The Journal of Foot & Ankle Surgery 55 (2016) 60–67

Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Treatment of Varus Ankle Osteoarthritis and Instability With a Novel Mortise-Plasty Osteotomy Procedure

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ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:
joint-preserving surgery
locking plate
opening wedge distal tibial osteotomy
synthetic bone graft substitute
Tomofix™
wide ankle mortise

ABSTRACT

Although joint-preserving surgery for intermediate ankle osteoarthritis has been reported to be effective, failures of supramalleolar osteotomy and plafond-plasty can occur because of persistent malalignment of the distal tibia and incongruent ankle mortise. We introduce a novel opening wedge distal tibial osteotomy procedure (mortise-plasty) with rigid plate fixation combined with synthetic bone wedges. We performed 27 mortise-plasties in 25 patients with varus ankle osteoarthritis and instability. Six males (24%) and 19 females (76%), with a mean age of 63 (range 28 to 79) years, were followed up for a mean of 27.3 (range 14 to 45) months. The mean preoperative visual analog scale score, American Orthopaedic Foot and Ankle Society score, and Takakura ankle scale score were 7.4 (range 5.4 to 10), 58.7 (range 18 to 84), and 55.9 (range 29 to 88), respectively. These scores improved significantly to 2.1 (range 0 to 6.5), 89.3 (range 67 to 100), and 84.7 (range 55 to 100) postoperatively ($p < .001$). The mean preoperative tibial–anterior surface angle and talar tilt angle were 84.9° (range 78° to 90°) and 8.3° (range 3° to 21°), respectively. At the most recent follow-up visit, the corresponding values were 95.0° (range 82° to 99°) and 1.8° (range 0° to 8°), respectively ($p < .001$). Computed tomography scans indicated that the ankle mortise narrowed by approximately 1.8 mm and the tibial plafond was lowered after osteotomy. No patients underwent lateral ligament reconstruction, ankle joint replacement, or arthrodesis. Mortise-plasty osteotomy corrects the intra-articular and extra-articular deformities simultaneously and provides good clinical and radiographic outcomes for patients with varus ankle osteoarthritis and instability.

Operative strategies for intermediate ankle osteoarthritis have recently become controversial because of the introduction of novel joint-sparing treatment options (1–5). Clinically, intermediate ankle osteoarthritis is defined as an ankle in stage 2, 3a, or 3b according to the modified Takakura system (1,2). The clinical goals in treating intermediate ankle osteoarthritis are to preserve normal joint function and prevent arthrosis development or halting additional progression (6–8).

Supramalleolar osteotomy is a transverse osteotomy of the distal tibia and fibula, and it rotates the entire ankle mortise and corrects the extra-articular deformity [i.e., the center of rotation of angulation (9), located above the ankle joint]. The mechanisms of action underlying supramalleolar osteotomy for varus ankle osteoarthritis are believed to consist of correcting the medial displacement of the load line and the lateral distribution of the stress concentrated medially within the ankle (6). Supramalleolar osteotomy is effective for patients in stage 2 or 3a with a preoperative talar tilt of <5°; however, the clinical results for patients with stage 3b have been unsatisfactory (2,6). Moreover, when a severe talar tilt of >7.3° (4) or >10° (2) is present, supramalleolar osteotomies have not been found to be effective in restoring the normal joint. Failure of supramalleolar osteotomy can also occur because of a persistent medial intra-articular tibial defect, resulting in recurrent varus deformity (5).

In 2012, Mann et al (5) devised intra-articular plafond-plasty to treat intra-articular varus deformity (i.e., center of rotation of angulation within the ankle joint). This technique effectively addressed the medial plafond deformity to suit the talus; however, coronal plane correction of the distal tibia had not been achieved. Although the overall clinical outcomes were good, plafond-plasty associated with lateral ligament reconstruction failed to correct the varus tilting of the talus and a residual talar tilt >10° remained.

Therefore, we hypothesized that failure of supramalleolar osteotomy and plafond-plasty could occur because of persistent coronal malalignment of the distal tibia and an abnormal joint congruity between the ankle mortise and the talus. To our knowledge, no

Financial Disclosure: None reported.
Conflict of Interest: None reported.
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http://dx.doi.org/10.1053/j.jfas.2015.06.011

