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Addressing hindfoot arthritis with concomitant tibial malunion or nonunion with retrograde tibiotalocalcaneal nailing: a novel treatment approach.

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Addressing Hindfoot Arthritis with Concomitant Tibial Malunion or Nonunion with Retrograde Tibiotalocalcaneal Nailing

A Novel Treatment Approach

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Background: Tibial malunions and nonunions are associated with degenerative changes about the ankle. A comprehensive literature review revealed no articles discussing treatment options for patients with tibial shaft malunion and ipsilateral ankle arthritis. The aim of our study was to evaluate a series of patients in whom tibial osteotomy and retrograde tibiotalocalcaneal nailing were used to treat both tibial deformity and ankle osteoarthritis.

Methods: Twenty-five patients underwent retrograde tibiotalocalcaneal nailing with concomitant realignment tibial osteotomy with takedown of the nonunion or malunion in a single procedure. All surgical procedures were performed by a single surgeon at a single institution. Baseline patient characteristics (age, sex, body mass index [BMI], preoperative diagnosis, and prior surgical procedures) were recorded. Data including visual analog scale (VAS) pain scores (0 to 10, with 0 indicating no pain and 10 indicating worst pain) and American Orthopaedic Foot & Ankle Society ankle-hindfoot (AOFAS-AH) scores were prospectively collected at the preoperative evaluation and the time of final follow-up, and patients were asked about their final satisfaction. Preoperative VAS scores averaged 8.3 (range, 7 to 10) of 10, which improved to an average of 2.8 (range, 0 to 6) at the time of final follow-up ($p < 0.01$). The preoperative AOFAS-AH scores averaged 43 (range, 18 to 62) of 100 and improved to 76 (range, 57 to 84) at the time of follow-up ($p = 0.022$). Twenty-one patients (84%) stated that they were extremely satisfied with the result of the procedure, three patients (12%) were satisfied, and one patient (4%) with a poor result was unsatisfied.

Conclusions: Tibial malunion or nonunion with concomitant hindfoot arthritis can be addressed with a single-stage procedure consisting of tibial osteotomy and retrograde intramedullary nailing for correction of the angular deformity and hindfoot fusion. This procedure provides a viable alternative to multiplanar external fixation or a staged procedure addressing the nonunion or angular deformity and the hindfoot arthritis separately.

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

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Tibial shaft fractures are the most common long-bone fractures[1], with an incidence of up to twenty-six per 100,000 people[2], and malunion and nonunion are most common with tibial shaft fractures, as compared with all other long-bone fractures[3,4]. The impact of tibial malunions and nonunions on adjacent-joint degeneration has received little attention in the literature. Rosemeyer and Pförringer coined the term "prearthrotic deformity" to describe the effect of angular deformity of the tibia on the distribution of weight across adjacent joints[5]. Sarmiento and Latta[6] as well as Watson-Jones[7] suggested a correlation between angular deformity and late degenerative changes in adjacent joints; they found that deformity of >5° could result in the development of late-onset degenerative changes in adjacent joints.

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Several studies have suggested that malunion does not lead to adjacent-joint arthritis[8-11]. However, Puno et al. noted a higher prevalence of ankle morbidity in patients who had joint malalignment along with tibial malunion; they concluded that anatomic reduction could reduce abnormal forces at adjacent joints and possibly delay arthritis, especially about the ankle[11]. In a study of the location of malunion deformities and their impact on the ankle in cadaveric specimens, Tarr et al. found that, the more distal the deformity, the greater the impact on an incongruous tibiotalar contact area[12]. Van der Schoot et al.[13] and Milner et al.[14] evaluated the late onset of arthritis after tibial shaft fractures. Both studies included long-term follow-up (fifteen and thirty to forty-three years after a tibial shaft fracture), and both groups of authors compared the injured and contralateral limbs and used objective and subjective data to draw conclusions. Both groups found more osteoarthritis in the knee and ankle on the injured side than in the uninjured extremity.

