debate. Although some authors recommend

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**Figure 6.** Case of a dome-shaped osteotomy in a congruent ankle. (A, B) Preoperative weight-bearing radiographs; (C, D) 9-month postoperative images of the same patient.

**Figure 7.** Case of an incongruent ankle with anterior extrusion out of the mortise (A, B). This has been corrected by a medial and posterior closing wedge osteotomy. As the joint appeared congruent intraoperatively, the fibula was left untouched. (C, D) Two-year postoperative weight bearing radiographs of the same patient. Note that the biplanar osteotomy not only centered the talus in the frontal but also in the sagittal plane.
3 to 5 degrees overcorrection, others reported that overcorrection only had a limited effect on a large varus tilt and recommend not to overcorrect too excessively in the supramalleolar area and to add a calcaneal osteotomy instead.44

2.2. Sagittal plane correction. In the sagittal plane, the tibial lateral surface angle should be corrected to its normal range of 81 to 82 degrees. This is particularly true in ankles with an anteriorly extruded talus (Figure 7). In these cases, a biplanar osteotomy is recommended, for example, frontal plane correction with additional anterior opening or posterior closing wedge osteotomies, to improve talar coverage in the anteroposterior direction.7 The surgeon needs to be aware that improving the coverage of the talus by bringing the ankle into more recurvatum alignment can cause anterior impingement. This can be addressed by a talonavicular arthrodesis.69

3. Fibula Osteotomy

All dome-shaped osteotomies require a length correction of the fibula in order to maintain joint congruity. With wedge osteotomies, the ankle joint is checked under image intensification after correction of the distal tibial articular surface angle, and if the joint does appear incongruent the length and position of the fibula is corrected. Intraoperatively, the appropriate length and rotation are defined by (1) appropriate closure of the medial clear space with restoration of the relationship of the medial malleolus and the medial surface of the talus, (2) an anatomic position of the talus within the mortise with parallel articular surfaces of the tibiotalar joint, and (3) restoration of the normal length relationship of the medial and lateral malleoli.14 Additional indicators for correct length are an unbroken “Shenton’s line of the ankle” and an unbroken curve between the lateral part of the talar articular surface and the fibular recess. In case of a normal TAS angle, where the alignment is addressed by a calcaneal osteotomy, the fibula may need correction of length and position to correct the tilting of the talus (Figure 8).

4. Deformity Below the Ankle Joint

If the deformity lies below the ankle joint line and in cases with remaining varus or valgus deformity after a supramalleolar correction, a correcting calcaneal osteotomy is performed. This normalizes the static overload by aligning the calcaneal tuberosity underneath the weight-bearing axis. Furthermore, shifting the force vector of the Achilles tendon eliminates the inversion in varus hind feet and the eversion in valgus feet, respectively.

However, the effect may be unpredictable or even lead to a paradoxical load shift (Figure 4) in patients with unstable ST joints. Preoperative imaging may be helpful to predict the outcome: patients with nonarthritic, convex-shaped or subluxated ST joints are at risk to not benefit from a calcaneal osteotomy for the treatment of ankle joint arthritis. In contrast, patients with coalition, arthritic ST joints, or previous ST fusion joints are likely to respond in a desired manner to a calcaneal osteotomy. Finally, in tilted ankles with a normal TAS, the length of the fibula may require correction to reduce the tilted talus (Figure 8).

5. Osteotomies of the Medial Column

The medial column has a great influence on the load distribution in the ankle joint. In case of a flattened longitudinal arch, corrective fusions (naviculo-cuneiform joints, [closing wedge] tarsometatarsal joint arthrodesis) or plantar flexion osteotomies (medial cuneiform or first metatarsal) are performed (valgus feet). Restoration of the medial arch dorsiflexes the talus and thereby stabilizes the ankle joint as well as reduces the load on the lateral side of the joint.46 In patients with a plantarflexed medial column (forefoot-induced hindfoot varus), a dorsiflexing osteotomy of the medial cuneiform or the first metatarsal is added. This reduces the load in the anteromedial aspect of the ankle joint.37,38

6. Soft Tissue Procedures

After the bony correction, soft tissue balancing is assessed. Tendon transfers (tibialis posterior or tibialis anterior in varus and flexor digitorum longus in valgus ankles) and ligament reconstructions (lateral ankle, deltoid, spring ligament) are added, if needed. However, the need for these procedures is controversial. A recent publication even questioned the need for ligament reconstructions after alignment corrections. The authors treated patients with cavovarus feet and lateral ankle joint instability with corrective osteotomies and tendon transfers only (without ligament reconstruction) and did not observe postoperative hindfoot instability.38

Results

Supramalleolar Osteotomy

Several authors have reported good clinical and radiographic results after supramalleolar correction for both varus and valgus ankles. Significant improvements of the clinical (AOFAS score) and radiographic parameters (alignment, mean Takakura stage; Table 1) were found in several studies. Complications included nonunions, malunion (over- or undercorrection), progression to end-stage OA, and soft tissue problems (neuroma, wound healing problems, bulky hardware).

