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Special Article

Supramalleolar osteotomies: what and when?

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Abstract

Supramalleolar osteotomy is an option in treating ankle osteoarthritis, being the main indication in cases with partial joint involvement and preserving at least 50% of the joint surface. With an adequate understanding of the pathology and a proper surgical indication for joint realignment, most patients do not need conversion to arthrodesis or ankle arthroplasty with short or medium follow-up.

Level of evidence V; Expert opinion.

Keywords: Ankle; Osteoarthritis; Osteotomy; Joint.

Introduction

Ankle osteoarthritis (OA) affects 1% of the population worldwide[1]. This condition commonly affects individuals 12 to 15 years younger than individuals with hip or knee OA[2]. This is because most ankle OA is post-traumatic, unlike hip and knee OA, which are mostly primary of these joints[1,3].

Surgical treatment of ankle OA is divided into two categories: non-joint-preserving surgeries and joint-preserving surgeries. The non-joint-preserving surgeries are ankle arthrodesis and arthroplasty, which are widely used, but with potential complications. Due to the blockage of the ankle joint, ankle arthrodesis can lead to OA in adjacent joints[4]. Ankle arthroplasty has a survival rate between 80% and 90% in 10 years, thus, depending on the patient's age, revision surgery is required.

Supramalleolar osteotomy is a joint-preserving surgery that has its main indication in partial OA of the joint, that is, in case of asymmetric OA in varus or valgus ankle, preserving at least 50% of the joint surface[5] (Figure 1). The goal of supramalleolar osteotomy is to realign the tibia with the talus in the coronal and sagittal planes, decreasing pressure in the compromised joint area and partially transferring this pressure to the most preserved area. Approximately two-thirds of ankle OA are asymmetrical, with greater medial or lateral joint involvement[6].

Deformity type and location

Asymmetric ankle OA can be classified as a varus or valgus, congruent or incongruent deformity. In congruent deformity, there is a slope of 4° or less between the proximal articular surface of the talus and the distal articular surface of the tibia. In incongruent deformity, there is a slope greater than 4° between the proximal articular surface of the talus and the distal articular surface of the tibia; this slope is called talar tilt (TT)[7,8] (Figure 2).

In most cases of asymmetric ankle deformity, the deformity apex occurs at the ankle level or near the ankle. Especially in wedge osteotomies as osteotomy is not performed at the apex of the deformity, a translation of the distal fragment occurs. Wedge osteotomies to correct valgus ankle led to the medialization of the distal fragment (ankle), while to correct varus ankle, it leads to the lateralization of the distal fragment (ankle). This translation of the distal fragment does not occur in dome osteotomy (Figures 3 and 4). In a valgus ankle, medializing the distal fragment results in excessive load on the lateral side of the ankle; thus, a lateral translation of the distal fragment is necessary. Similarly, for varus ankle correction, the lateral translation of the distal fragment leads to medial overload in the ankle, so the medial translation of the distal fragment must be included. This corrective translation should be performed, especially in major deformities[9].

Study performed at the Hospital Mãe de Deus, Porto Alegre, RS, Brazil.

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Supramalleolar dome osteotomy is an alternative to wedge osteotomy and should be indicated, especially in OA where the deformity is metaphyseal, which occurs mainly in congruent OA.

Osteoarthritis severity classification

The Takakura classification[10] is used to grade OA and define the surgical procedure required (Table 1).

Grade 4 involves the entire ankle joint; therefore, supramalleolar osteotomy is a contraindication. The exception would be cases where there is a broader planning, for example, performing a supramalleolar osteotomy to improve ankle alignment and later perform an ankle arthroplasty. In grade 3b, supramalleolar osteotomy may be indicated; however, due to the degree of joint involvement, results are worse than in grades 1, 2, and 3a[11,12].

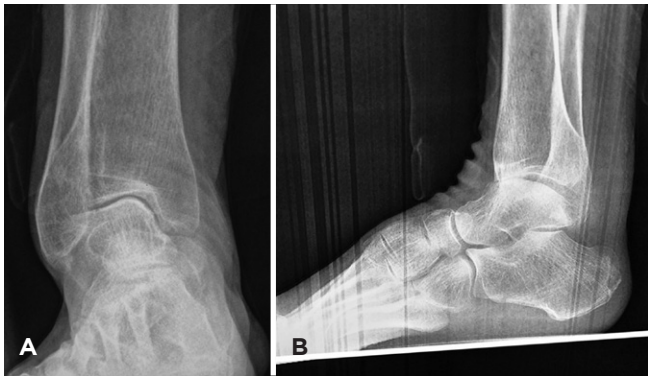

Figure 1. Weight-bearing (A) anteroposterior and (B) lateral ankle radiographs. Asymmetric ankle OA with varus deformity of the distal articular surface of the tibia with partial ankle joint preservation.