There are numerous options for treating tibial malunions in patients with ankle arthritis. Addressing both the deformity and the ankle arthritis is essential for successful functional outcomes. Treatment options include (1) tibial osteotomy with ankle arthrodesis or arthroplasty, (2) external fixation to correct the malunion or nonunion with ankle arthrodesis, and (3) tibiotalocalcaneal nail fixation for correction of the tibial malunion or nonunion and arthrodesis of the ankle. There is a strong correlation between the onset of arthritis and tibial shaft fractures. However, to our knowledge, no prior article has discussed treatment options for tibial shaft malunion and ipsilateral ankle arthritis.

Materials and Methods

This study was an institutional review board-approved retrospective case series. An initial database search was undertaken to identify patients with a tibial malunion and/or nonunion with tibiotalar arthritis who had undergone single-stage reconstruction of the deformity. Data including visual analog scale (VAS) pain scores (0 to 10, with 0 indicating no pain and 10 indicating worst pain) and American Orthopaedic Foot & Ankle Society ankle-hindfoot (AOFAS-AH) scores were prospectively collected at the preoperative evaluation and the time of final follow-up, and patients were asked about their satisfaction with the outcome of the procedure. Statistical analysis was performed with use of a matched two-tailed t-score. A p value of <0.05 was considered significant.

Exclusion criteria were active infection, leg-length discrepancy of >5 cm, malunion or nonunion at the ankle joint level secondary to ankle fracture, and treatment with a staged procedure or with a single-stage deformity correction with ankle arthroplasty.

Twenty-five patients underwent a single-stage correction of the tibial malunion or nonunion with tibiotalocalcaneal nailing. Their average age was fifty-eight years (range, forty-six to seventy-six years). There were thirteen men and twelve women (see Appendix). The average body mass index (BMI) was 28.6 kg/m^2 (range, 19.3 to 47 kg/m^2). Three patients had severe rheumatoid arthritis, and each of them took prednisone, methotrexate, and an alpha tumor necrosis factor (TNF) inhibitor. Eight patients had peripheral neuropathy of the affected limb secondary to diabetes (all insulin-dependent) with an average preoperative hemoglobin A1C of 11.3%. Six patients had had prior infection, which was inactive at the time of the index procedure with normal serological values (erythrocyte sedimentation rate, C-reactive protein, and white blood cell count [WBC]) and a negative WBC-labeled scan[3] or magnetic resonance image[15] for osteomyelitis. Nineteen of the twenty-five patients had undergone previous surgical procedure(s) (range, one to eight). The median number of prior surgical procedures for the twenty-five patients was three (range, zero to eight).

Of the twenty-five patients, sixteen had a healed angular malunion, four had combined malunion and nonunion deformity (Figs. 1-A and 1-B), and five had a tibial nonunion without substantial malalignment. A varus and recurvatum combination was the most commonly seen deformity (twelve of twenty-five cases) (Fig. 2-A). Overall, the average sagittal plane malalignment was 26° and the average coronal plane malalignment was 21°.

Ankle joint arthritis was assessed clinically for pain, range of motion, and palpable crepitance with passive motion. Weight-bearing radiographs were

Fig. 1-A

Figs. 1-A and 1-B Clinical photographs and lateral tibial radiographs showing combined malunion and nonunion deformity. **Fig. 1-A** In the sagittal plane.

Fig. 1-B
In the coronal plane.

assessed for joint space narrowing, subchondral sclerosis, and osteophyte formation. Anteroposterior, mortise, and lateral radiographs were all assessed because apparent maintenance of joint space in one plane can lead to a false impression that arthritis is not present. The subtalar joint and transverse tarsal joints were independently assessed clinically and radiographically. Long-term deformity can lead to fixed accommodative changes at the level of the subtalar

Fig. 1-C

Fig. 1-D

Fig. 1-C Lateral radiograph made at five years postoperatively. **Fig. 1-D** Anteroposterior radiograph made at five years postoperatively.

