The Extruded Talus:
Results of Reimplantation

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Background: There is considerable debate regarding the appropriate treatment of the extruded talus regardless of the presence of a fracture. The purpose of this study was to report the clinical results, complications, and functional outcome following reimplantation of the traumatically extruded talus.

Methods: A database of 119 patients with an open injury of the talus occurring between 1995 and 2003 at a level-I trauma center was reviewed to identify patients with a complete talar extrusion. Demographic, imaging, and treatment data were obtained from a review of the medical records. Follow-up was undertaken during clinic visits or by telephone. Preoperative and follow-up radiographs were reviewed to identify posttraumatic arthritis, osteonecrosis, or talar collapse, and the Musculoskeletal Functional Assessment was used to assess functional outcome.

Results: Twenty-seven patients were identified. A minimum follow-up of one year (average, forty-two months) was obtained for nineteen patients. Infection and the need for a secondary surgical procedure were the primary determinants of clinical outcome. Two of the nineteen patients had documented infections: one had developed at two weeks and one, after a calcaneal osteotomy at nineteen months. Twelve patients had no subsequent surgery, and seven had subsequent procedures (range, one to four procedures). No patient underwent a delayed amputation. The average Musculoskeletal Functional Assessment score at the time of follow-up was 29.8 (range, 5 to 59). With the numbers studied, no association was found between functional outcome and the following variables: ipsilateral lower-extremity injury, associated talar fracture, secondary procedures, osteonecrosis, or age.

Conclusions: While functional outcome is difficult to assess, salvage of the extruded talus appears to be a relatively safe operation, with a minimal risk of infection, which allows maximal flexibility in aftercare by preserving the most normal ankle anatomy possible.

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

Open talar fractures with extrusion of the talar body or the entire talus are typically the result of high-energy trauma and are frequently associated with markedly displaced fractures, severe soft-tissue injury, contamination, and disruption of the talar blood supply. The appropriate treatment of a completely extruded talus, with or without fracture, remains controversial. The more commonly observed talar body fractures, talar neck fractures, and partial talar dislocations are best managed with early diagnosis, anatomic reduction and fixation, scrupulous wound care, and careful soft-tissue handling. Talar dislocations and, the most violent extreme, complete talar extrusion, are both exceedingly rare. A number of series and case reports have described devastating complications and limited short-term successes with talar reimplantation in a small number of patients. The largest published series, to our knowledge, included eighteen open injuries of the talus, twelve of which were partial or total talar extrusions. The authors reported an early infection rate of 38% with an average follow-up of over seven years. Infection was more commonly observed in the patients with an extruded talus, and this predicted a poorer outcome. Secondary procedures were necessary in nearly half of the patients, irrespective of whether the injury included talar extrusion.

We reviewed our experience with complete talar extrusions to assess the safety of talar reimplantation and to determine the need for subsequent operations. The purpose of this retrospective review was to assess the clinical results and functional outcome after reimplantation of the extruded talus.

Materials and Methods

Over a nine-year period, 558 patients with a talar fracture were treated at a level-I trauma center. Of those, 119 patients (119 ankles) with an open injury of the talus were retrospectively identified from a prospectively designed orthopaedic trauma database. Talar extrusion was defined by one of the following three scenarios: (1) there was definitive documentation of talar extrusion through the open wound at the time of surgery; (2) the talus was previously extruded and had been replaced in the emergency department, or (3) the patient had...
been referred after replacement of a previously extruded talus. Patients who had immediate amputation (eleven) or gunshot wounds to the talus (five) were excluded. The majority of the patients who underwent immediate amputation had more proximal injuries, which precluded limb salvage. These criteria were implemented to exclude associated injuries that could not be treated with reconstruction. The remaining twenty-seven patients with twenty-seven extruded tali were included and formed the initial study group for this review.