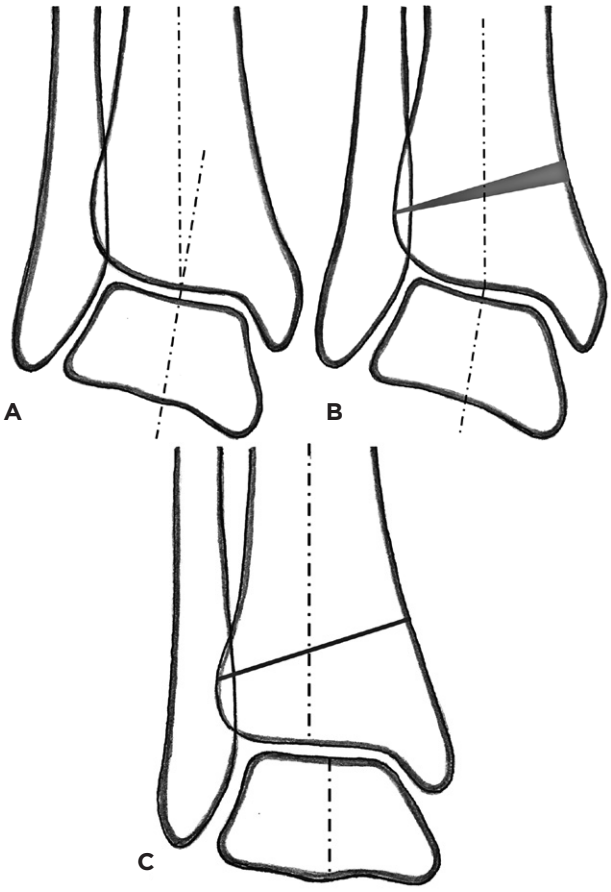

Figura 3. (A) Congruent valgus deformity with the apex at ankle level; (B) supramalleolar osteotomy with medial closing wedge proximal to the deformity apex; (C) correction of the alignment of the distal articular surface of the tibia with medialization of the center of the talus.

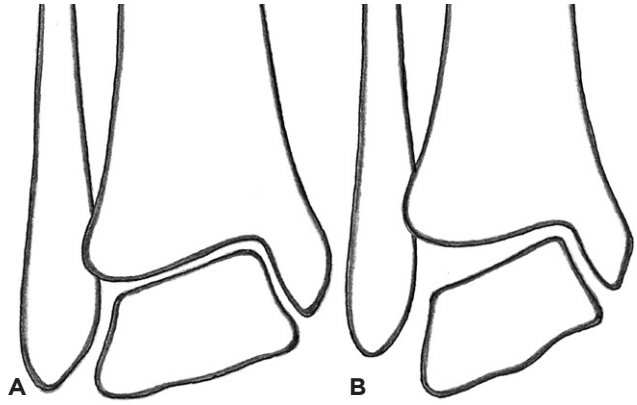

Figure 2. Shows the two asymmetric ankle OA types: (A) congruent, with the talus parallel to the distal articular surface of the tibia; and (B) incongruent, with the talus inclined to the distal articular surface of the tibia.

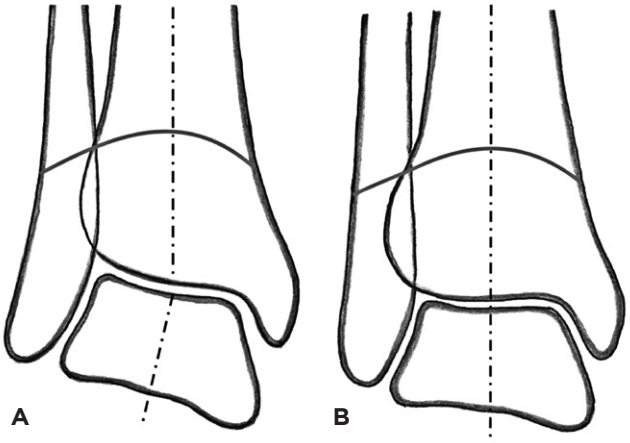

Figure 4. (A) Dome osteotomy of the distal tibia; (B) with the dome osteotomy, the center of the talus was aligned with the mechanical axis of the tibia.

Preoperative clinical evaluation

Clinical alignment of the lower limbs is analyzed. Patients with varus ankle may have calcaneal valgus alignment, and the correction may lead to excessive calcaneal valgus with sub fibular impingement. Passive ankle extension is evaluated to identify gastrocnemius contracture and assess ankle medial and lateral ligament stability, inversion force of the posterior tibial tendon, and the eversion force of the peroneal brevis and longus tendons.

