A Cohort Study of Patients Undergoing Distal Tibial Osteotomy without Fibular Osteotomy for Medial Ankle Arthritis with Mortise Widening

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Background: Although the supramalleolar osteotomy can shift the weight-bearing axis laterally, it cannot reconstruct a widened ankle mortise caused by progression of medial ankle osteoarthritis. The aim of this study was to evaluate radiographic and clinical outcomes of distal tibial osteotomy without fibular osteotomy in patients with medial ankle osteoarthritis and mortise widening.

Methods: Distal tibial osteotomy without fibular osteotomy was performed in eighteen patients to treat medial ankle osteoarthritis with mortise widening. Fifteen women and three men with a mean age of fifty-seven years (range, forty-nine to sixty-four years) were followed for a mean of thirty-four months (range, twenty-four to sixty-six months). Mortise widening was diagnosed using valgus stress radiographs and intraoperative examination. The clinical outcome was assessed with the American Orthopaedic Foot & Ankle Society (AOFAS) score, visual analog scale (VAS) score for pain, and the ankle osteoarthritis scale (AOS) score. The translation of the talus within the ankle mortise, talar tilt, medial distal tibial angle, and anterior distal tibial angle were evaluated on weight-bearing radiographs made preoperatively and postoperatively.

Results: The AOFAS score improved significantly from 78.4 points (95% confidence interval [CI], 74.6 to 80.5 points) to 89 points (95% CI, 86.5 to 90.5 points) ($p < 0.001$). The VAS score for pain also decreased significantly from 6.7 points (95% CI, 6 to 7.5 points) to 2.7 points (95% CI, 2.3 to 3.3 points) ($p < 0.001$). The mean AOS score was 29.8 points (95% CI, 22 to 38.2 points) at the latest follow-up. The center of the talus moved laterally within the ankle mortise after the distal tibial osteotomy. The mean medial distal tibial angle changed from 86.6° (95% CI, 85.7° to 87.6°) to 92.9° (95% CI, 91.6° to 94.3°) ($p < 0.001$), and the mean anterior distal tibial angle changed from 81.1° (95% CI, 78.6° to 83.6°) to 84.3° (95% CI, 81.9° to 86.4°) ($p < 0.001$). However, talar tilt was not corrected significantly ($p = 0.916$).

Conclusions: Distal tibial osteotomy without fibular osteotomy reduces pain in the short term in patients with ankle arthritis, a widened mortise, and minimal talar tilt.

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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A supramalleolar osteotomy of the tibia and fibula creates angulation and translation of the ankle joint without changing the width of the ankle mortise. When there is ankle osteoarthritis with mortise widening, supramalleolar osteotomy may not achieve a stable osseous mortise. If the tibia is cut and angled toward the fibula without osteotomy of the fibula, a functional narrowing of the mortise may occur. Plafondplasty has been suggested as