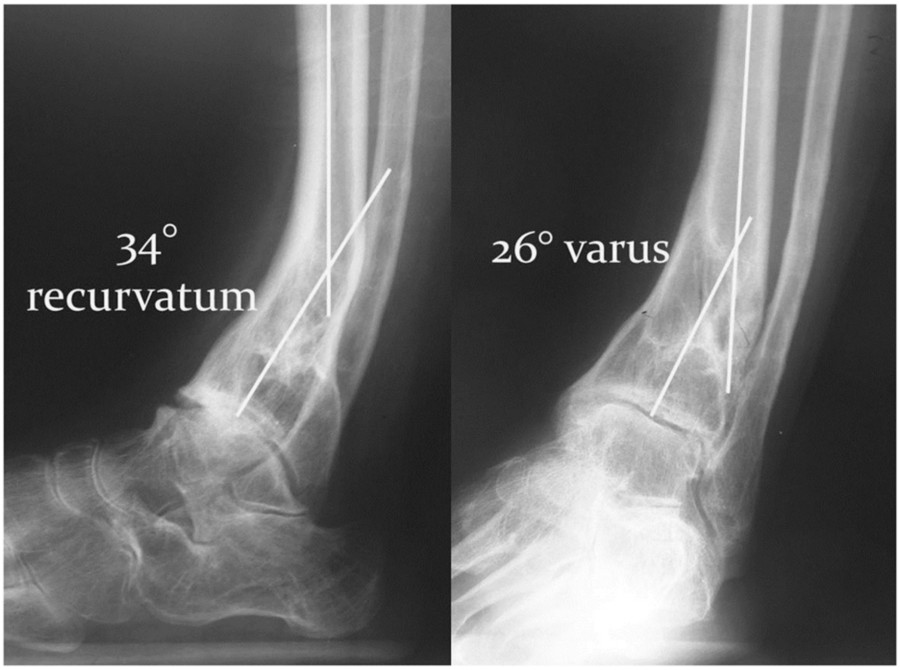

Fig. 2-A
Lateral and anteroposterior radiographs of a patient with the most commonly seen recurvatum and varus malunion deformity.

joint, resulting in pain and stiffness. An inflexible subtalar joint can decrease the ability to correct alignment and lead to less desirable results. Assessment for an inflexible subtalar joint is based more on clinical findings than on radiographic findings, although radiographic evidence of arthritis would additionally support the need to include the subtalar joint in the fusion. Inclusion of the subtalar joint when there was radiographic evidence of arthritis aided in the correction of the deformity and allowed the use of a single device to address the arthritis and malunion. The senior author (S.M.R.) hypothesized that, whenever subtalar involvement was suspected, that joint should be included in the fusion to improve the final alignment and stability. Ajis et al. recently compared patients who had undergone ankle arthrodesis with those who had received a tibiotalocalcaneal fusion[15]. There was no significant difference between the groups with regard to patient outcomes, a finding that supports the use of tibiotalocalcaneal fusion to ensure better deformity correction and fixation of the ankle.