There were sixteen male and eleven female patients ranging in age from eighteen to sixty-eight years (average, 36.5 years). The mechanisms of injury included a motor-vehicle collision (eighteen patients), a fall from a height (three), a motorcycle crash (two), a plane crash (two), an industrial crush injury (one patient), and a tractor injury (one). Fifteen left tali and twelve right tali were injured. The locations of the associated traumatic open wounds were lateral in six, medial in six, posteromedial in six, anterolateral in four, anterior in two, and in an undocumented location in three. Eight patients had pure pantalar dislocations without associated talar fractures. Three patients had minor associated talar fractures, which included two lateral process fractures and one talar head fracture. The remaining sixteen patients sustained an associated major talar fracture defined as either a talar neck or body fracture. Talar neck fractures were classified according to the system of Hawkins as modified by Canale and Kelly. Thirteen patients had Hawkins type-III or IV talar neck fracture-dislocations, with extrusion of the entire talar body. Three patients had talar body fractures with associated extrusion of the remaining posterior portion of the talar body.

All patients were evaluated in the emergency department and received immediate wound irrigation with normal saline solution and reduction of the extruded talus. In the patients in whom the talus had no soft-tissue connections, the talus was placed in sterile bacitracin solution and was transported with the patient to the operating room. Once there, the talus was placed in two or three successive bacitracin solutions and was scrubbed gently before reimplantation. Wounds were covered with saline solution-moistened gauze and were wrapped to prevent contamination. Two patients had the extruded talus reduced at another facility, and they were transported with the limb splinted and wrapped in moist gauze. Four patients had irreducible dislocations in the emergency department. Two of these patients had delays in going to the operating room because of other life-threatening injuries, and they had wound irrigation with at least 3 L of normal saline solution in the emergency department and reduction of the extruded talus. One patient had a transport time of greater than twelve hours but was taken immediately to the operating room on arrival at our facility. The remaining patients were taken directly from the emergency department to the operating room. The time between the injury and being taken to the operating room ranged from 1.5 hours to 19.5 hours, with an average of 6.7 hours.

Preoperative antibiotics were chosen on the basis of the wound contamination and included a cephalosporin and gentamicin; penicillin was added if gross or farm contamination was present. All patients received a tetanus toxoid booster. Osteose stabilization was carried out at the discretion of the individual surgeon on the basis of the associated soft-tissue wounds and the overall medical status of the patient. Stabilization included internal fixation, external fixation, or combinations of the two. In two patients, a temporary external fixator with use of a calcaneal and tibial pin was placed and definitive fixation was placed later. In one patient, screw fixation was augmented with a similar external fixator because of soft-tissue instability. The remaining fractures were fixed with screws and plates, and one pure dislocation was treated with an external fixator. Associated fractures were fixed similarly with small-fragment implants. Associated lateral and medial malleolar fractures were treated with one-third tubular plates or cannulated screws, respectively. In several patients, Synthes mini-fragment implants (Synthes USA, Paoli, Pennsylvania), which typically involved a 2.0-mm plate with 2.0-mm or 2.7-mm screws on the medial or lateral side of the talus, were placed as illustrated in Figures 1-A through 1-D. Six patients had definitive soft-tissue closure over a suction drain at the initial operation. Thirteen patients had staged soft-tissue débridement and osseous stabilization. Eleven wounds were closed primarily and were reopened for serial débridement and staged osseous stabilization. In two patients, dead pouches were placed initially; one of these wounds was closed at the subsequent procedure, and the other received a free flap on the fourth day after the injury. No wound was allowed to granulate or close by secondary intention. Data on the patients who were followed are provided in the Appendix. Initial surgical procedures were those performed during the initial hospitalization including the initial débridement, soft-tissue stabilization, and definitive fixation. Subsequent procedures were those performed after healing or to correct a deformity (see Appendix). The shortest interval between the injury and a subsequent procedure was three months. Removal of external fixation was done in the outpatient clinic and is not reported as a subsequent procedure. Postoperative immobilization in a rigid cast was continued for six weeks. Range-of-motion exercises were initiated at six weeks after the injury. All patients were asked to remain non-weight-bearing for three months after the injury. Weight-bearing was initiated in a graduated fashion at that time, with resumption of full weight-bearing within six weeks after its initiation. No attempt was made to limit weight-bearing, even in the presence of osteonecrosis, unless symptoms made it necessary. Much of the follow-up was undertaken at other institutions because of the great referral distances; however, all patients were asked to abide by the above limitations.