Preoperative radiographic evaluation

The radiographic evaluation consists of a panoramic radiograph of the lower limbs, weight-bearing anteroposterior (AP) and lateral radiographs of the ankle, and weight-bearing AP and lateral radiographs of the foot. The medial distal tibial angle (TAS) consists of the angle formed between the line of the anatomical axis of the tibia and the line joining the most medial point to the most lateral point of the distal articular surface of the tibia on the AP radiograph of the ankle, with a normal value of 86° to 89°[13,14]. This angle shows if the deformity is above the ankle. The tibiotalar surface angle (TTS) consists of the angle formed between the line of the anatomical axis of the tibia and the line joining the most medial point to the most lateral point of the proximal articular surface of the talus on the AP radiograph of the ankle; this angle shows the alignment of the talus with the axis of the tibia. The difference between TAS and TTS is indicated as TT, which shows the inclination degree of the talus considering the distal articular surface of the tibia. As previously mentioned, a TT equal to or less than 4° characterizes a congruent joint, and a TT greater than 4° characterizes an incongruent joint. In lateral radiographs with ankle load, the tibial lateral surface angle (TLS) is evaluated, which is the angle between the line of the anatomical axis of the tibia and the line joining the most posterior point to the most anterior point of the distal articular surface of the tibia, normally being 83° (± 2°). The sagittal talar translation (STT) is also evaluated, which is the ratio between the distance from the middle of the talar dome, assessed with a circle fitting in the talar dome, to the tibial axis and the length of the distal tibial articular surface on the lateral view[15]. The Saltzman incidence shows the alignment of the hindfoot through the moment arm of the calcaneus on hindfoot view. A horizontal distance between the tibial axis (weight-bearing axis of the leg) and the most inferior point of the calcaneus was defined as the moment arm[16] (Figure 5).

In addition to radiographic evaluation, MRI or CT scans may be necessary. The first is indicated mainly in early cases of OA, where edema in the subchondral bone may be the only sign

Table 1. Takakura's classification for ankle osteoarthritis and varus deformity[10]

Stage	Radiographic findings
1	No joint space decrease, subchondral sclerosis, and osteophyte formation
2	Reduced medial joint space
3a	Obliteration of the space, with contact of the subchondral bone of the medial articular surface of the talus with the medial malleolus (medial leak only)
3b	Worsening of the joint space obliteration, contact of the subchondral bone of the medial talar dome with the medial tibial plafond
4	Complete obliteration, with full contact of the dorsal subchondral bone of the talus with the subchondral bone of the tibial plafond

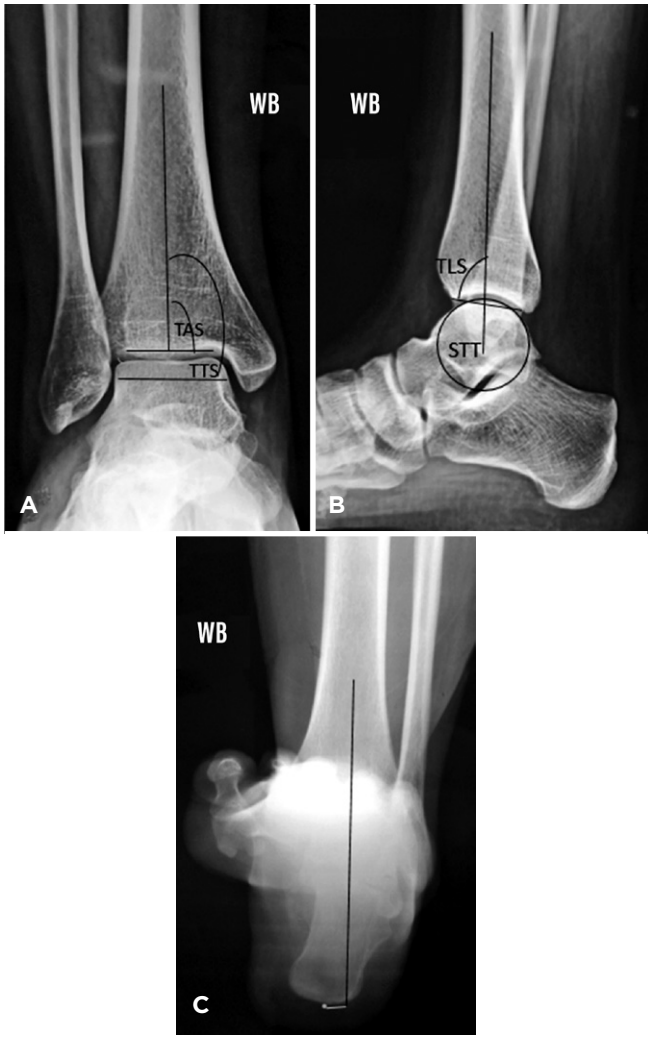

Figure 5. Radiographic evaluation of the ankle. (A) AP weight-bearing plain radiograph of the ankle evaluating the medial distal tibial surface angle and the tibiotalar surface angle; (B) Lateral weight-bearing plain radiograph of the ankle with evaluation of the tibial lateral surface angle and sagittal talar translation; (C) Saltzman's hindfoot weight-bearing with moment arm evaluation of the calcaneus.

indicative of joint impairment, while the second is indicated in most cases, with three-dimensional reconstruction being very useful for identifying osteophytes that need to be resected during surgical intervention.