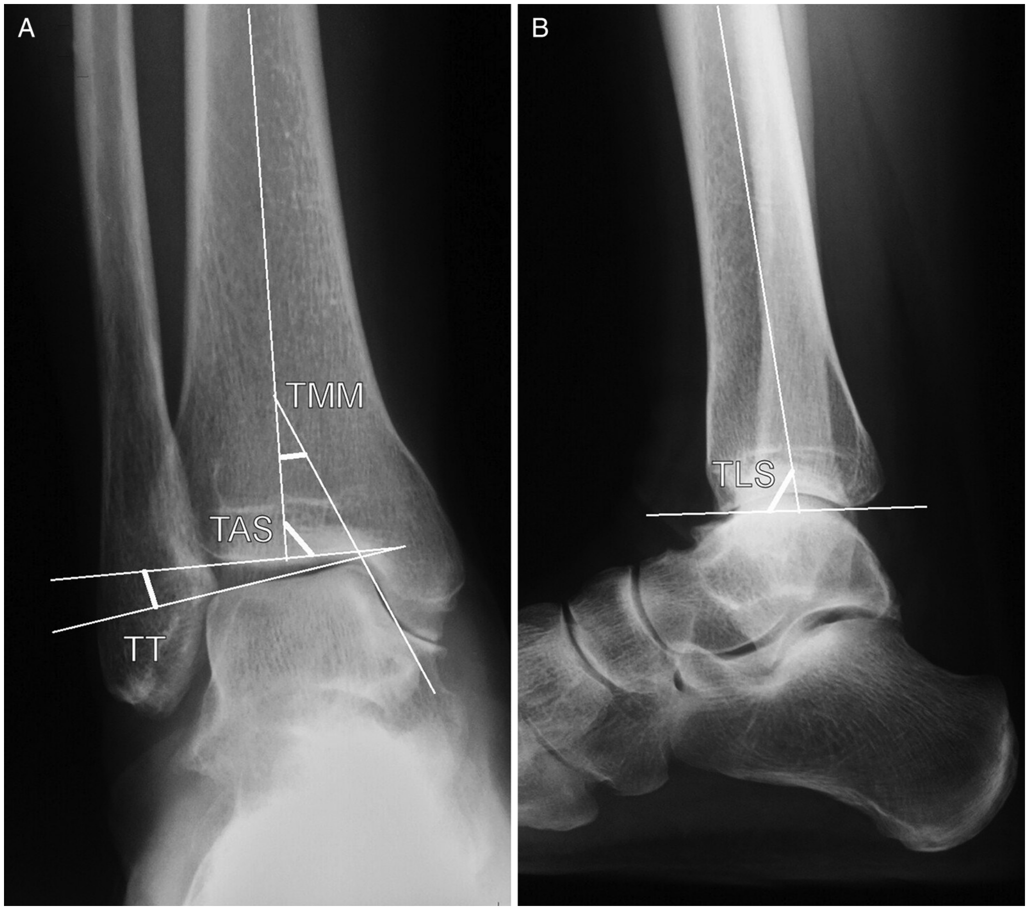

Fig. 1. (*A*) Anteroposterior and (*B*) lateral weightbearing radiographs of the ankle showing the radiographic variables. TAS, tibial–anterior surface (angle); TLS, tibial–lateral surface (angle); TMM, tibial axis–medial malleolus (angle); TT, talar tilt (angle).

reports referring to simultaneous correction of intra-articular and extra-articular deformities in a single procedure have been published.

We introduce a novel tibiotalar joint-sparing procedure—opening wedge distal tibial osteotomy (mortise-plasty)—to correct the coronal plane deformity and to simultaneously improve abnormal joint congruity. In this technique, the osteotomy line was set at the level of the tibiofibular syndesmosis (i.e., 1.5 cm above the ankle joint) to shut the relatively widened ankle mortise (5) and lower the tibial plafond after spreading the distal tibia. We have confirmed that our novel procedure overcomes some limitations of traditional supramalleolar osteotomy and plafond-plasty, and the entire ankle mortise changes its shape dramatically to suit the talus. Furthermore, this is the first report on the clinical and radiographic outcomes after a distal tibial osteotomy using synthetic bone wedges. In the present study, we report the results of this novel opening wedge distal tibial osteotomy procedure (mortise-plasty) for correction of varus ankle osteoarthritis and instability.

Patients and Methods

Our institutional review board approved the present retrospective case study (approval no. FHR-25-3), and all patients provided written informed consent for inclusion in the review. From March 2011 to October 2013, we performed 27 consecutive opening wedge distal tibial osteotomies in 25 patients with varus ankle osteoarthritis and instability. Six male (24%) and 19 female (76%) patients, with a mean age of 63 (range 28 to 79) years were followed up for a mean of 27.3 (range 14 to 45) months.

Evaluations

Patients were considered suitable candidates for this joint-sparing procedure if they had (1) intractable ankle pain and instability refractory to conservative treatment, (2) intermediate primary varus ankle osteoarthritis, (3) varus tilting of the talus within the mortise $\geq 3°$ on the anteroposterior weightbearing radiographs, and (4) varus tilting that was passively reducible (i.e., parallel joint line) with manual valgus force under fluoroscopic assessment before surgery. Conservative treatment, including medication, lateral wedge plantar orthosis, and an ankle brace, had failed to relieve the symptoms for ≥ 3 months. Patients with ankle osteoarthritis secondary to trauma or associated with previous fracture treatment were excluded. Also, patients who smoke were excluded to avoid an increased risk of postoperative infection and delayed bone healing.

Three patients (3 ankles [11.11%]) had undergone previous operative treatment in the affected lower limb, including tarsal tunnel release, opening wedge high tibial osteotomy, and Achilles tendon suture in 1 patient each. Of these 3 previous procedures, the former 2 (66.67%) were performed at our institution and the latter (33.33%) at another institution.

The clinical outcome measures included a visual analog scale for pain, the American Orthopaedic Foot and Ankle Society (AOFAS) ankle-hindfoot scale, and the Takakura ankle scale (1). The Takakura ankle scale was used because it assigns more points to the ankle range of motion than does the AOFAS scale. Of the 100-point score, 40 points are for pain and 20 each for the ability to walk, range of motion, and activities of daily living. The results were classified as excellent for scores >90, good for scores 80 to 89, fair for scores 70 to 79, and poor for scores <70 points (1,2). Other clinical findings that were assessed included range of motion, the ability to sit upright on the floor with the legs crossed (Japanese style sitting), and possible postoperative complications. These clinical assessments were performed preoperatively and every 6 months postoperatively. The preoperative and most recent follow-up clinical outcome variables were used in the present study.

Anteroposterior and lateral weightbearing radiographs were taken in each case, and all ankles showed varus deformities involving medial joint space narrowing. The severity of osteoarthritis was evaluated using the Takakura–Tanaka classification system (1,2). The radiographic outcome variables included the tibial–anterior surface (TAS) angle, tibial–lateral surface angle, tibial axis–medial malleolus (TMM) angle, and talar tilt (TT) angle (Fig. 1). Patients underwent radiographic evaluations at regular intervals postoperatively. The most recent follow-up radiographs were analyzed for correction of the preoperative varus ankle deformity. The criterion for radiographic success was set at $\leq 3°$ of the tibiotalar varus on the anteroposterior weightbearing radiographs.