Follow-up radiographs included anteroposterior radiographs of the ankle and foot, lateral radiographs of the foot, and a Canale view. Talar body collapse was noted. Osteonecrosis was defined as an area of increased density limited to the talar dome compared with adjacent structures. Magnetic resonance imaging was not used routinely to diagnose or follow osteonecrosis. Degenerative arthritis of the subtalar and/or tibiotalar joint was defined as any joint narrowing, subchondral sclerosis that appeared on both sides of a joint, or osteophyte formation.
The Musculoskeletal Functional Assessment (MFA) was administered at the most recent clinical follow-up evaluation or by telephone from a trained medical interviewer who was not involved in the patient’s treatment\(^{18,19}\). The MFA consisted of 100 questions encompassing mobility, hand and fine motor function, housework, self-care, sleep and rest, leisure and recreation, family relationships, cognition, emotional adjustment, and employment. Overall scores range from 0 to 100 points, with each category scored individually as well. Low scores indicate better function.

**Results**

*Initial Hospitalization (All Twenty-Seven Patients)*

Of the twenty-seven patients reviewed, three did not undergo reimplantation. One patient had a below-the-knee amputation and another was lost to follow-up. The remaining patients underwent reimplantation. The mean length of initial hospitalization was 4.3 days, ranging from 2 to 10 days.

*Initial Surgical Procedures*

Anteroposterior (Fig. 1-C) and lateral (Fig. 1-D) radiographs, made one year after operative fixation of the fractures, show a healed talar neck fracture with sclerosis on both sides of the tibiotalar joint (posttraumatic arthritis) and increased density in the talar body (osteonecrosis), but the patient was fully able to walk and was without pain at one year and ten months after the injury.
amputation on the second day after the injury because of a severely crushed foot. One patient underwent takedown on the third day after the injury for what was thought to be an unreconstructible injury because of talar bone loss and comminution. Another patient underwent a primary tibiocalcaneal arthrodesis, with a portion of the extruded talar body used as bone stock.

Infection
The only infection identified during the initial hospitalization occurred in the patient who had undergone a primary tibiocalcaneal arthrodesis. The infection was identified on the sixteenth day after the injury, and it responded to irrigation, débridement, and intravenous antibiotic therapy. The patient was discharged after twenty-eight days to a local care facility in another city with healthy-appearing wounds. He was lost to further follow-up. This patient is reported since he was the only one to have an infection in the first three months after the injury. The other twenty-six patients were followed for at least three months without clinical evidence of infection.

Follow-up (Nineteen Patients)
A minimum duration of follow-up of one year was attained for nineteen patients. Thirteen of them had radiographs made at greater than one year after the injury, and fifteen completed the MFA at the latest clinical follow-up evaluation. Nine patients had both.

Nine patients had a major talar fracture (talar neck or body), while nine had a pure dislocation or a talar head or lateral process fracture only.

Infection
No patient had a late infection of the ankle. One patient had an infection of the calcaneus develop nineteen months after reimplantation following a calcaneal osteotomy to treat talar collapse. It resolved with surgical débridement and antibiotic treatment and did not recur.

Development of Collapse or Arthritis
Radiographic evaluation of longer than one year from the time of injury was available for thirteen patients. There were eight patients with a fracture and five patients without a major fracture of the talus. In the five patients without an associated major fracture of the talus, only one had evidence of talar collapse. In contrast, six of eight patients with a talar fracture had evidence of talar collapse. Collapse occurred within one year for all patients with a fracture but occurred after thirteen months in the patient without a fracture. Another patient had signs of osteonecrosis at one year after the injury, but the talus did not go on to collapse even two years later; however, this patient did have arthritic changes in the ankle joint (Figs. 1-A through 1-D).

Three patients had evidence of arthritis, including sclerosis, joint-space narrowing, or osteophytes, all of which occurred within eighteen months after the injury. Two of those with arthritic changes had talar neck fractures, and one had no fracture. Three patients had no radiographic abnormalities at one year; one had no fracture, and two had lateral process fractures.