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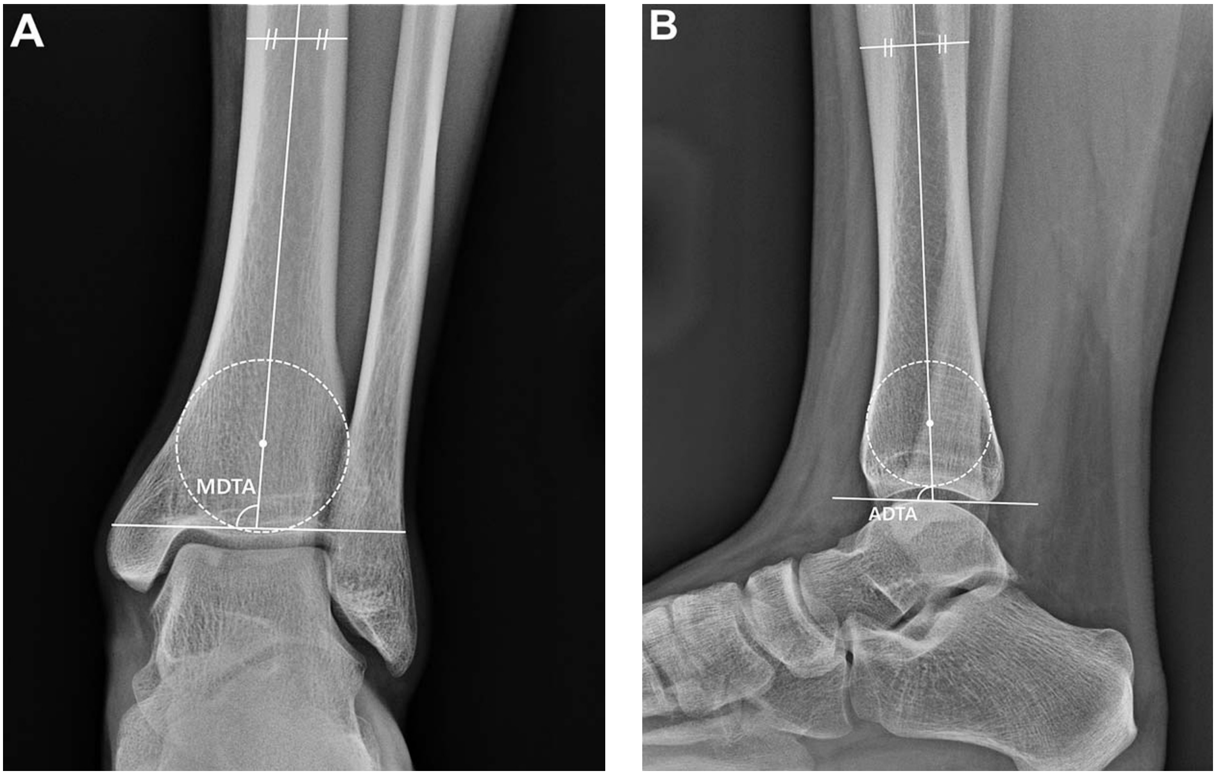

Fig. 1-A

Fig. 1-B

Figs. 1-A and 1-B The measurements of the angle between the tibial axis and the tibial plafond on weight-bearing radiographs. **Fig. 1-A** The medial distal tibial angle (MDTA) on an anteroposterior radiograph. **Fig. 1-B** The anterior distal tibial angle (ADTA) on a lateral radiograph.

a method to correct the alignment of the tibial plafond[1]. Plafondplasty is based on the concept that the deformity should be corrected at the center of rotation and angulation[2], and the center of rotation and angulation of the deformity is located in the tibial plafond when there is an intra-articular defect from erosion of a portion of the tibial plafond or malunion after tibial plafond fracture. However, in ankles with mortise widening from medial erosion into the medial malleolus (see Appendix), angulation in the middle of the tibial plafond is not necessary. We performed a procedure termed *distal tibial osteotomy without fibular osteotomy* in our patients. A similar procedure was previously reported in the Japanese literature[3]. In this procedure, the osteotomized distal fragment is shifted inferolaterally using the lateral apex of the osteotomy as a hinge.

We hypothesized that the distal tibial osteotomy without fibular osteotomy is a useful treatment in ankle osteoarthritis with medial translation of the talus and widening of the ankle mortise. The aim of this study was to investigate the results of distal tibial osteotomy without fibular osteotomy.

Materials and Methods

From January 2008 to May 2011, distal tibial osteotomy without fibular osteotomy was performed after failed conservative treatment in eighteen consecutive patients who had symptomatic medial ankle arthritis with >3 mm of medial clear space on the valgus stress radiograph and/or intraoperatively. When ankle mortise widening was suspected, but it was not definite on the valgus stress radiograph, the medial joint space was explored intraoperatively. Exclusion criteria were patients with neuropathic arthropathy, end-stage osteoarthritis, inflammatory arthritis, or ankle osteoarthritis secondary to bone deformity from congenital abnormality, fracture, or paralysis. This study was approved by our institutional review board. Fifteen women and three men with a mean age of fifty-seven years (range, forty-nine to sixty-four years) were followed for a mean of thirty-four months (range, twenty-four to sixty-six months). There was no loss of follow-up (see Appendix). The last follow-up evaluation was the most recent one when the patients were examined radiographically.

