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CASE REPORT

Osteotomy, Arthrodesis, and Arthroplasty for Complex Multiapical Deformity of the Leg

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Abstract

Background Assessment of diaphyseal deformity in the tibia consists of delineating anatomic axes or cortical lines with resultant apices of deformity. Single-apex deformities have been well described both in terms of assessment and treatment, whereas double-level deformities with metaphyseal and/or juxtacortical involvement are less straightforward. Multiapical deformities of the lower extremity, though uncommon, are the next level of complexity and provide the surgeon with a difficult correctional mission.

Case Description We report two cases of multiapical deformity of the tibia, both of which were secondary to a distant history of tibial fracture with resultant knee and ankle joint degeneration and deformity. Both cases had three levels of deformity that were addressed with tibial osteotomy, ankle fusion, and total knee replacement. Initial presentation, problem lists, surgical treatment, and subsequent results are reviewed.

Literature Review Treatment of a post-traumatic three-level deformity has never specifically been addressed in the literature, although the principles of treatment are the same as for less complex deformities.

Purposes and Clinical Relevance These two cases present a treatment approach for complex, multiapical deformity of the tibia. The same principles of deformity correction used to treat less complex deformities are applied to these patients with an overarching synthesis that takes all aspects of the three deformities into account. Although these cases are complex and difficult, good results in terms of deformity correction and pain relief can be obtained.

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Introduction

Traumatic malalignment of the lower extremity has the potential to cause severe degeneration in the knee and ankle [5, 6]. Most of the literature focuses specifically on changes in the ankle or the knee cartilage alone in relation to tibial malunion and not on both [1, 10]. However, with long-standing diaphyseal tibial deformity, degeneration in both the ankle and the knee can occur [5, 6].

Principles for the treatment of uniapical tibial deformity have been well described [2–4]. Double-apex deformities of the tibia have been described in the literature, and the same principles have allowed for the development of surgical techniques to correct these deformities [2, 4]. Diaphyseal deformities can generally be addressed at the apex of deformity. However, periarticular deformities require translation of bone ends as the osteotomy cannot be performed at the apex of the deformity if the joint or physis is to be spared [2].

The application of these principles to a three-level deformity of the tibia, which includes a diaphyseal deformity as well as arthrosis of both the knee and the ankle, can provide a plan for the treatment of patients with these complex deformities. Here, we chronicle the approach taken in patients with multiapical tibial deformity to restore a near normal mechanical axis while simultaneously improving function. Correction of the three-level deformity is achieved with osteotomy, arthrodesis, and arthroplasty.

Case Reports

Case One

A 76-year-old woman was referred to the service for severe left ankle and knee pain and a valgus deformity of her left lower

Fig. 1. Case one. **a** The patient at her initial presentation. **b** The patient's pre-operative AP x-ray of the left tibia and fibula. **c** Pre-operative AP x-ray of the left ankle. **d** An AP x-ray of the left ankle 9 months after the frame was removed. **e** An AP x-ray of the left knee 3 months after her TKR. **f** A 51-in. AP hip to ankle standing x-ray 9 months after the frame was removed. **g** A clinical photo of the patient taken 9 months after frame removal

extremity (Fig. 1a). She stated the pain had been worsening over the past 6 months and had made it much more difficult to walk. She had suffered an open tibial fracture at the age of 54 that required multiple surgeries and healed in a shortened and deformed position. More recently, she sustained a lateral tibial plateau fracture. She also has a history of diabetes mellitus and smoking, although she had quit 10 years prior to evaluation.

On examination, she was 5′1″ tall and 184 lb with a valgus deformity of her distal tibia and genu valgum. She stood comfortably with a 2.4-cm block under her left foot. Her left knee demonstrated full extension with flexion to 130 degrees. She had grade I valgus instability of the knee. She had a thigh–foot axis of 20 degrees external on the left and 10 degrees external on the right. Her left ankle demonstrated dorsiflexion to neutral and 30° plantar flexion (compared to 5 and 40° respectively on her right). In order to accommodate her limb length discrepancy, she walked with her ankle in about 20° of equinus. Passive range of motion testing through inversion and eversion of the patient's foot showed that her subtalar motion on the left was 30° inversion and −5° eversion (20° and 10° respectively for her right). She was neurovascularly intact.