Subtalar joint compensatory capacity

Poor hindfoot alignment (inframalleolar deformity) results from alterations in the alignment or shape of the calcaneus, leading to changes in the subtalar joint orientation. Takakura et al.[10] speculated that the subtalar joint has a compensatory function preventing OA progression: in ankle varus deformity, the subtalar joint would assume a valgus orientation, with OA progression only occurring when there is a loss of this compensatory function[10]. A subsequent clinical study confirmed these findings[17]. Using radiographs, Hayashi et al.[18] demonstrated there was a more valgus subtalar joint in the intermediate stages of OA in varus ankle, while in the more advanced stages, the subtalar joint assumed a neutral or varus position, that is, there was a loss of subtalar compensatory power[18].

There is an anatomical variability in the subtalar joint, which leads to differences in its capacity to accommodate and adapt. A study showed that 88% of the population have a concave posterior facet of the subtalar joint, and 12% have a flat posterior facet. Individuals with a flat posterior facet have decreased mobility of this joint in the coronal plane, with less compensating power for varus or valgus ankle[19]. A study showed that patients with OA in varus ankle have a varus inclination of the subtalar joint posterior facet, and patients with OA in valgus ankle have a valgus inclination of the subtalar joint posterior facet[15]. Patients with OA of the subtalar joint also have a decreased compensatory capacity in the subtalar joint for ankle varus or valgus deformities. Therefore, the subtalar joint behavior in asymmetric ankle OA is complex and varies.

The subtalar joint ability to compensate for deformity in cases of asymmetric ankle OA can result in paradoxical deformities. For instance, this may lead to ankle varus deformity while the calcaneus remains neutral or valgus.

Surgical indication

Varus ankle treatment

The procedure starts with an open joint debridement but can be performed by arthroscopy in certain cases. The objective is to perform the resection of bone spurs and remove intra-articular free bodies. Avoiding excessive anterior bone resections in the tibia is important, as this can lead to instability and anterior migration of the talus.

In the coronal plane, as previously mentioned, TAS has an anatomical inclination of 86° to 89°. The type of supramalleolar osteotomy to be performed depends on where the deformity apex is, the soft tissue conditions, and whether the OA is congruent or incongruent. Congruent deformities are preferably corrected with dome osteotomy, and incongruent osteotomies are corrected with wedge osteotomy, which may be a lateral closing wedge or a medial opening wedge, depending on the case[20] (Figure 6). If patient has medial cartilage loss, the goal of the osteotomy is to obtain 2º to 4º valgus at the TAS, that is, a slight valgus at the end of the correction. In cases of large incongruent deformity, equal to or greater than 15°, due to the large amount of bone to be grafted or resected in a wedge, a dome osteotomy can be considered[5].

The medial opening wedge osteotomy allows a gradual varus correction until the appropriate degree is achieved in the coronal plane; in addition, if necessary, an anterior opening wedge can be performed aiming at the correction in the sagittal plane, by moving the anatomical axis of the tibia closer to the center of rotation of the talus. This correction in the sagittal plane is necessary for patients with anterior translation of the talus in relation to the tibia. The decision to perform a simultaneous fibular osteotomy is typically made intraoperatively and is based on the degree of deformity present. In our experience, fibula osteotomy is performed in most cases. Hintermann et al.[5] generally perform fibular osteotomy in deformities greater than 10°[5].

The lateral closing wedge osteotomy has the advantage of not requiring a bone graft. Theoretically, it provides greater stability and reduces pressure within the ankle joint due to the subtraction of bone. It usually requires fibular osteotomy; otherwise, the fibula can get long and have a subfibular impact. Disadvantages include the increased difficulty in gradually correcting the deformity and the requirement for a biplanar wedge when correction is needed in both the coronal and sagittal planes (Figure 7).

In some cases, a medial impaction of the distal articular surface of the tibia can occur, and if greater than 5°, an intra-articular osteotomy called “plafondplasty” can be performed to restore articular congruence[21]. A Kirshner wire is inserted into the apex of the intra-articular deformity, and an additional wedge osteotomy is performed using bone graft and fixation, usually performed with an anterior plate in the tibia.