A standard load of 150 N was applied to the ankle using the Telos device (METAX, Hungen, Germany) for valgus-varus stress and anterior drawer test. Medial clear space of >3 mm on the valgus stress radiographs was indicative of mortise widening. The mortise widening, which was suspected on the stress radiographs but not definite, was confirmed under direct vision by a gap of ≥3 mm when abduction and external rotation forces were applied intraoperatively.

Radiographs and clinical scores were reviewed retrospectively by one clinical fellow (T.-K.A.) and one assistant professor (J.-H.C.) specializing in foot and ankle surgery who did not attend the surgical procedures. The medial distal tibial angle on the anteroposterior radiograph and the anterior angle between the tibial shaft and tibial plafond on the lateral radiograph (anterior distal tibial angle) were measured using weight-bearing radiographs. The tibial axis on anteroposterior and lateral radiographs was drawn by connecting the midpoint between the cortex at 10 cm proximal to the joint line on anteroposterior and lateral radiographs with the center of a circle positioned to fit between three cortices at the distal metaphysis of the tibia (Figs. 1-A and 1-B). Talar tilt, which was measured on a weight-bearing anteroposterior radiograph, was the angle between the tibial plafond and talar dome. To evaluate the translation of the talus within the ankle mortise preoperatively and postoperatively, the center of the talus was defined as a point located along a line connecting the medial and lateral malleolus. It was also assumed

TABLE I Interobserver and Intraobserver Reliabilities of Radiographic Measurements

	Interobserver Reliability (95% CI)	Intraobserver Reliability (95% CI)
Medial distal tibial angle *(deg)*		
Preop.	0.93 (0.82-0.97)	0.89 (0.69-0.96)
Follow-up	0.96 (0.88-0.98)	0.92 (0.80-0.97)
Anterior distal tibial angle *(deg)*		
Preop.	0.93 (0.82-0.97)	0.92 (0.77-0.97)
Follow-up	0.97 (0.91-0.99)	0.93 (0.80-0.97)
Talar tilt *(deg)*		
Preop.	0.96 (0.89-0.99)	0.93 (0.80-0.97)
Follow-up	0.98 (0.95-0.99)	0.98 (0.94-0.99)
Talus center migration *(mm)*		
Preop.	0.98 (0.96-0.99)	0.95 (0.87-0.98)
Follow-up	0.97 (0.92-0.99)	0.94 (0.84-0.98)
Medial clear space on valgus test *(mm)*		
Preop.	0.96 (0.90-0.99)	0.93 (0.82-0.94)

that a circle originating from the center of the talus is tangential to the midpoint of the talar dome (Fig. 2). A new radiographic parameter that we termed *talus center migration* was measured on the weight-bearing anteroposterior radiograph. Talus center migration was defined as the shortest distance between the tibial axis to the center of the talus. Positive values mean that the talus center is located medial to the tibial axis. Preoperative and postoperative radiographic stages were also evaluated. Mortise widening was measured as the perpendicular distance between the medial surface of the talus at the level of the talar dome and the lateral surface of the medial malleolus[4] (see Appendix). The reliability of all radiographic parameters was determined. The two aforementioned observers performed measurements for interobserver reliability, and the same observers measured joint space width twice at intervals of one month for intraobserver reliability. The intraclass correlation coefficient (ICC) was used for interobserver and intraobserver reliability. Radiographic stages were classified according to the modified Takakura classification system[5], with stage I indicating no narrowing of the joint space but evidence of early sclerosis and osteophyte formation; stage II, narrowing of the medial joint space; stage III, obliteration of the medial joint space with subchondral bone contact (with stage IIIA, obliteration limited to the medial malleolus; and Stage IIIB, obliteration extended to the roof of the talar dome); and Stage IV, obliteration of the whole joint space with complete bone contact. Three ankles were in stage II; thirteen, in stage IIIA; and two, in stage IIIB.

Clinical assessment was performed preoperatively and postoperatively using the American Orthopaedic Foot & Ankle Society (AOFAS) scale[6] and a 10-cm visual analog scale (VAS) for pain, with 0 indicating no pain and 10, the worst pain that the patient can imagine. For the ankle osteoarthritis scale (AOS)[7], only postoperative measurement was performed because no baseline data were available for the majority. Postoperative clinical scores were obtained at the time of the latest follow-up. While not validated, the AOFAS scale was used for comparison with other studies because many studies use it for clinical assessment. The AOS is a reliable and validated patient-reported instrument that specifically focuses on the pain and disability of ankle arthritis. The maximal score of the AOS is 180 points, the sum of each pain and disability score. In this study, the score of the AOS was converted into a percentage. Postoperative complications were noted (see Appendix).