Radiographs

A 51-in. AP hip to ankle radiograph displayed a limb length discrepancy of 3.4 cm when measured directly, 2.5 cm coming from the tibia. Her mechanical axis deviation was 65 mm lateral. She had a lateral distal femoral angle (LDFA) of 86° and a medial proximal tibial angle (MPTA) of 100° [4]. There was valgus deformity of 14° of the proximal tibia and 22° of the distal tibia (Fig. 1b), a recurvatum deformity of 20° of the distal tibia, and 20° equinus of the foot. There was significant lateral compartment osteoarthritis and genu valgum of the knee as well as advanced osteoarthritis of the tibiotalar joint. An MRI of the ankle performed 2 months prior to presentation revealed an intact subtalar joint without arthritic change.

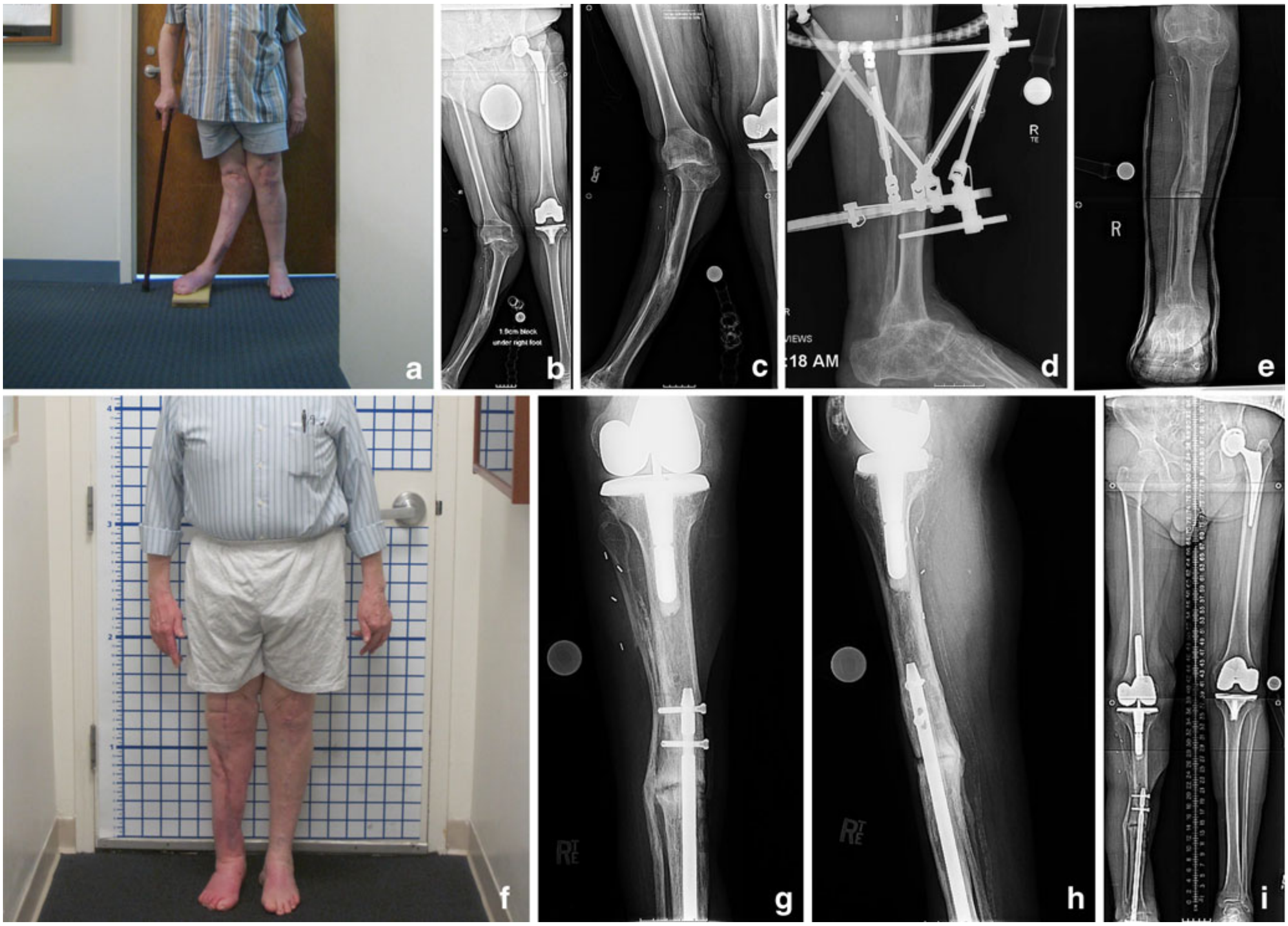

Fig. 2. Case two. **a** The patient at his initial presentation. **b** At the initial clinic visit, a 51-in. AP hip to ankle standing x-ray was taken. **c** Pre-operative AP x-ray of the right tibia and fibula. **d** Lateral x-ray of the right tibia and fibula was performed 1 year post-frame application. **e** Two months after the frame was removed, just prior to the percutaneous tibial plating, this AP x-ray of the right tibia and fibula was taken. **f** A clinical photo of the patient taken 1 year after total knee replacement and 10 months after ankle fusion nail. **g** Ten months after the antibiotic cement-coated retrograde ankle fusion nail, this AP x-ray of the right tibia was taken. **h** Ten months after the antibiotic cement-coated retrograde ankle fusion nail, this lateral x-ray of the right tibia was performed. **i** Ten months after the antibiotic cement-coated retrograde ankle fusion nail, erect bipedal radiograph