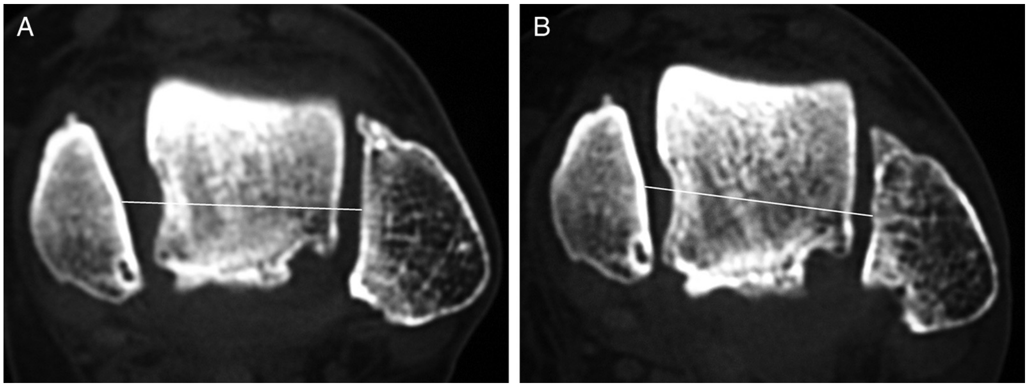

Fig. 2. Axial computed tomography scans demonstrating (*A*) preoperative and (*B*) postoperative mortise widths measured between the middle points of the medial and lateral malleoli at the level of the talar dome.

Twenty-three patients (25 ankles [92.59%]) underwent multiplanar reconstruction computed tomography (CT) scans preoperatively and at 1 to 2 weeks postoperatively. Axial CT scans were evaluated to compare the preoperative and postoperative mortise widths, which were measured between the middle points of the medial and lateral malleoli at the level of the talar dome (Fig. 2). Rapideye Core™ software (Toshiba Medical Systems, Tokyo, Japan) was used as the image measurement device. The size of the osteotomy gaps measured at the medial, middle, and lateral tibial plafonds was obtained from the postoperative coronal CT scans (Fig. 3). These values indicate the magnitude of the narrowed ankle mortise and lowered tibial plafond. The incidence of lateral hinge fracture was also examined on the coronal CT scans. All clinical and radiographic evaluations were performed by 2 of us (Y.K., Y.S.).

Operative Technique

All the procedures were performed by 1 of us (H.K.) with the patient under general anesthesia and continuous lumbar epidural block, if possible, for postoperative pain control. The patient was placed in the supine position on the operating table with a pneumatic tourniquet applied to the thigh. A 3-cm longitudinal incision was made on the medial side of the distal tibia at the level of the planned osteotomy. The medial tibial cortex was incised subperiosteally, taking care not to damage the long saphenous vein and accompanying saphenous nerve traversing the operative site. Prophylactic partial tenosynovectomy of the posterior tibial tendon was performed to visualize its anatomic location and to prevent postoperative stenosing tenosynovitis. The osteotomy line was positioned at the level of the tibiofibular syndesmosis (i.e., 1.5 cm above the ankle joint) to minimize the resultant opening. Under fluoroscopic guidance, the horizontal osteotomy was performed toward the middle point of the tibiofibular syndesmosis along a line parallel to the distal joint line of the tibia, leaving the lateral cortex intact as the hinge of the proximal and distal osteotomy fragments. We avoided an oblique osteotomy as much as possible, because this would create a large osteotomy gap and render later locking fixation intractable owing to an increased medial step-off of the distal osteotomy fragment. By the stepwise insertion of 3 or 4 thin chisels and using a broad bone opener (0.63 in. in width), the osteotomy site was gradually opened until the lateral articular surface of the talus contacted the medial articular surface of the lateral malleolus. This procedure enhanced the stability of the talus by closing the relatively widened ankle mortise (5,10) and lowering the tibial plafond (Fig. 4). Two β-tricalcium phosphate (Hoya Corp., Tokyo, Japan) or interconnected porous hydroxyapatite ceramic (MMT, Co., Ltd., Osaka, Japan) wedges were inserted into the osteotomy site. The β-tricalcium phosphate wedges had a porosity of 67%, and the porosity of the hydroxyapatite wedges was 72% to 78%. The basic size of the synthetic bone wedge was 10 mm wide, 30 mm long, and 7, 10, 12, or 15 mm high. The height of the wedge could be easily adjusted during surgery to accommodate the size of the opening using a micro-bone saw or rongeur. The β-tricalcium phosphate wedges were used to treat 9 ankles (33.33%), and hydroxyapatite wedges were applied to 18 ankles (66.67%) in this study (Fig. 5). A 5-mm rigid locking plate (Tomofix™ small; DePuy Synthes, West Chester, PA) was inserted through a subcutaneous tunnel and stabilized with a minimally invasive plate osteosynthesis technique. In most instances, intraoperative plate contouring was required to prevent soft tissue irritation and increase patient comfort (Fig. 6).

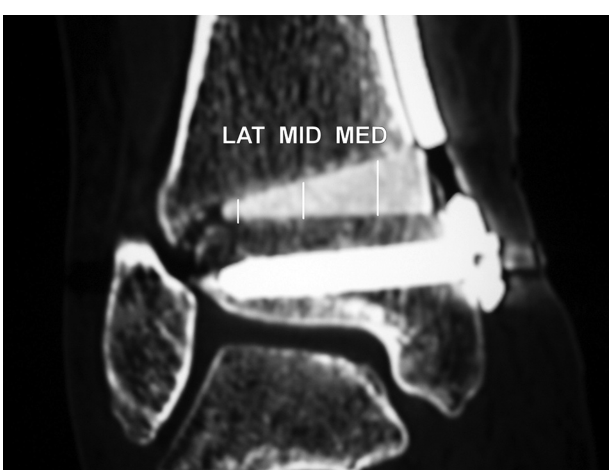

Fig. 3. Coronal computed tomography scan demonstrating the osteotomy gaps measured at the medial, middle, and lateral tibial plafonds. Note a lateral hinge fracture toward the tibiofibular syndesmosis. MED, medial; MID, middle; LAT, lateral.