The paired t test was used because all parameters except radiographic change were normally distributed using the Kolmogorov-Smirnov test. To evaluate changes in the radiographic stage, we assigned quantitative scores of 1, 2, 3, 4, and 5 to stages I, II, IIIA, IIIB, and IV, respectively, of the modified Takakura classification system, and the Wilcoxon signed-rank test was used. Significance was set at $p < 0.05$.

Fig. 2

Talus center migration is the distance between the tibial axis and the center of the talus. The center of the talus was defined as a point located along a line connecting the tips of the medial and lateral malleolus, and it was assumed to be the center of a circle tangential to the midpoint of the talar dome.

TABLE II Radiographic Parameters

	Preoperative*	Latest Follow-up*	P Value
Medial distal tibial angle† *(deg)*	86.6 (85.7 to 87.6)	92.9 (91.6 to 94.3)	<0.001
Anterior distal tibial angle‡ *(deg)*	81.1 (78.6 to 83.6)	84.3 (81.9 to 86.4)	<0.001
Talar tilt angle *(deg)*	5.6 (4.8 to 6.6)	5.5 (3.8 to 7.6)	0.916
Talus center migration *(mm)*	3.5 (1.9 to 5.2)	−2.2 (−3.4 to −1.1)	<0.001
Hindfoot alignment angle *(deg)*	5.2 (3.1 to 7.2)	2.1 (−0.5 to 4.6)	0.05
Takakura stage	2.9 (2 to 4)	2.1 (1 to 5)	0.004

*Data are given as the mean with the 95% confidence interval in parentheses. †The angle between the tibial shaft and the tibial surface on the anteroposterior radiograph. ‡The angle of the tibial joint surface on the lateral radiograph.

Surgical Technique

All surgical procedures were performed by the senior author (W.-C.L.). In the first seven patients, a medial longitudinal incision was used. The approach was changed from medial to anterior in the next eleven patients because of the difficulty in applying the plate on the medial side as a result of the step-off at the osteotomy site after spreading the osteotomy. A longitudinal incision was made along the anterior midline of the ankle from 10 cm proximal to 5 cm distal to the joint. Further dissection was done between the extensor hallucis longus and extensor digitorum longus for exposure of the distal part of the tibia. An oblique osteotomy was planned along the line connecting a point at the medial tibial cortex 5 cm proximal to the ankle joint and a point on the lateral tibial cortex 5 mm proximal to the joint. After insertion of two or three Kirschner wires along the planned osteotomy line, the position of the Kirschner wires was confirmed by fluoroscopy. Multiple holes were made along the planned osteotomy line, and the osteotomy was completed by connecting the holes using a thin osteotome, with the intention of minimizing injury to the anterior and posterior distal tibiofibular ligament. When diastasis occurred from complete section of these ligaments, one or two transverse screws were inserted from the fibula to the tibia. Diastasis was found intraoperatively in two of seven patients for whom the medial approach was used and managed with a transfixation screw. After the osteotomy was spread using the lateral apex as a hinge to shift the distal tibial fragment inferiorly (Fig. 3), a locking plate was applied for stabilization. Autogenous iliac bone graft was packed into the defect. Postoperatively, the patients were managed with non-weight-bearing with a short leg cast for six weeks. Then a short leg splint or ankle-foot orthosis was applied, and weight-bearing was allowed depending on the rate of healing of the osteotomy (Figs. 4-A, 4-B, and 4-C).