Problem List

1. Fourteen degrees of valgus deformity at the knee with advanced lateral compartment arthrosis
2. Oblique-plane deformity of the tibia of 22° valgus with 20° of recurvatum
3. Twenty degrees of equinus deformity at the ankle
4. Advanced OA of the ankle with questionable subtalar involvement (Fig. 1c)
5. Leg-length discrepancy of 3.4 cm, although the patient feels comfortable with a 2.4-cm lift

The index surgery to correct the multiapical deformity consisted of an ankle arthrodesis for the ankle arthritis and to correct the equinus deformity, a distal tibial osteotomy with application of an Ilizarov/Taylor Spatial Frame (Smith and Nephew, Inc.; Memphis, TN) to assist in the correction of the valgus, recurvatum, and limb length discrepancy. This three-ring construct remained in place for 5 months and corrected the distal two deformities. The proximal tibial deformity was then addressed via a constrained total knee replacement 6 months after the distal frame removal to avoid over/under-correction and contamination of the knee implant (Fig. 1d).

Three months after the knee replacement, the patient's mechanical axis deviation was 17 mm medial; she had an LDFA of 93°, MPTA of 92°, and an LLD of 11 mm shorter on the left (Fig. 1e–g). Clinically, she had full range of motion of her knee of 0–130°, 5° of dorsiflexion and 15° plantarflexion through her midfoot and denied any significant pain. Three years since the index surgery, she continues to have normal alignment of her left lower extremity, full range of motion of her knee, and no pain.