In most cases of supramalleolar osteotomy, fixation is performed with a plate in the tibia, and a compression screw can be added to the osteotomy. In the fibula, the fixation is performed with a plate. In complex cases, fixation with an external fixator and gradual deformity correction can be used, especially with fixators that allow three-dimensional correction.

Valgus ankle treatment

Like in the varus ankle correction, surgery starts with a joint debridement, usually open, and arthroscopy in certain cases.

In cases of congruent articulation, correction is preferably made with dome osteotomy; in cases of incongruent articulation, medial closing wedge (majority of cases) or lateral opening wedge (minority of cases) is preferably performed. The medial closing wedge osteotomy is performed to obtain 2º to 4º varus at the tibial joint surface. The lateral cortex of the distal tibia is more resistant than

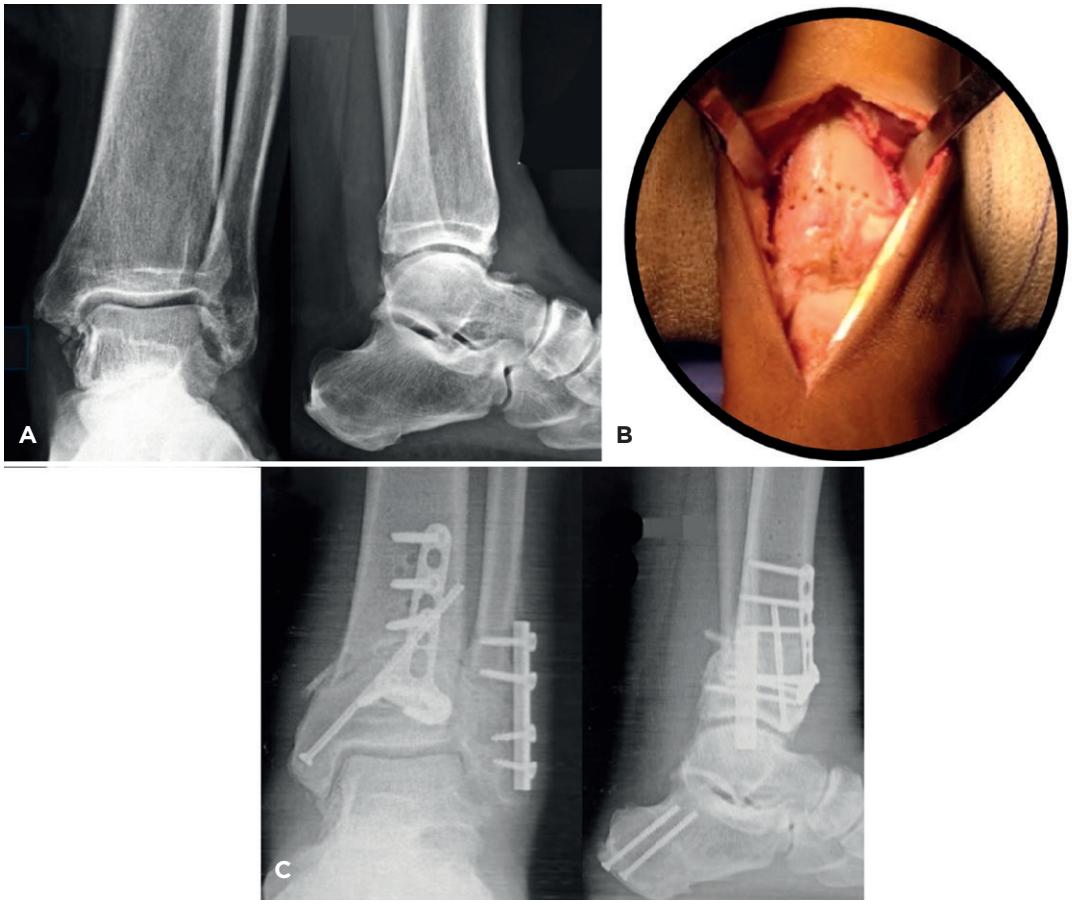

Figure 6. Male patient, 40 years old, with two previous medial ankle debridement surgeries by bone impact. Distal tibial dome osteotomy, fibular osteotomy, and calcaneus valgus osteotomy were performed. (A) Preoperative radiographs; (B) intraoperative image of the distal tibial dome osteotomy; (C) postoperative radiographs.