All patients underwent a single-stage reconstruction including deformity correction via realignment osteotomy, with nonunion takedown when needed, combined with an arthrodesis of the ankle and subtalar joints. The osteotomy requires careful preoperative radiographic planning to establish the center-of-rotation axis of the deformity and to plan the triplanar cuts required for deformity correction. These are drawn onto radiographs in the operating room during the procedure. Under fluoroscopic guidance, Kirschner wires are drilled across the tibia, replicating the osteotomy cuts drawn on the radiographs. Different osteotomy cut techniques can be utilized. The senior author's preference is to make multiple drill holes along the plane of the planned cut utilizing a drill bit, with continuous irrigation to prevent thermal necrosis, connected to an osteotome. Care must be taken to ensure correction in the coronal, sagittal, and rotational planes. Fine adjustments are then undertaken with a microsagittal saw (with use of continuous irrigation) until the required alignment is obtained, recreating the mechanical axis of the limb. Once proximal alignment is corrected, the ankle and subtalar joints are prepared in a standard fashion, exposing the subchondral bone. Definitive fixation is obtained with a retrograde intramedullary nail (VersaNail; Biomet, Warsaw, Indiana) inserted through the plantar aspect of the calcaneus and extending into the tibial shaft, ending at least 5 cm proximal to the level of deformity correction. A 10-mm-diameter nail was utilized in five cases and a 12-mm-diameter nail, in twenty cases. All fractures that had resulted in ankle arthritis in this study had involved the distal half of the tibia. The length of the implanted nail was 15 cm in ten cases with metaphyseal fracture, 20 cm in twelve cases with metaphyseal-distal diaphyseal fracture, and 25 cm in three cases in which the central portion of the shaft had been involved.

The resected distal part of the fibula was utilized as a bone graft in fifteen cases, and iliac crest bone graft was used in ten cases. An implantable bone stimulator was used in addition in three high-risk cases in which multiple revisions had been performed. Five patients used an ultrasound bone stimulator postoperatively.

Nineteen patients underwent tibiotalocalcaneal fusion, and six underwent pantalar (talonavicular and calcaneocuboid) fusion. These joints were included in the analysis if there was arthritic involvement within the transverse tarsal joint (two patients had severe talonavicular arthritis) or fixed compensatory rotational deformity at the transverse tarsal joint (four patients), which would result in a nonplantigrade foot once the tibial, ankle, and subtalar joints had been appropriately aligned. The transverse tarsal joints are approached although standard open incisions, the articular cartilage and subchondral bone is removed, and the joints are derotated to neutral. Fixation is obtained with use of two parallel retrograde screws across the talonavicular joint, and staples across the calcaneocuboid joint.

Postoperatively, the patients remained non-weight-bearing for six weeks when they had had a traumatic injury and for ten to twelve weeks when they had neuroarthropathy or weaker bone. Thereafter, the patients were allowed to bear weight as tolerated in a fracture boot until they were pain-free. Healing was assessed clinically (indicated by the absence of pain on stressing of the osteotomy/fusion site and no warmth clinically at the surgical site) and radiographically (cortical bridging at the osteotomy site and cross-bridging at the fusion site). Computed tomography scans were not routinely used to confirm healing if the patient was asymptomatic within six months after the surgery.

Patients completed the AOFAS-AH questionnaire, VAS pain-score questionnaire, and provided a subjective outcome score (extremely satisfied, satisfied, moderately satisfied, or unsatisfied). Clinical evaluation included gait analysis, evaluation of incision healing, measurement of range of motion, and assessment of pain, and radiographic evaluation was performed as well. One patient who was not available for follow-up had developed an infection requiring additional surgery. That patient was included in the outcome analysis at the time of most recent follow-up; she was considered to have had a poor result, and she was unsatisfied with the result of the surgery.

TABLE I Questionnaire Results

	Mean (Range)			
Questionnaire	Preoperative Score	Postoperative Score	Change in Score	P Value
AOFAS (max. score, 100)	43 (18-62)	76 (57-84)	+33	0.022
Adjusted AOFAS *(%)*	—	88 (66-97.7)	+45	<0.01
VAS (max. score, 10)	8.3 (7-10)	2.8 (0-6)	−5.5	<0.01

Source of Funding
No outside funding was utilized for this study.

Results

Twenty-four patients were available for follow-up at a mean of 6.5 years (range, twenty-eight to 123.6 months).

All nonunions, osteotomy sites, and fusion sites healed clinically and radiographically, at an average of 19.5 weeks (range, eleven to forty-six weeks). Radiographs made at the time of final follow-up revealed continued stable healing of the fusion and osteotomy sites without loss of alignment (Figs. 1-C and 1-D). With the exception of one case, all wounds healed without additional intervention.