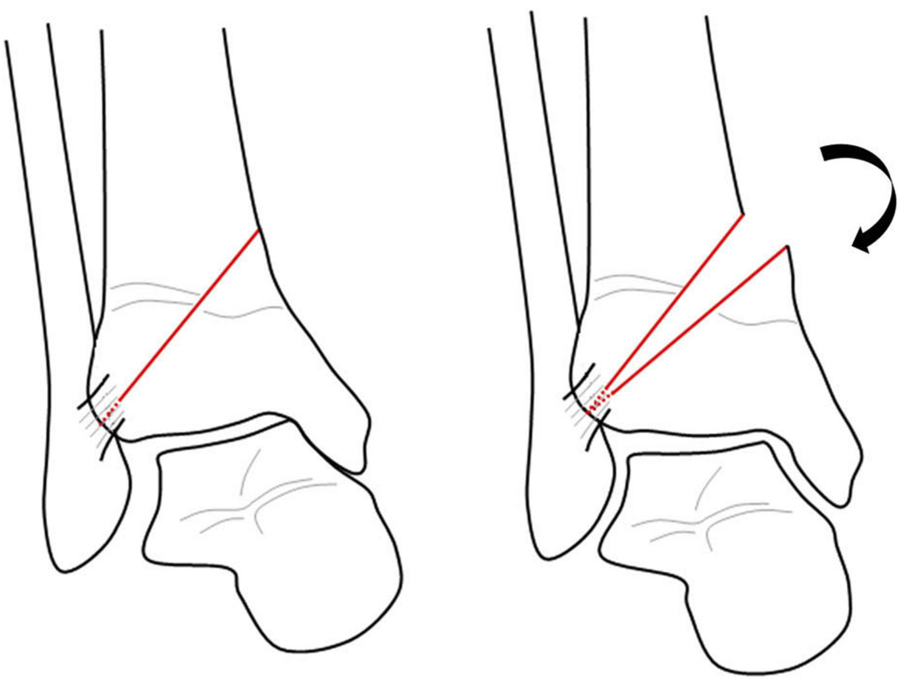

Fig. 3

Schematic drawings of the distal tibial osteotomy without a fibular osteotomy. An oblique osteotomy was planned along the red line connecting a point at the medial tibial cortex 5 cm proximal to the ankle joint and a point on the lateral tibial cortex at 5 mm proximal to the joint (left image). The width of the ankle mortise becomes narrow as the distal fragment is inferiorly displaced (right image). Geometrically, talar tilt increases because the tibial plafond is more angulated relative to the talar dome.

Fig. 4-A

Fig. 4-B

Fig. 4-C

Figs. 4-A, 4-B, and 4-C Radiographs of a sixty-six-year-old man with medial ankle osteoarthritis. **Fig. 4-A** Preoperative weight-bearing anteroposterior radiograph showing medial translation of the talus, erosion of the medial malleolus, and mortise widening. **Fig. 4-B** Valgus stress test radiograph showing mortise widening. **Fig. 4-C** Weight-bearing anteroposterior radiograph made one year after the distal tibial osteotomy, without fibular osteotomy, and application of an anterior plate.

TABLE III Clinical Score Results

	AOFAS Score* *(points)*	VAS Score*	AOS Score*†
Preop.	78.4 (74.6 to 80.5)	6.7 (6 to 7.5)	
Latest follow-up	89 (86.5 to 90.5)	2.7 (2.3 to 3.3)	29.8 (22 to 38.2)
P value	<0.001	<0.001	

*Data are given as the mean with the 95% confidence interval in parentheses. AOFAS = American Orthopaedic Foot & Ankle Society, and VAS = visual analog scale. †The values are given as the percentage of the maximum score. AOS = ankle osteoarthritis scale.

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Results

On reliability analysis of the radiographic measurements, the ICC for interobserver comparisons ranged from 0.93 to 0.98 and the ICC for intraobserver comparisons, from 0.89 to 0.98 (Table I).

The mean medial distal tibial angle and mean anterior distal tibial angle showed a significant difference ($p < 0.001$) after surgery (Table II). The mean medial distal tibial angle and mean anterior distal tibial angle changed from 86.6° (95% confidence interval [CI], 85.7° to 87.6°) to 92.9° (95% CI, 91.6° to 94.3°) and from 81.1° (95% CI, 78.6° to 83.6°) to 84.3° (95% CI, 81.9° to 86.4°), respectively. However, the mean talar tilt did not show a significant change ($p = 0.916$). Talar tilt increased by >2° in four ankles and decreased by >2° in three ankles. The center of the talus moved lateral to the tibial axis (Table II). Radiographic stages improved ($p = 0.004$), but three of fifteen patients with radiographic stage III showed no improvement (see Appendix).