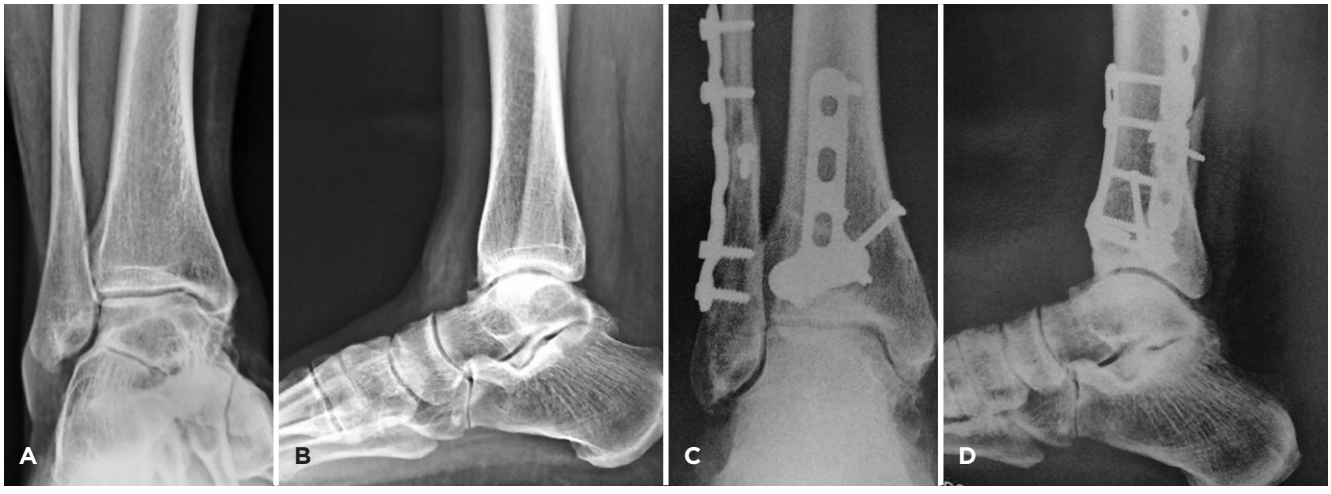

Figure 7. Lateral tibial closing wedge and fibular osteotomy to treat asymmetric varus ankle OA. (A) AP and (B) Lateral pre-operative radiographs; (C) AP and (D) lateral post-operative radiographs.

the medial cortex, thus, with the placement of an anterior or anteromedial plate, there is good stability and a low risk of instability in the synthesis. In performing dome osteotomy, it is always necessary to perform a fibular osteotomy. In the closing wedge osteotomy, if there is no adequate reduction of the talus with joint congruence, fibular osteotomy should be performed to rotate the fibula or, if necessary, lengthen the fibula[22] (Figure 8).

Lateral opening wedge osteotomy for valgus correction is reserved for cases with poor medial soft tissue quality or concerns about shortening caused by the closing wedge. Bone graft and fibular osteotomy are required. A disadvantage of lateral opening wedge osteotomy is that the medial cortex of the distal tibia is weaker than the lateral cortex, thus, even if the distal tibia is laterally fixed with a plate, a medial incision may be necessary to place a second plate medially aiming to minimize the risk of instability and reduction loss[5].

In cases of large incongruent deformity, deformities equal to or greater than 15°, due to the large amount of bone to be grafted or resected in a wedge, a dome osteotomy can be considered[5].

Fibular osteotomy

Biomechanical studies show the importance of maintaining or recovering joint congruence in supramalleolar osteotomy to achieve a more reliable pressure redistribution at the ankle[23,24]. Placement of the talus congruently at the ankle joint may require adjustment in fibula length[23,25]. Each case should be assessed individually, particularly in cases of congruent deformities. Beyond correcting the angulation of the distal articular surface of the tibia, it is crucial to evaluate the potential need for fibular shortening or lengthening based on preoperative radiographic assessments, typically compared with the contralateral ankle. Even when the fibula length is adequate in radiographic evaluation, osteotomy is necessary in many cases to allow the best reduction of the talus in the ankle (Figure 9).

In dome osteotomy, fibular osteotomy is always necessary. In wedge osteotomy, the decision to perform fibular osteotomy may be intraoperative if the isolated correction of the distal articular surface of the tibia is not enough to improve articular congruence. Intraoperatively, the parameters to be

Figure 8. Patient with asymmetric valgus OA submitted to medial closing wedge and fibular osteotomies. (A and B) Preoperative radiographs; (C) tomography showing epiphyseal lateral lesion; (D and E) postoperative radiographs.

evaluated are: 1) recovery of the medial clear space, that is, the relationship between the medial articular surface of the talus and the medial malleolus; 2) parallelism between the distal articular surface of the tibia and the talar dome; and 3) recovery of the normal length relationship between the lateral malleolus and the medial malleolus[26]. Stufkens et al.[24], in a biomechanical study, report that failure to perform fibular osteotomy limits correction with supramalleolar osteotomy in the tibia[24].