In our own series, Krahenbuhl et al assessed the complications and risk factors for failure in 294 supramalleolar osteotomies. Thirty-eight patients progressed to end-stage
Figure 8. Preoperative (A, B) and 9-month postoperative (C, D) weight-bearing radiographs of a 52-year-old male patient with valgus-type arthritis. The apex of the deformity lies below the ankle joint (A, B), and therefore a medial displacement calcaneal osteotomy was done. Joint congruity was restored by lengthening of the fibula.

OA and were converted to a total ankle replacement (30 cases) or fusion (8 cases) after 5 years (2-16 years). The 5-year survivorship in this series was 88%. Patients younger than 60 years with early- to mid-stage ankle OA (Takakura stages 1 to 3a) showed the best outcome. This is in accordance with earlier findings of Tanaka et al, who subsequently suggested that a stage 3b may not qualify for a supramalleolar osteotomy. However, Lee et al found improvement of all their patients with a preoperative Takakura stage 3b to a Takakura stage 2.

Krahenbuehl et al found that patients older than 60 years and those with a large preoperative tilt in the ankle mortise had a higher risk for early failure. We also were able to confirm that the cut-off for a worse outcome is around 7 degrees of talar tilt in the mortise. Other risk factors include postoperative joint incongruity (eg, inadequate length or position of the fibula) and ankle joint instability.

Corrections distal to the ankle show less direct effect on the coronal plane alignment of the ankle. Only the calcaneal osteotomies directly influence the overall axis of the
hindfoot. In arthritic ankles, calcaneal osteotomies have mainly been used in varus feet where the effect on the ankle has been assessed in several studies.\textsuperscript{16,17,38,42,60} In valgus feet, calcaneal osteotomies are mainly used to address sequelae of posterior tibial tendon dysfunction and collapse of the medial arch because of a destructive arthritic process. However, they have been shown to have a beneficial effect on the tibiotalar load distribution.\textsuperscript{16,21,47,54,60}

Osteotomies of the medial arch have no direct influence on the hindfoot alignment but indirectly affect the axes of the hindfoot.\textsuperscript{10} Knowledge of the effect of these procedures on the ankle joint is sparse. Krause et al found good outcomes in cavovarus feet treated with osteotomies and tendon transfers. Combining the treatment included osteotomies of the medial column, the calcaneus, tendon transfers, and cheilectomy of the ankle joint and lead to reduction of symptoms and down-staging of arthritis on the ankle joint radiographs (less signs of ankle OA).\textsuperscript{38}

Summary

A majority of patients with arthritis of the ankle joint present with a malaligned hindfoot. Corrective osteotomies aim to reduce peak pressures in the ankle joint to slow down the progression of ankle joint arthritis. Depending on the underlying pathology, they may be combined with procedures that balance the soft tissues (ligament reconstruction, tendon repairs and transfers). Supramalleolar deformities are corrected with supramalleolar osteotomies, paying great attention to preserve or restore joint congruity. The type of supramalleolar osteotomy (opening and closing wedge osteotomy, dome-shaped osteotomy) is determined by the level of deformity, the type of fixation, the soft tissue mantle, and the type of joint presentation (congruent vs incongruent joints). Best results were reported on patients with Takakura stages 1-3a with 10-year survivorships of 82%. Main risk factors for early tilt are advanced stages of OA, a tilt >7 degrees, age >60 years, postoperative joint incongruity.

Inframalleolar deformities result from variations of the calcaneal shape, the shape and orientation of the subtalar joint, and forefoot deformities. They can be addressed with calcaneal osteotomies; however, the effect on the ankle joint may not be predictable in patients with preserved inversion or eversion at the ST joint. The medial column is included in the preoperative planning. A plantarflexed talus (supinated forefoot) increases the risk for valgus tilting in the ankle joint and thereby increases the load transfer laterally in the ankle joint. A plantarflexed medial column increases the pressure on the anteromedial aspect of the ankle joint.

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