Compared with the preoperative values, the clinical scores improved significantly ($p < 0.001$) at the time of the last follow-up (Table III). However, nine of the eighteen patients reported postoperative pain over the implants, warranting their removal. Six patients had lateral osseous impingement and underwent spur excision from the anterior and inferior margin of the lateral malleolus and lateral process of the talus through an oblique incision along the anterior margin of the lateral malleolus. Implant removal was necessary in six of seven patients in whom the medial approach was used and in three of eleven patients in whom the anterior approach was used. One intra-articular osteotomy was made inadvertently. One patient with stage IIIB ankle arthritis underwent total ankle arthroplasty because of postoperative deterioration (data not included) (see Appendix). No other complications were observed.

Discussion

Although studies about supramalleolar osteotomy have noted that talar tilt should be considered an indication for a successful outcome[5,8], we believe that correction of mortise widening of the ankle joint should be also considered. The ankle has a stable structure in which translation of the talus is blocked by the malleoli. However, with syndesmosis diastasis, fibular fracture, or malalignment resulting in mortise widening, the talus loses its stability and moves laterally within the ankle joint. Biomechanical studies have shown that the lateral translation of the talus results in a reduced tibiotalar contact area and a nonphysiologic load to the ankle joint[9-11].

Mortise widening that can occur in some medial ankle osteoarthritis may potentially affect the stability of the ankle. As medial ankle osteoarthritis progresses, the talus migrates to the medial side of the ankle causing medial joint-space narrowing, which may eventually result in erosion of the medial malleolus and mortise widening, with incongruity of the ankle mortise and talus. Our view is that narrowing of the ankle mortise is necessary to restore congruity. Ankle mortise widening is the result of intra-articular erosion in most patients (Fig. 3), although ankle mortise widening in ankles without contact of osseous surfaces in the medial gutter suggests the possibility of some developmental widening of the mortise. To treat those patients with medial ankle osteoarthritis with mortise widening, restoration of the width and shape of the ankle mortise as well as lateral shifting of the weight-bearing axis is required.

In the present study, ankle mortise widening was determined by radiographic findings and intraoperative confirmation. Athanasiou et al.[12] reported that normal cartilage thickness of the medial gutter was a mean of 2.3 mm in a cadaveric study. Park et al.[4] reported that the mean medial clear space (and standard deviation) was 2 ± 0.4 mm during neutral ankle flexion on valgus stress radiographs. Mortise widening was suspected if the medial clear space on valgus stress radiographs was >3 mm. In the current study, two ankles (two patients) that had borderline medial clear space width of 2.5 mm and 3 mm were explored intraoperatively because the talus center migration was medial, and they were found to have definite mortise widening (see Appendix). Widening of the medial clear space in deltoid ligament injury is usually accompanied by valgus talar tilt, which is different from medial clear space widening without or with minimal talar tilt in ankles with mortise widening. We believe this radiographic parameter can be used to assess mortise widening.

In distal tibial osteotomy without fibular osteotomy, the amount of shifting of the osteotomized fragment is limited by the fibula, whereas supramalleolar osteotomy achieves a greater amount of shifting of the weight-bearing axis with fibular osteotomy. However, adequate correction of the tibial plafond was achieved in our patients, and talus center migration also proved that the center of the talus moved laterally after distal tibial osteotomy.

In measuring the radiographic parameters, we used a modified tibial axis in regard to the medial distal tibial angle, anterior distal tibial angle, medial clear space width on the valgus stress test, and talus center migration. The talus center migration was newly developed in this study, although there was excellent ICC.