Preoperative VAS scores averaged 8.3 (range, 7 to 10) of 10. This improved to an average of 2.8 (range, 0 to 6) at the time of final follow-up ($p < 0.01$) (Table I).

Preoperative AOFAS-AH scores averaged 43 (range, 18 to 62) of 100. This improved to an average of 76 (range, 57 to 84) at the time of final follow-up ($p = 0.022$). The final AOFAS-AH score was also modified by removing the points for sagittal motion (ankle was fused) and for hindfoot motion (subtalar joint was fused), making a total maximum score of 86, and calculating the score as a percentage: (x/86) multiplied by 100. The postoperative modified score averaged 88% (range, 66% to 97.7%). If the percentage was assessed as a score out of 100 and compared with the preoperative AOFAS-AH score (out of 100), the average improvement was 45 points (with 43 improving to 88) and the postoperative score was more than double the preoperative score ($p < 0.05$) (Table I).

All deformities were corrected to neutral alignment (Fig. 2-B), and all patients had a plantigrade foot and the ability to wear off-the-shelf shoes without bracing. Most patients did state that they

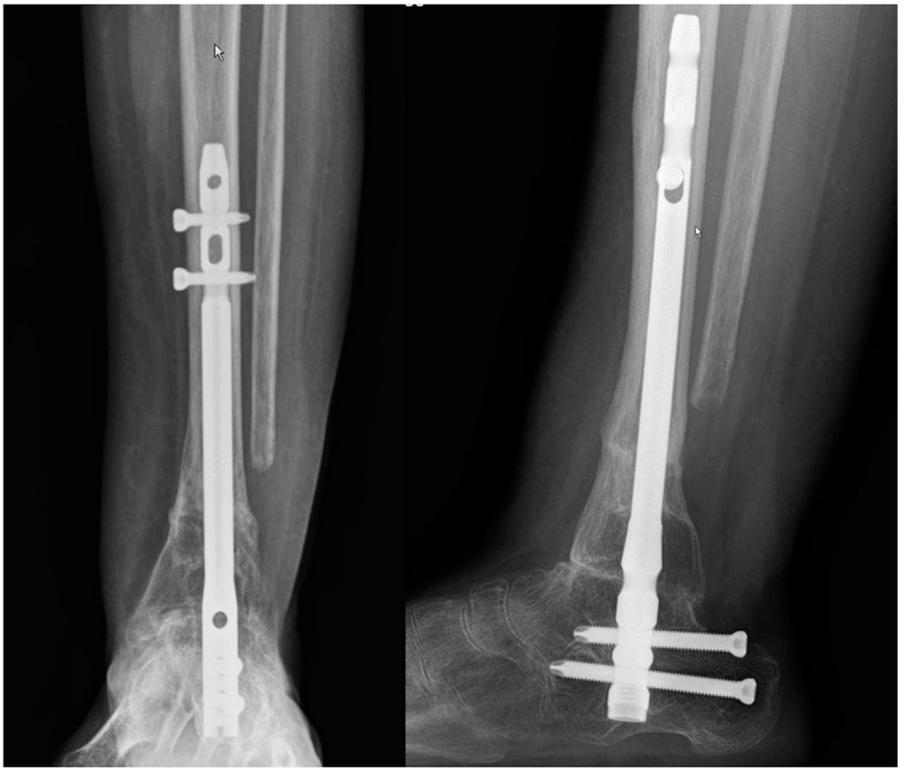

Fig. 2-B
Seven-year follow-up anteroposterior and lateral radiographs showing the correction of the alignment and malunion.

would wear their recommended rocker-bottom-soled shoes for prolonged walking. No patient had developed evidence of transverse tarsal joint or midfoot arthritis at the time of final follow-up.