Concomitant Procedures

Fifteen patients (15 ankles [55.55%]) underwent ≥1 concomitant procedure, including intra-articular debridement and cheilectomy in 7 (25.93%), calcaneocuboid distraction arthrodesis in 3 (11.11%), and percutaneous subchondral drilling, distal first metatarsal osteotomy, subtalar joint arthrodesis, simultaneous contralateral ankle arthrodesis, and fifth metatarsocuboid joint arthrodesis combined with medial displacement calcaneal osteotomy in 1 (3.7%) each. One unusual patient (1 ankle [3.7%]), who had smoked 2 months before surgery, underwent a biplanar opening wedge osteotomy to enhance the initial stability of the osteotomy site by an anterior bump. Simultaneous lateral ligament reconstruction or Achilles tendon lengthening was not performed. No patients, except for 2, who had undergone bilateral ankle osteotomy 3 weeks and 4 months apart, had undergone a staged procedure.

Postoperative Management

Quadriceps and ankle mobilization exercises were begun on the second day after surgery. Partial (one-half) weightbearing activities were allowed on the operated leg at 1 week and full-weight, single crutch walking was often permitted at 3 weeks postoperatively. Stair exercises with or without a T cane were prescribed at 6 weeks postoperatively. The patients were able to return to work involving labor or participate in recreational sports at around 8 weeks postoperatively. The postoperative regimen was modified to accommodate any concomitant procedures.

Plate Removal

After sufficient bone healing, all patients were recommended for scheduled plate removal to increase their comfort and eliminate the risk of implant-related complications.

Statistical Analysis

Statistical analysis of the descriptive data was performed using a Wilcoxon signed-rank test with the level of significance set at $p < .05$.

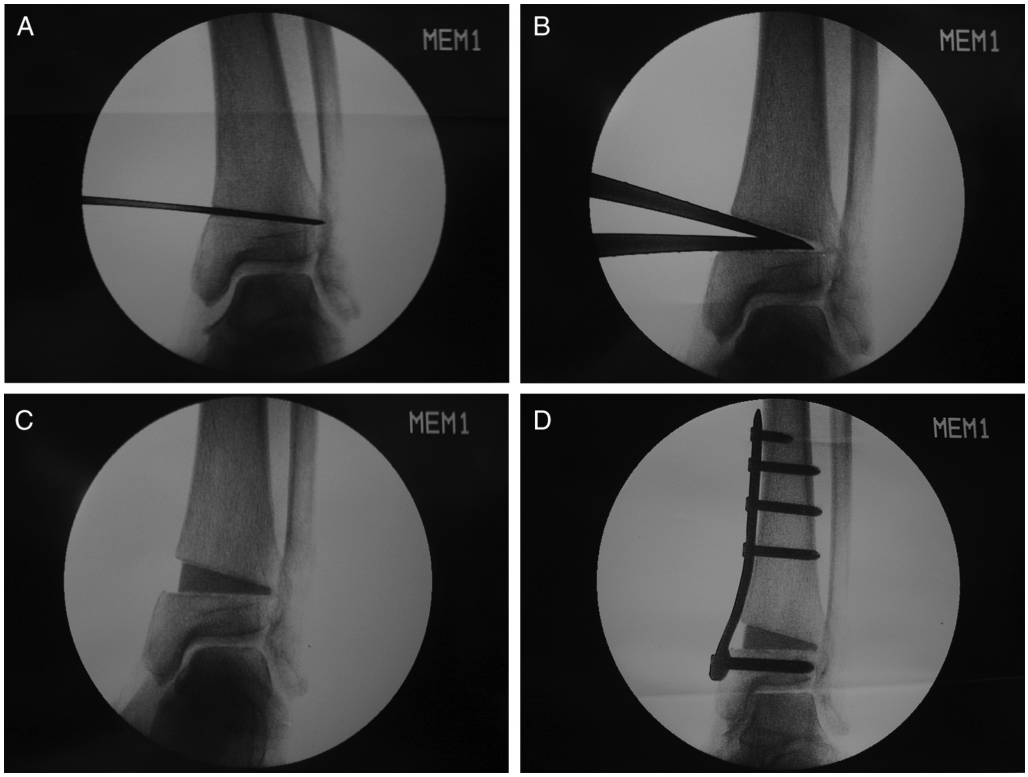

Fig. 4. (*A*) Intraoperative radiographs demonstrating the horizontal osteotomy toward the middle point of the tibiofibular syndesmosis along a line parallel to the distal joint line of the tibia. (*B*) Using a broad bone opener, the osteotomy site was gradually opened until the lateral articular surface of the talus contacted the medial articular surface of the lateral malleolus. (*C*) Two synthetic bone wedges were inserted into the osteotomy site and (*D*) stabilized with Tomofix™ (DePuy Synthes).

Results

All patients obtained uneventful bone union, and 25 (92.59%) of 27 ankles had pain relief and improvement in walking ability after the osteotomy. All but 1 patient (26 ankles [96.29%]) underwent scheduled plate removal. The mean interval between the initial osteotomy and plate removal was 156.7 (range 96 to 251) days. The mean preoperative plantarflexion and dorsiflexion angles were 44.3° (range 35° to 60°) and 13.5° (range 0° to 30°), respectively. At the most recent follow-up examination, the corresponding values were 43.5° (range 35° to 55°) and 12.5° (range 5° to 20°). The ankle range of motion was increased in 8 ankles (29.63%), decreased in 14 (51.85%), and remained unchanged in 5 (18.52%). Given the small number of patients, no significant differences could be detected between the preoperative and postoperative range of motion.