Mean talar tilt did not significantly decrease after distal tibial osteotomy, while the clinical scores and radiographic stage improved in most patients (see Appendix). Talar tilt increased in six of eighteen ankles, with an increase of >2° in four of those ankles. Distal tibial osteotomy changes the shape of the ankle mortise, which narrows the width of the ankle mortise while slanting the tibial plafond relative to the talar dome. In contrast, the supramalleolar osteotomy does not increase the talar tilt because it does not change the shape of the ankle mortise. Thus, the preoperative talar tilt adequate for distal tibial osteotomy may be smaller than the previously suggested limit for supramalleolar osteotomy of either 7.3° or 10°[5,8]. However, distal tibial osteotomy may be used as an interim procedure to delay definitive surgery for ankles with substantial talar tilt because an excellent clinical result was obtained in ankles with >7° of talar tilt in our study and good clinical results were shown for an ankle with a mean talar tilt of 11° in our study.

Lateral ligament reconstruction has been regarded as an important step in the treatment of medial ankle osteoarthritis since lateral instability is known to be a cause of medial ankle osteoarthritis[1,13-15]. Other authors have reported that treatment of chronic lateral ankle instability is not important in the result of realignment surgery as chronic instability disappears after shifting of the weight-bearing load to the lateral aspect of the ankle[5,8]. Osteoarthritis may have developed as a result of chronic ankle instability in some ankles in this series, which can be surmised from the history of chronic instability and talar tilt of >10° on the preoperative varus stress test[16] (see Appendix). However, postoperative anteroposterior weight-bearing radiographs showed a congruent lateral gutter, which had been incongruent preoperatively, and lateral ligament reconstruction would not further tighten the already congruent lateral gutter to decrease the talar tilt. Although the talar tilt persisted after surgery, no patient reported lateral ankle instability postoperatively; thus, the talar tilt on the postoperative radiograph was considered a result of the increased slant of the tibial plafond due to the distal tibial osteotomy, and we do not think lateral ligament reconstruction is essential for a successful result. While hindfoot varus can also cause medial ankle osteoarthritis, the mean preoperative hindfoot varus was 5.2°, which was changed to 2.1° postoperatively (Table II).

When only the distal end of the tibia is osteotomized proximal to the syndesmosis and the fibula is not osteotomized, separation of the proximal part of the syndesmosis should occur to angulate the distal tibial fragment. Therefore, distal tibial osteotomy aims at the distal part of syndesmosis to prevent disruption of the tibiofibular syndesmosis. Thus, the width of the distal fragment becomes narrow laterally and a fracture into the joint is a possible complication, which occurred intraoperatively in one patient.

In the beginning of the study, the osteotomy was only performed in five patients with mortise widening of >2 mm, evidenced either by a medial clear space on a valgus stress radiograph or medial translation of the talus relative to the tibia. In the subsequent patients, the indication was extended to patients with a smaller amount of widening or widening of the medial gutter on abduction and external rotation of the foot under direct view intraoperatively. Six patients with medial clear space of <4 mm experienced lateral osseous impingement postoperatively.

There are limitations in this study. First, no comparison was made with the supramalleolar osteotomy, for which the results of more cases with longer-term follow-up have been reported[5]. Distal tibial osteotomy was used after failure occurred with supramalleolar osteotomy in some ankles; thus, we did not perform supramalleolar osteotomy for the same indication in this study. Another limitation is that the follow-up period is shorter to determine the optimal preoperative indication regarding talar tilt because talar tilt increased in some ankles after distal tibial osteotomy. Talar tilt means that the concentration of weight-bearing load is in a small area; thus, the long-term results in ankles with a large talar tilt may not be as good as the results in the current study at a mean follow-up of thirty-four months.

In this study, we focused on the specific osteoarthritis with marked erosion of the medial malleolus. This type of osteoarthritis may be infrequently encountered during clinical practice. However, distal tibial osteotomy may be the only option to spare the joint for this specific type of osteoarthritis. In conclusion, distal tibial osteotomy without fibular osteotomy may be indicated in ankles with a widened mortise and minimal talar tilt.

Appendix

eA Tables showing data on the patients, including clinical and radiographic findings, and figures showing radiographs of an ankle with medial osteoarthritis, medial translation of the talus, and mortise widening; measurement of mortise widening; medial ankle osteoarthritis with mortise widening and talar tilt in a sixty-two-year-old woman; and an ankle in a patient with stage-II osteoarthritis before and after treatment with a distal tibial osteotomy without fibular osteotomy are available with the online version of this article as a data supplement at jbjs.org. ■

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