When asked about their satisfaction with the surgery, twenty-one patients (84%) stated that they were extremely satisfied, three patients (12%) were satisfied, and the one patient (4%) with a poor result was unsatisfied.

There were no cases of hematoma, seroma, dehiscence, or infection at either the iliac crest or fibular donor site. Although the patients were not questioned specifically about discomfort at the donor site, none complained of such discomfort at any of the postoperative follow-up visits.

The patient who had the poor result and was unsatisfied was a forty-seven-year-old woman with severe rheumatoid arthritis managed with long-term TNF inhibitor (Enbrel [etanercept]), methotrexate, and prednisone. She had sustained a low-energy distal tibial metaphyseal fracture, which had been managed in a cast. The fracture had collapsed into severe varus with a nonunion of the distal part of the tibia and the fibula articulating with the floor laterally, resulting in a grade-1 ulcer over the tip of the fibula (see Appendix). Postoperatively, she developed lateral wound dehiscence, which was treated with local wound care. Fourteen weeks postoperatively, she developed purulent drainage from the lateral incision with bone visible at the base of the wound. She underwent removal of the intramedullary nail, extensive debridement, and application of a multiplanar external fixator for continued stabilization. She was subsequently managed with six weeks of intravenous vancomycin after cultures were positive for methicillin-resistant *Staphylococcus aureus* (MRSA). The wound was managed with a vacuum-assisted closure system and subsequently healed. The fixator was removed after an additional seven weeks (twenty-one weeks after the index surgery), and she was subsequently managed with a cast, a fracture boot plus, and external bone stimulation. The fusion subsequently healed after eleven months (forty-six weeks), by which time she was walking utilizing a cane and a rocker-bottom modification of her shoe. Her AOFAS-AH score at this point was 57 of 100 (modified score, 66%), but she was very unhappy with how long the treatment had taken and refused further follow-up.

Discussion

Retrograde intramedullary nailing for tibiotalocalcaneal arthrodesis is not a new concept; it was reported as early as 1906[16]. Currently, the literature suggests a wide range of conditions treatable with tibiotalocalcaneal arthrodesis. It has been described as a salvage procedure for patients with a failed ankle fusion or total ankle arthroplasty with severe bone loss, Charcot arthropathy, rheumatoid arthritis, posttraumatic arthritis, previous talectomy, or bone loss after tumor resection or tuberculous arthropathy[17-21].

Proponents of retrograde intramedullary nailing cite the high rate of fusion and the biomechanical strength of the construct, which successfully achieve a painless biomechanically stable plantigrade foot[20,21]. Historically, fusion rates have ranged from 74% to 93%[22-24]. In a systematic literature review, Jehan et al. found the overall union rate to be 86.7%[21]. However, previous reports quote complication rates that approach 56%, the most prevalent being implant failure (30%), nonunion (23.8%), and infection (15.1%)[21].

Quill described a fusion rate of 90% and an overall complication rate of 17.5% in his series of forty patients[24]. The most common complications were painful or broken implants, and one patient had a painful pseudarthrosis. Kile et al. also described a high rate of successful fusion (93.3%), as well as reporting a 27% rate of complications, including two pseudarthroses, two stress fractures, and two soft-tissue infections[19].

Pinzur reported on five patients with malunited stress fractures of the tibia and fibula secondary to the sequelae of Charcot neuroarthropathy who had been treated with tibiotalocalcaneal intramedullary nailing after failure of nonoperative intervention[25]. All patients were diabetics with an insensate extremity at high risk for ulceration and possible amputation if surgery was attempted. Patients undergoing retrograde nailing experienced less subsidence than their counterparts who underwent antegrade nailing. One patient who underwent retrograde nailing sustained a periprosthetic fracture at the proximal tip of the intramedullary nail. Even with the complications, after one year of follow-up all five patients had returned to their preoperative level of functioning, all were able to wear accommodative bracing, and the deformity progression had halted.