The mean visual analog scale, AOFAS ankle-hindfoot scale, and Takakura scale scores were 7.4 (range 5.4 to 10), 58.7 (range 18 to 84), and 55.9 (range 29 to 88), respectively, preoperatively. The corresponding postoperative scores had improved to 2.1 (range 0 to 6.5), 89.3 (range 67 to 100), and 84.7 (range 55 to 100; $p < .001$ for all comparisons). The overall results were excellent in 13 ankles (48.15%), good in 10 (37.04%), fair in 3 (11.11%), and poor in 1 (3.7%) for the

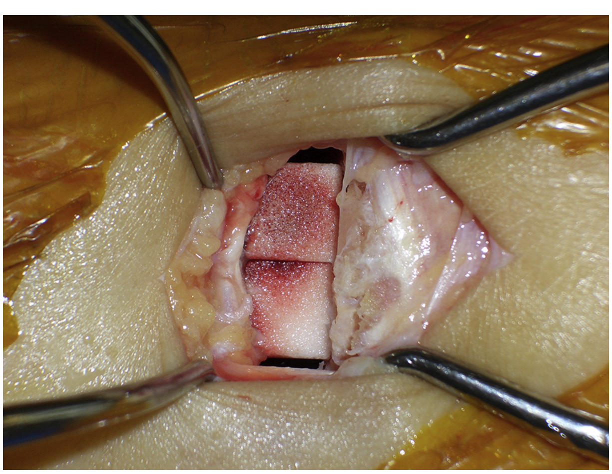

Fig. 5. Intraoperative photograph showing 2 hydroxyapatite wedges inserted into the osteotomy gap.

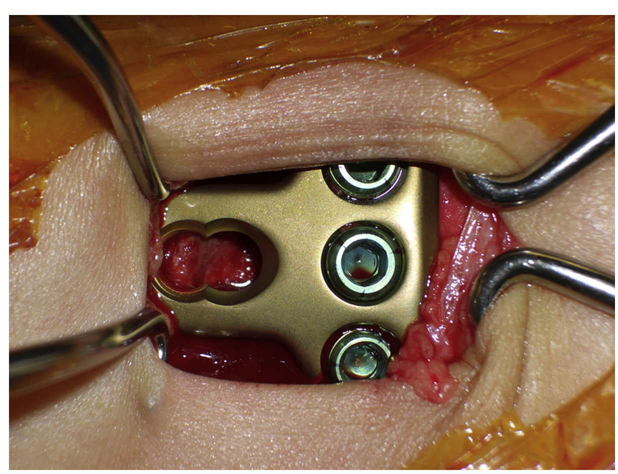

Fig. 6. Intraoperative photograph showing the distal tibia secured with Tomofix™ (DePuy Synthes) using a minimally invasive plate osteosynthesis technique.

Table
Clinical and radiographic outcome variables (N = 27 ankles in 25 patients)

	Preoperative	Follow-up	p Value
VAS score	7.4 ± 3.1	2.1 ± 1.6	<.001
AOFAS scale score	58.7 ± 16.3	89.3 ± 12.1	<.001
Takakura ankle scale score	55.9 ± 16.0	84.7 ± 16.9	<.001
TAS angle (°)	84.9 ± 3.0	95.0 ± 3.9	<.001
TLS angle (°)	82.3 ± 4.3	83.9 ± 4.0	.026
TMM angle (°)	28.4 ± 5.9	20.1 ± 4.2	<.001
TT angle (°)	8.3 ± 5.3	1.8 ± 2.2	<.001
Mortise width (mm)*	32.8 ± 1.9	31.0 ± 2.1	<.001

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; TAS, tibial–anterior surface; TLS, tibial–lateral surface; TMM, tibial axis–medial malleolus; TT, talar tilt; VAS, visual analog scale.
Data presented as mean ± standard deviation.
* Mortise width measured in 25 ankles in 23 patients.

AOFAS scale score and excellent in 11 ankles (40.74%), good in 9 (33.33%), fair in 5 (18.52%), and poor in 2 (7.41%) for the Takakura score (Table).

Thirteen patients (13 ankles [48.15%]) could sit in the Japanese style before surgery, and the result was the same after surgery. However, 4 patients (4 ankles [14.81%]), who could not sit Japanese style preoperatively could do so postoperatively. In contrast, another 4 patients (4 ankles [14.81%]), who could sit Japanese style preoperatively could not do so postoperatively. However, 5 patients (6 ankles [22.22%]) could not sit straight simply because of concomitant knee osteoarthritis and might have had lower Takakura scores (loss of 4 points).

Complications included implant-related pain in 3 ankles (11.11%), hematoma in 2 (7.41%), and superficial infection, tarsal tunnel syndrome, unstable lateral hinge fracture, and asymptomatic correction loss of 6° after early plate removal (14 weeks) in 1 (3.7%) each. One patient (1 ankle [3.7%]), who had developed a wound infection at 4 weeks postoperatively, underwent immediate plate removal and conversion to a circular external fixator with success. Another patient (1 ankle [3.7%]), who had developed subacute tarsal tunnel syndrome, required tarsal tunnel release 4 months after the initial osteotomy. No patients developed lateral subfibular pain (4) associated with valgus angulation and lateral translation of the hindfoot. No case of delayed union, implant failure, screw loosening, or collapse of the synthetic bone wedges before plate removal occurred.