Case Two

A 60-year-old man was referred to the service for constant right knee pain and a severe valgus deformity of the right lower extremity (Fig. 2a). The pain had been progressively worsening over the past 5 years, and at presentation, he was unable to ambulate without assistance. At the age of 5, he suffered a crush injury to the right lower extremity that resulted in a foot drop. He required multiple surgeries on his right lower extremity including multiple skin grafts and a Lambrinudi arthrodesis at the age of 15 [11]. Of significance, he has a history of right tibial osteomyelitis from his previous injury. On examination, he was 5′5″ tall and 175 lb with a valgus deformity of his right knee, tibia, and ankle; a recurvatum deformity of his right knee; and an external rotation deformity of his right foot. His right knee demonstrated 25° of hyperextension to 120° of flexion and a grade III valgus instability. The thigh–foot axis was 45° external on the right and 15° external on the left. In his right ankle he could dorsiflex to neutral and had 30° of plantarflexion (10° to 40° on the left) with no true active dorsiflexion although it was felt that his tibialis anterior was contracting. Consistent with his previous fusion, his right subtalar joint had no motion; his left ranged from 20° of inversion to 10° of eversion. His neurovascular exam was consistent with a peroneal nerve palsy and was otherwise within normal limits.

Radiographs

A 51-in. AP hip to ankle radiographs showed a limb length discrepancy of 7.7 cm when measured indirectly; segmental measurements showed 4-mm and 2-mm differences in the femur and tibia respectively (Fig. 2b). His mechanical axis deviation was 115 mm lateral. His LDFA was 83°, and his MPTA was 116°. There was a hyperextension deformity of the knee of 27° and a posterior proximal tibial angle of 76°. Lastly, there was a valgus tilt of the talus of 8° and a lateral distal tibial angle of 85° when in relation to the tibial plafond and 77° when in relation to the talus.

Problem List

1. Twenty-eight degrees valgus of the right knee with osteoarthritis and grade III valgus instability
2. Twenty-seven degrees hyperextension instability at the knee
3. Tibial deformity of 20° valgus with 30° of external rotation (Fig. 2c)
4. Right ankle valgus deformity of 8°
5. Leg length discrepancy of about 7.7 cm
6. History of infection/osteomyelitis

He underwent a tibial osteotomy with application of an Ilizarov/Taylor Spatial Frame to correct the tibial diaphyseal malunion deformity and a tibiotalar arthrodesis to correct the ankle deformity as well as provide relief from the significant osteoarthritis of the tibiotalar joint. The arthrodesis relieved the ankle pain and valgus deformity about the ankle, and the foot frame was removed 6 months after surgery. The tibial malunion required roughly 12 months in the frame. There was some concern about insufficient bony bridging at the tibial osteotomy site (Fig. 2d, e). Ten weeks after tibial frame removal, a tibial plate was inserted using a percutaneous technique to stabilize the osteotomy site. At the same time, a constrained total knee replacement was performed to correct the 17° of residual valgus deformity about the knee.

Seven weeks postoperatively, the patient was noted to have some skin breakdown over the plate. The plate was removed, and a retrograde ankle fusion nail coated with antibiotic impregnated cement was inserted, bypassing the site of the tibial osteotomy. With the wound breakdown over the nonunion, an antibiotic coated nail was used as a prophylactic measure to avoid a deep bone infection. He had a residual wound at the site of the plate on which a vac-dressing was placed. The patient is now 1 year out from his total knee replacement. His wounds are fully healed, and there is no sign of infection (Fig. 2f). His knee replacement never indicated any signs or symptoms of infection despite the wound issues at the diaphyseal osteotomy site. He currently has full extension at the knee, with flexion to 110°. His mechanical axis deviation is 5 mm medial, and he has a leg-length discrepancy of 3 cm shorter on the right. X-rays showed progressive signs of union in his tibia (Fig. 2g, h). He was given a ¾-in. lift on the right side with a rocker-bottom shoe. He is ambulating without pain and continues to improve from a functional standpoint.