Newer implant designs have broadened indications of tibiotalocalcaneal arthrodesis with retrograde nailing although contraindications do remain. Angular deformity of the distal part of the tibia must be addressed at the time of the nailing. Positioning of the fusion for the ankle and subtalar joints is an important consideration influencing both clinical outcome and patient comfort. Unless the alignment of the lower extremity is appropriately addressed, the goal of a stable plantigrade foot cannot be accomplished.

We report the feasibility and success of a single-stage reconstruction of a tibial fracture malunion or nonunion with concomitant ankle arthritis. We do not claim that this is the only approach to these difficult cases, but we did demonstrate the ability to achieve correction of the deformities via osteotomies, healing of the nonunion via appropriate stabilization utilizing an intramedullary nail system, and successful fusion of arthritic ankles and subtalar joints. It is crucial to obtain a plantigrade foot and appropriate ankle/hindfoot alignment with the fusion. We recommend inclusion of the subtalar joint and utilization of an intramedullary device to ensure deformity correction and a stable ankle-hindfoot construct. In the future, diagnostic injections may aid in the confirmation of subtalar joint involvement, to help differentiate which patients would benefit from the addition of a subtalar fusion and which might be better served with correction to above the subtalar joint. To date, we have not seen any clinically relevant adjacent-joint disease, perhaps because of the low activity demand of many of these patients. Alternate treatment options may include correction utilizing a multiplanar external fixation system, or staged correction of the deformity/nonunion followed by a second procedure at which the ankle joint is addressed with a fusion or an arthroplasty.

In our study, fusion was present in all twenty-four patients at a mean of 19.5 weeks (range, eleven to forty-six weeks). Fusion was assessed radiographically in two planes by looking for consolidation across the joint space and clinically by applying two-point bending stress across the joint.

There was one major complication (4%) leading to a reoperation and removal of the implant with the application of an external multiplanar fixator for a deep infection in an immunocompromised patient with underlying inflammatory arthropathy.

The success of this technique is manifested by improvements in the AOFAS-AH and VAS scores. After adjustment for hindfoot and sagittal ankle motion, the average AOFAS-AH score doubled from 43 to 88 ($p < 0.01$), and the VAS score decreased by an average of 5.5 (Table I). The fusion rate in this study (96%) was higher than that reported in the literature. In a systematic review of the results of tibiotalocalcaneal arthrodesis with retrograde intramedullary nailing, Jehan et al. reported an overall fusion rate of 86.7%[21]. Their review included a larger percentage of patients with inflammatory arthritis, with 22.6% having a fusion to treat an inflammatory process. We treated only three patients (12%) who had inflammatory arthritis. Nassar and Cracchiolo reported that inflammatory arthritis can lead to nonunion after hindfoot surgery, with rates as high as 30%[26]. Additionally, given our small sample size ($n = 25$), the true prevalence of nonunion may have been underreported in our database.

Weaknesses of the study include its retrospective nature as well as the utilization of the AOFAS scoring system and patient satisfaction survey, neither of which has been statistically validated. Because the AOFAS scoring system was the questionnaire used at the time of the surgical procedure, the same system was utilized at final assessment for comparative analysis. The use of our patient satisfaction question was included given the recent emphasis on patient-centered outcomes.

In conclusion, tibial malunion or nonunion with concomitant hindfoot arthritis can be addressed with a single-stage procedure consisting of a tibial osteotomy and retrograde intramedullary nailing for correction of the angular deformity and fusion of the arthritic hindfoot. This procedure provides a viable alternative to multiplanar external fixation or a staged procedure addressing the nonunion/angular deformity and the hindfoot arthritis separately. Accurate correction with meticulous joint preparation is required to achieve good results.

Appendix

eA A photograph and radiograph showing the preoperative deformity of a woman with severe rheumatoid arthritis who subsequently developed an infection following surgical reconstruction as well as a table showing patient demographic data are available with the online version of this article as a data supplement at jbjs.org. ■

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