According to the Takakura–Tanaka classification system (1,2), 9 ankles (33.33%) were classified as stage 2, 11 (40.74%) as stage 3a, and 7 (25.93%) as stage 3b. The mean preoperative TAS, tibial–lateral surface, TMM, and TT angles were 84.9° (range 78° to 90°), 82.3° (range 76° to 95°), 28.4° (range 19° to 45°), and 8.3° (range 3° to 21°), respectively. At the most recent follow-up visit, the corresponding values were 95.0° (range 83° to 99°), 83.9° (range 74° to 93°), 20.1° (range 14° to 31°), and 1.8° (range 0° to 8°; $p = .026$ for the TLS angle and $p < .001$ for the other comparisons). Radiographic success (postoperative TT angle of ≤3°) was obtained in 22 of 27 ankles (81.48%). Five patients (5 ankles [18.52%]) still had a residual TT angle >3° (range 4° to 8°); however, none of them related persistent ankle instability, and no lateral ligament reconstruction was required. Of these 5 patients, 4 (80%) had had a stage 3b deformity preoperatively and 1 (20%) a stage 3a deformity. The radiographic outcomes are shown in Fig. 7.

The axial CT scans revealed that the mean preoperative mortise width was 32.8 (range 29.8 to 37.7) mm. This value had decreased to 31.0 (range 27.5 to 35.6) mm postoperatively ($p < .001$). The actual height of the inserted synthetic bone wedges was 10 mm in 23 ankles (85.18%) and 12 and 15 mm in 2 ankles (7.41%) each. We used no 7-mm wedges in the present study. Coronal CT scans demonstrated that the mean postoperative osteotomy gap measured at the medial, middle, and lateral tibial plafonds was 10.0 (range 9.1 to 14.1) mm, 6.8 (range 5.5 to 9.7) mm, and 3.3 (range 2.0 to 5.8) mm, respectively. Eighteen lateral hinge fractures (72%) were observed in 25 ankles on the coronal CT scans. Of these, 1 patient (1 ankle [3.7%]), on whom a 15-mm wedge had been used, showed complete disruption of the lateral hinge concomitant with a 4-mm clear space. This patient was successfully treated with restricted non-weightbearing for 4 weeks and use of low-intensity pulsed ultrasound for 8 weeks after surgery. No intra-articular plafond fractures had occurred after spreading the distal tibia.

Discussion

The aim of corrective osteotomy in the treatment of varus ankle osteoarthritis is to shift the stresses acting on the ankle to a portion of the joint that is not involved in the degenerative process (6–8). The redistribution of loads and stresses seen by the tibiotalar joint can be approached either above or below the ankle with an osteotomy of the tibia or calcaneus (8). Supramalleolar osteotomy has been used to restore normal joint geometry in the case of an extra-articular, above the ankle joint deformity, and this procedure has been reported to be effective for the treatment of primary, as well as traumatic, moderate ankle osteoarthritis (1,2,4,11). Tanaka et al (2) concluded that supramalleolar osteotomy was indicated for ankles in stage 2 or 3a but not indicated for ankles in stage 3b or with a TT angle >10°. In contrast, Lee et al (4) suggested that supramalleolar osteotomy was recommended only for the treatment of ankle osteoarthritis in patients with minimal talar tilt and neutral or varus heel alignment (i.e., heel alignment ratio >0.3). They also emphasized that the optimal threshold for predicting a high postoperative talar tilt was 7.3° of the preoperative talar tilt.

According to the recent report by Mann et al (5), chronically unstable varus ankles will commonly demonstrate dysplasia of the medial malleolus that has occurred over time. The medial aspect of the malleolus will no longer be vertical and will have a medially inclined articulation arising from chronic pressure of the medially driven talus. Increased and chronic contact pressure from the tilted talus within the plafond results in an intra-articular defect over the medial aspect of the tibial articular surface. They recommended an osteotomy with an intra-articular apex to correct this deformity (5). Although their plafond-plasty associated with lateral ligament reconstruction effectively addressed the intra-articular deformity and the overall clinical outcomes were good, an extra-articular deformity at the level of the center of rotation of angulation (i.e., the TAS angle) remained unchanged, and a mean residual talar tilt of 10.7° was noted.

More recently, Lee et al (12) reported excellent radiographic results after realignment surgery of ankle osteoarthritis associated with paralytic cavovarus. They succeeded in correcting the severe talar tilt and spared the tibiotalar joint using diverse procedures, including triple arthrodesis. However, 6 of 12 ankles (50%) underwent second-stage surgery because of undercorrection of the deformity, and triple arthrodeses were performed in 7 (58.33%). We believe that, in patients with osteoarthritic ankles without paralytic disorders, multiple hindfoot arthrodeses should be avoided whenever possible owing to the vital importance of maintaining functional motion and load transfer during gait throughout the hindfoot joint complex.

In our series, radiographic success was not accomplished in 5 of 27 ankles (18.52%). One patient (1 ankle [3.7%]), who had the largest TT angle of 8° and TMM angle of 31° after surgery, had the largest TT angle of 21° and TMM angle of 45° before surgery. According to the cadaveric study by Ramsey and Hamilton (10), when the talus displaced 1, 2, 4, and 6 mm laterally, the average reduction in the tibiotalar contact area will be 42%, 56%, 65%, and 68%, respectively. Therefore, we believe that achieving the static contact between the