Discussion

A three-level multiapical deformity, strictly tibial in origin, provides a substantial correctional challenge. These patients typically have drastic and severe deformity that substantially limits their functional capacity. This deformity requires the creation of a new surgical plan, adapted from previous teachings, to produce the best possible patient outcome [2]. While two-level multiapical deformities are a considerable procedure to execute, the literature provides guidance in the development of the appropriate course of action to facilitate a positive outcome. Paley and Tetsworth offer the only description of an approach to a double-apex tibial deformity [2]. They explain two-level deformities exclusive to the tibia as being either diaphyseal and proximal or distal metaphyseal/juxtaarticular or the proximal and distal deformity without a diaphyseal deformity [2]. Russell et al. also describe a clamshell osteotomy approach to tibial diaphyseal malunions. However, the cases discussed here provide recommendations for the juxtaarticular deformity as well as a minimally invasive technique for the tibial malunion [7]. These cases describe a three-level deformity involving the proximal and distal juxtaarticular tibia associated with a diaphyseal deformity. The initial tibial malunion led to late arthrosis and deformity in the ankle and knee.

Alteration of the normal biomechanical forces transmitted across the knee and ankle secondary to deformity can induce osteoarthritic changes of the aforementioned joints [5, 6]. However, the rate of degeneration and the overall contribution of joint surface damage related to either the trauma or the resulting deformity has been difficult to fully assess [5]. Certainly, injury to the ankle can be overlooked in the setting of a diaphyseal tibial fracture [9]. Regardless of the origin of the arthritis, these two cases are prime examples of how tibial malunions have the ability to affect both the knee and ankle joints [3]. Surgery for valgus malunion correction is indicated once the malalignment is greater than 15° at either the ankle or knee [5].

The treatment of the diaphyseal deformity used the uniapical approach to an angular deformity. An opening wedge tibial osteotomy was executed with application of an Ilizarov/Taylor Spatial Frame in order to correct the valgus recurvatum in the first case and the valgus, external rotation in the second case [6]. The ankle fusion corrected the distal tibial deformity and alleviated the pain associated with the arthritic changes of the ankle. Antibiotic cement-coated nails have been shown to be an effective treatment for infected nonunion addressing the infection and helping achieve bony union in nearly 85% of cases in one study [12]. Therefore, the use of one in case two as a prophylactic measure was to ensure the patient did not develop an infected nonunion that required further surgery.

The total knee replacement was performed last in this staged correction for a few reasons. First, the distal corrections can sometimes relieve some of the arthritic knee pain, thereby possibly obviating or at least delaying the need for knee replacement. Also, the total knee replacement allows near-perfect correction without increasing the likelihood of over/under-correcting the deformity [4]. Furthermore, performing the knee replacement last, once the frame has been removed, lessens the likelihood of any possible contamination of the new artificial joint. Infection is a concern when performing arthroplasty after external fixation. Hydroxyapatite (HA)-coated pins are thought to possibly decrease the loosening that traditionally occurred with non-HA coated pins and, as a result, also decrease bacterial contamination of the bone [8]. Moreover, an appropriate time interval between frame removal and arthroplasty also helps to lessen the risk of infection. Ideally, 6 months is a reasonable amount of time. In case two, we moved to TKR sooner because the knee valgus deformity was felt to be a negative factor towards bony union of the diaphyseal osteotomy. As was seen in both cases presented, even after several months of wearing a frame, the total knee replacement never developed any signs of infection. Therefore, a proposed treatment approach of a three-level tibial deformity begins with a tibial osteotomy with application of an Ilizarov/Taylor Spatial Frame in association with an ankle arthrodesis followed by a total knee arthroplasty after frame removal.

While the literature does not provide an example of a surgical approach to a three-level deformity, it presents fundamental principles that are vital to understand in order to thoroughly evaluate a complex deformity and subsequently tailor an appropriate surgical intervention [4]. These cases offer an approach to a three-level multiapical tibial deformity. The staged surgical correction allows the surgeon to reevaluate the proximal juxtaarticular tibial deformity after adequate correction of the distal two deformities so that the most suitable knee replacement may be inserted and over/under-correction can more easily be avoided.

Disclosures Each author certifies that he or she has no commercial associations that might pose a conflict of interest in connection with the submitted article.

Each author certifies that his or her institution has approved the reporting of these cases, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participating in the study was obtained.

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