Sagittal plane deformity

In the sagittal plane, procurvatum and retrocurvatum deformities should be considered in ankle OA correction with osteotomy. Procurvatum deformity is better tolerated than retrocurvatum deformity. In retrocurvatum deformity, there is an anterior translation of the talus, with consequent greater pressure peaks in the ankle joint, causing a greater joint damage. Procurvatum deformity can cause pain due to the impact of the anterior bone on the ankle joint, but it has a greater tendency to preserve the joint surface[20,27,28].

Associated procedures

In patients with varus ankle, varus maintenance due to an inframalleolar deformity may occur because of subtalar joint stiffness, posterior tibial tendon contracture, or calcaneal deformity[5]. In the presence of varus stiffness of the subtalar joint, it is necessary to perform a subtalar arthrodesis. When varus persists after supramalleolar osteotomy, it is often necessary to release the deltoid ligament. In varus patients with decreased eversion force, an alternative is the transfer of the peroneal longus tendon to the peroneal brevis tendon, aiming to increase the eversion force. Calcaneus osteotomy may be necessary to correct the residual inframalleolar deformity, being performed with lateral wedge and lateral sliding of the tuberosity or only lateral sliding of the tuberosity. In patients with excessive plantar flexion of the first metatarsal, it may be necessary to perform dorsal closing wedge osteotomy at the base of the first metatarsal for dorsiflexion of this metatarsal. If there is an accentuation of the tilt of the talus with varus stress of the ankle, lateral ligament repair of the ankle can be performed, for example, by the Broström-Gould technique; however, according to Krause et al.[29], in a study with cavovarus feet and lateral ankle instability, osteotomies and tendon transfers were sufficient, without lateral ligament repair and without the occurrence of postoperative ankle instability[29].

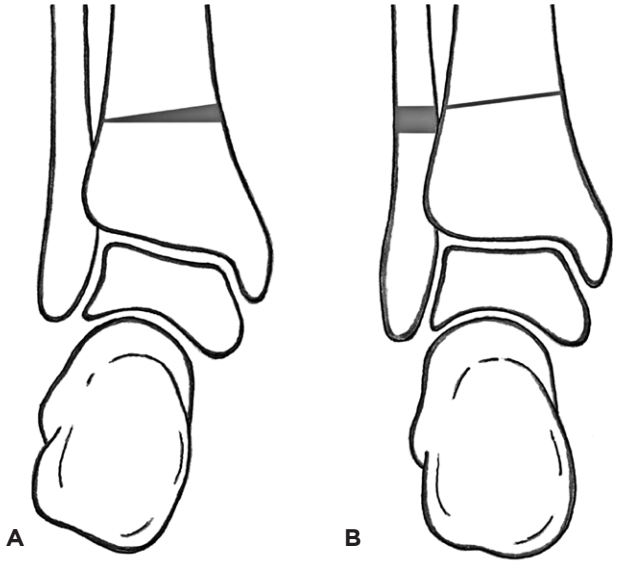

Figure 9. (A) Medial tibial closing-wedge osteotomy for valgus ankle deformity; (B) lengthening of the fibula is necessary to maintain the correct relationship between the medial and lateral malleolus.

In patients with valgus ankle, the inframalleolar deformity may be the result of peritalar instability, subtalar contracture, valgus malposition of the calcaneus, insufficiency of the medial soft-tissue structures (including the deltoid ligament and the posterior tibial tendon), or breakdown of the medial longitudinal arch[5]. If the patient has a valgus hindfoot and subtalar arthrodesis is not required, a calcaneal varus osteotomy with medial sliding of the tuberosity can be performed. In specific cases, a medializing calcaneal osteotomy may be required combined with subtalar arthrodesis. The need for deltoid ligament reconstruction should be carefully assessed. If required, stabilization of the medial column can be addressed, for example, by performing arthrodesis of the first metatarsocuneiform joint. This procedure may involve using a dorsal-based bone graft to achieve stabilization and maintain appropriate flexion of the first metatarsal. Tendon balance should be evaluated and, if necessary, the flexor digitorum longus tendon can be transferred to the navicular to improve inversion, while the peroneal brevis tendon can be transferred to the peroneal longus tendon to decrease the eversion force of the hindfoot and improve plantar flexion of the first metatarsal.

Passive ankle dorsiflexion should be assessed during physical examination in varus or valgus deformity cases. If a limitation is identified, it is crucial to determine whether the gastrocnemius or the calcaneal tendon causes the restriction. This evaluation guides the appropriate surgical intervention intending to improve ankle dorsiflexion.