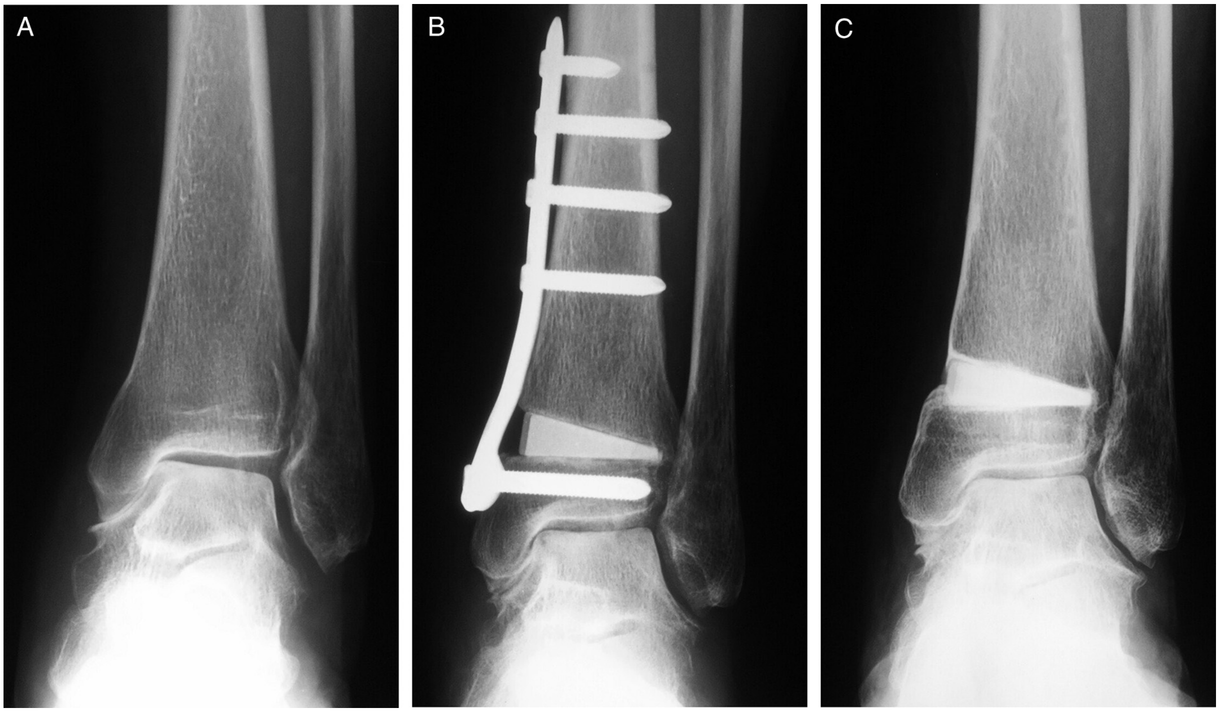

Fig. 7. Anteroposterior weightbearing radiographs of the left ankle in a 57-year-old female with stage 3a varus ankle osteoarthritis and instability: (*A*) preoperatively, (*B*) 1 month postoperatively, and (*C*) 3 years postoperatively.

lateral surface of the talus and the medial surface of the lateral malleolus is essential for stabilizing the talus within the mortise. Although the static contact of the talofibular articulation was obtained and the clinical result was good in this patient, we believe that patients with a preoperative TT angle >15° and/or TMM angle >45° might be beyond the limits of this joint-sparing procedure. Thus, perhaps an ankle arthrodesis might provide better results in such cases. Another patient (1 ankle [3.7%]), who had had a TT angle of 9° and stage 3b deformity before surgery, had an unsatisfactory result with a residual TT angle of 7° and a stage 4 deformity after surgery. Although this patient was the only candidate for later ankle joint replacement or arthrodesis, the patient had refused a second surgery at the most recent follow-up visit.

With regard to the TAS angle, overcorrection has been considered appropriate because all load must be supported by the remaining cartilage on the lateral side of the joint (1,2,6). Takakura et al (1) aimed to achieve a TAS angle of 93° to 94°. Tanaka et al (2,6) emphasized that overcorrection according to varus deformity brought much better results than undercorrection, especially for advanced osteoarthritis, and they aimed for a TAS angle of for 96° to 98°. Lee et al (4) reported that overcorrection alone did not correct the severely tilted talus and sometimes caused lateral subfibular pain. They attempted to achieve a TAS angle of 95°. If the deformity remained, they recommended correcting it using a medial displacement calcaneal osteotomy. In contrast, our technique does not osteotomize the distal fibula, and the ankle mortise is narrowed. Thus, we do not consider the TAS angle as an intraoperative reference. Instead, we open the distal tibia until the lateral articular surface of the talus contacted the medial articular surface of the lateral malleolus. Thus, the TAS angle unintentionally became approximately 95° postoperatively. We believe this novel osteotomy procedure can minimize the adverse effect of mortise distortion and possible lateral ankle impingement.

Regarding joint congruity, no previous study on ankle osteoarthritis has assessed the changes in mortise widths and osteotomy gaps on the CT scans. In the present study, the mean mortise width was decreased from 32.8 mm preoperatively to 31.0 mm postoperatively. The mean osteotomy gap measured at the medial, middle, and lateral tibial plafonds was 10.0, 6.8, and 3.3 mm, respectively. These measurements indicated that the ankle mortise was narrowed by approximately 1.8 mm and the tibial plafond was lowered after osteotomy. In our early cases, we attempted primary and second-look arthroscopy to assess the amount of cartilage regeneration in the medial compartment of the ankle. However, after spreading the distal tibia, we noted that little space for probing was present, even using a 2.7-mm arthroscope, because the tibiotalar joint was tightened. Therefore, we no longer routinely perform arthroscopic examination for fear of iatrogenic articular cartilage injuries.

The incidence of nonunion or delayed union after supramalleolar osteotomy has been reported to be 5.76% to 22.22% (1,2,13–15). According to the initial report by Takakura et al (1), 4 delayed unions (22.22%) occurred in 18 ankles fixed by a small medial plate. Stamatis et al (13) noted 2 nonunions and 1 delayed union (13.04%) after 23 consecutive supramalleolar osteotomies using a periarticular or cervical spine plate. Tanaka et al (2) reported that nonunion occurred in 4 of 26 ankles (15.38%) after supramalleolar osteotomy with a conventional medial plate. Best and Daniels (14) described the results of 5 supramalleolar tibial osteotomies stabilized with a Puddu plate. Although all osteotomies had healed within 4 months after surgery without complications, the number of subjects was too small and the patients remained non-weightbearing in a below-the-knee cast for a mean of 7.2 (range 6 to 12) weeks. Horn et al (15) found 3 nonunions (5.76%) in 52 deformed ankles treated with supramalleolar osteotomy using circular external fixation. In contrast, we noted a high incidence of lateral hinge fractures among our patient cohort on the coronal CT scans; however, all osteotomies had united within 8 weeks postoperatively. We did not observe any delayed union, implant failure, screw loosening, or collapse of the synthetic bone wedges before plate removal. One important factor of our procedure is the use of an angular stable locking system combined with synthetic bone graft substitutes. Thus, the stress applied to the osteotomy site is distributed across the synthetic bone wedges and the Tomofix™ plate (DePuy Synthes) (16–19). To our knowledge, only 1 previous report has described the use of Tomofix™ (DePuy Synthes) for fixation of a distal tibial osteotomy (20).