Complications

Loss of correction can occur due to failure in fixation, for example, by excessive early loading or by not identifying associated pathologies, such as ligament instability, neuromuscular pathologies, or inframalleolar deformities. Delay of consolidation or pseudarthrosis may occur due to insufficient fixation or failure of fixation. Overcorrection or undercorrection can result from errors in planning, impro-

per surgical execution, or loss of correction during the postoperative period[30]. In case of deformities in the coronal and sagittal planes, both must be corrected; otherwise, pain may persist. This is particularly true in sagittal plane recurvatum deformities with anterior ankle joint overload due to anterior talus translation[5]. Intraoperatively, peripheral nerve lesions may be present in the lateral incision (sural nerve lesion), anterior incision (deep peroneal nerve lesion), and medial incision (saphenous nerve lesion). In varus ankle correction with varus correction for valgus, we can have tibial nerve stretching and the development of acute tarsal tunnel syndrome, which is a concern, especially in patients with adhesions due to previous surgeries[5].

Results

Several studies have shown good clinical and radiographic results with supramalleolar osteotomy for treating varus ankles[10,31-34] and valgus ankles[22,26]. Krahenbuehl et al.[11] reported the outcomes of 294 supramalleolar osteotomies, demonstrating an 88% survival rate over five years. The best results were observed in patients under 60 years and in those with early-stage OA (Takakura grades 1, 2, and 3a). With a mean follow-up of five years (2 to 16 years), 13% of patients (38/294) evolved to severe ankle OA, having undergone ankle arthroplasty (30 patients) or ankle arthrodesis (8 patients)[11]. Tanaka et al.[12] found a similar result, reporting that good results of supramalleolar osteotomy occur in Takakura classification grades 1, 2, and 3a[12]. However, Lee et al.[32] found a different result, reporting that patients classified as Takakura 3b in the preoperative period had radiographic improvement, being graded as Takakura 2 in the postoperative period[32]. Pagenstert et al.[35] reported a study with 35 patients with five years of follow-up after supramalleolar osteotomy, and 91% of patients did not submit to arthroplasty or ankle arthrodesis[35].

Preoperative TT equal to or greater than 7° has been considered a worsening factor in results; however, Choi et al.[36] report 31 patients with varus OA and mean TT of 12.1° where, despite of showing no significant radiographic improvement (TT from 12.1° preoperatively to 9.9° postoperatively), patients showed improvement in clinical results. Additionally, patients who underwent correction with supramalleolar osteotomy and inframalleolar correction had better results than patients who underwent supramalleolar osteotomy only[36].

Although complete radiographic correction of the TT is not achieved, clinical improvement occurs in most patients with surgery[37]. These results suggest that the clinical outcome is independent of complete radiographic anatomical correction.

Mann et al.[21] report that, in cases with relevant intra-articular defect of the tibial plafond, the association of plafondplasty with supramalleolar osteotomy was superior to performing isolated plafondplasty, suggesting that the combination of the two osteotomies would be the best option for these complex cases[21].

Nuesch et al.[38] compared the gait of patients submitted to supramalleolar osteotomy for varus ankle realignment to that of controls with seven years of follow-up; patients had a slower gait and lower mobility in the sagittal plane. Despite the changes in gait, the patients' quality of life was considered good[38].

With short or medium follow-up, only 10% of patients submitted to supramalleolar osteotomy required ankle arthroplasty or arthrodesis[5].

Factors that increase the failure rate in supramalleolar osteotomy are age above 60 years, TT equal to or greater than 7°, postoperative joint incongruence, and ligament instability[9,11,12,33,37].

Conclusion

Supramalleolar osteotomy is an alternative for the treatment of asymmetric ankle OA. The osteotomy type depends on the deformity level, the type of fixation to be used, the quality of the soft tissue envelope, and whether the deformity is congruent or incongruent. The best results occur when the indication is made for treating Takakura grades 1, 2, or 3a, with 82% survival at 10 years. Worsening factors in results are age above 60 years, preoperative TT equal to or greater than 7°, preoperative OA degrees Takakura 3b or 4, and postoperative joint incongruence.

Inframalleolar deformities occur due to the shape of the calcaneus, the shape and orientation of the subtalar joint, and forefoot deformities. The effect of a calcaneus osteotomy on the ankle is not predictable, as it depends on the behavior of the coronal plane of the subtalar joint. The medial column of the foot must be evaluated preoperatively; an unstable medial column provides the flatness of the foot and, thus, the lateral weight-bearing on the ankle, while a medial column with plantar flexion provides the cavism of the foot and, thus, an anteromedial weight-bearing on the ankle.

Authors' contributions: Each author contributed individually and significantly to the development of this article: PCC *(https://orcid.org/0000-0001-7388-7229) Conceived and planned the activities that led to the study, approved the final version, interpreted the results of the study, participated in the review process and approved the final version. All authors read and approved the final manuscript. *ORCID (Open Researcher and Contributor ID).

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