Historically, an opening wedge osteotomy of the distal tibia has been better than a closing wedge osteotomy because a closing wedge osteotomy will result in lateral muscle weakness (1,2). In addition, distal tibial deformities are usually associated with mild to moderate shortening of the affected limb; therefore, an opening wedge osteotomy is preferred to help restore length (1,11). An opening wedge supramalleolar osteotomy has been performed by way of an open procedure, and the osteotomy site was secured with screws, plates, or an external fixator (13–15,21). Potential complications of the medial wound can be disastrous, and wound breakdown can lead to exposure of the implant (22,23). Stamatis et al (13) described 1 superficial infection (7.69%) in 13 supramalleolar osteotomies using a low profile plate. Lui (23) noted 1 case of wound breakdown (14.28%) after 7 valgus and varus opening wedge osteotomies, even with a minimally invasive approach. Horn et al (15) reported a total of 33 infections (63.46%) including 27 pin site infections, 4 cases of cellulitis, and osteomyelitis and septic arthritis in 1 patient each after 52 supramalleolar osteotomies using circular external fixation. Sen et al (21) performed gradual correction of ankle and hindfoot deformities in 11 patients with the Ilizarov technique. They encountered pin tract problems in all 11 patients, including 8 pin tract infections (72.73%) and 3 Schanz pin infections (27.27%). In the present study, although the osteotomy line was positioned far distally compared with those of previous procedures (1–5,22,23), our infection rate was 3.7% (1 of 27 ankles). This result suggests that our minimally invasive osteotomy and fixation techniques eliminate additional soft tissue damage and minimize the risk of wound complications.

Our clinical and radiographic outcomes strongly support the 2 recent biomechanical studies on cadavers published in 2011 (24,25). Stufkens et al (24) concluded that supramalleolar valgus osteotomy without concurrent fibular osteotomy would cause anteromedial overloading of the tibiotalar joint and supramalleolar varus would lead to a posterolateral shift. Interestingly, the opposite changes were observed; that is, the center of force and peak pressure shifted in a posterolateral direction for valgus deformities and in an anteromedial direction for varus deformities, when an additional fibular osteotomy was made directly above the syndesmosis to create a wide ankle mortise. Knupp et al (25) suggested that isolated correction of the distal tibial joint angle without addressing the fibula might be the main step in patients with an unstable or incongruent ankle mortise to normalize the load distribution and force transfer to the tibiotalar joint.

Regarding the lateral ligament reconstruction, Lee et al (26) noted the importance of lateral instability in the origin of medial ankle osteoarthritis, and the success of the surgery was dependent on the stability of the lateral ligament. Mann et al (5) also noted that bony correction alone would not help to attain ankle stability and encouraged lateral ligament reconstruction to protect the osteotomy from recurrence of the deformity. In contrast, Lee et al (12) concluded that lateral ligament reconstruction cannot withstand the weightbearing load in a severely tilted ankle and that proper static alignment and dynamic balance are more important than ligament reconstruction. Although no studies comparing bony stabilization (e.g., mortise-plasty) versus soft tissue stabilization (i.e., lateral ligament reconstruction) have been published, we believe that, especially in aged subjects, the bony procedure will exert superior stabilizing effects on the talus compared with the soft tissue procedure. Mortise-plasty improves abnormal joint congruity between the medial malleolus, tibial plafond, lateral malleolus (i.e., ankle mortise), and talus. Our patients needed no lateral ligament reconstruction, ankle joint replacement, or arthrodesis in the short-term follow-up period. To our knowledge, this is the first report on a joint-sparing surgical technique that corrects coronal plane malalignment (extra-articular deformity) and improves abnormal joint congruity (intra-articular deformity) simultaneously in a single procedure.

The present study had some limitations and weaknesses. The first was the somewhat small number of subjects and short-term follow-up period. We admit that any studies on joint-sparing procedures require long-term follow-up periods, because the outcomes could gradually deteriorate with time. The second was regarding the assessment of lower limb and hindfoot alignment. Preoperative and postoperative radiographic evaluation was performed using standard weightbearing radiographs. For more accurate assessment, long leg and hindfoot alignment radiographs should be taken. The third was its retrospective study design and lack of inclusion of a comparative group. However, the postoperative clinical and radiographic results seemed favorable in the short term compared with those in previous reports (1–5).

In conclusion, our novel mortise-plasty osteotomy using synthetic bone graft substitutes provides good clinical and radiographic outcomes for patients with varus ankle osteoarthritis and instability. We do not advocate that the routine use of synthetic bone wedges in distal tibial osteotomies become the standard. However, we believe the described method deserves to be a possible, even challenging, treatment option when treating asymmetric ankle osteoarthritis with varus talar tilt. Most importantly, rigid locking fixation with careful postoperative weightbearing is recommended to attain uneventful bone healing. With the described technique, stable correction of osteoarthritic ankles, early weightbearing exercises, and quick recovery are possible. However, although good results were obtained in our patient cohort, the present report should be considered preliminary, and additional studies are required.

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