Therefore, of the eight patients with a major fracture who were followed radiographically, all had collapse, osteonecrosis, or arthritis. Of the five patients without a fracture, three had no abnormalities. Due to the small sample sizes, no significant relationship could be demonstrated between postoperative regimen, motion, or weight-bearing and the development of radiographic abnormalities.

Secondary Surgical Procedures
Seventeen secondary surgical procedures related to the talus and hindfoot had been performed in seven patients (four with and three without a fracture). The number of procedures per patient ranged from one to four. The average number of surgical procedures per patient was 0.9 when all nineteen patients are considered but increased to 2.4 when only the seven patients are considered.

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considered. The subsequent procedures included removal of hardware for magnetic resonance imaging, followed by total ankle arthroplasty with subtalar fusion and then removal of the fibular hardware associated with the total ankle arthroplasty in one patient. Radiographs made seven years after the injury are shown for this patient in Figures 2-A and 2-B. A total ankle arthroplasty and a calcaneal osteotomy were performed in one patient who had collapse of the talus. Removal of fibular hardware (unrelated to the talar fracture but in the same ankle) with débridement of the lateral process of the talus and then three subsequent flap revisions for debulking were undertaken in one patient. Cheilectomy of the tibia was undertaken in one patient. Attempted iliac crest bone-grafting to the talus for collapse followed by calcaneal osteotomy and then two surgical débridement procedures for infection in the calcaneus was undertaken in one patient. A tibiotalar fusion was undertaken in one patient, followed by removal of hardware eight months later after a successful arthrodesis. One patient reported a procedure at another hospital three years after the injury but documentation of it could not be obtained.

**Functional Outcomes**

Outcomes data were obtained for fifteen patients. Overall, the average MFA score (and standard deviation) was 29.8 ± 16 points (range, 5 to 59 points). Compared with the published normative values for patients with an isolated lower-extremity injury (an average MFA of 22.9) and the values for the normal population (an average MFA of 9.3)\(^{18,19}\), the values for our patients demonstrated that they had continued disability\(^{18,19}\). With the numbers available, there was no significant difference in the average MFA in a comparison of the seven patients with a talar neck fracture (31 ± 17.7) and the seven patients without a talar neck fracture (28.5 ± 15.4). Similarly, with the numbers studied, patient age, ankle or subtalar arthritis, osteonecrosis, talar collapse, an ipsilateral lower-extremity injury, and the need for a secondary surgical procedure were not related to a poorer functional outcome according to the MFA score.

**Discussion**

Talar extrusions result from violent trauma and are often complicated by fracture or other associated injuries. The initial surgical treatment for a partially or completely extruded talus remains controversial. Both removal and reimplantation have been recommended\(^3,6,12,13\). The obvious early risk of reimplantation is infection. However, discarding the talus adversely affects hindfoot function and limits subsequent reconstructive options. Therefore, a reasonable initial objective in managing these patients may include retaining the talus, especially if infection can be avoided. While the long-term consequences of retaining the talus are unknown, osteonecrosis with late collapse and posttraumatic arthritis remain potential complications. Long-term goals include maximizing function and preserving the ability to perform reconstructive procedures.

Previous studies on the treatment of open talar fractures, open talar dislocations, and talar extrusions have described high infection and complication rates. Detenbeck and Kelly were the first, as far as we know, to report on open talar dislocations in seven patients, all of whom ultimately required talectomy for the treatment of persistent infection\(^20\). Other authors have reviewed large series of open talar fractures and have reported in-
Infection rates of 15% and 24%\textsuperscript{12,21}. Two separate case reports were published in 1997 with successful reimplantation of three extruded talus\textsuperscript{12,22}. A single successful reimplantation was reported in 2004 with five-year follow-up\textsuperscript{23}. Despite having no soft-tissue connections, the talus survived and at five years showed subchondral sclerosis and joint-space narrowing anteriorly without evidence of osteonecrosis or talar body collapse\textsuperscript{24}. A review of all of the English-language literature on the subject demonstrated a total of thirty-two reported open dislocations (see Appendix). Infection rates have ranged from one of one of those reimplanted\textsuperscript{2} to six of twelve extrusions reported by Marsh et al.\textsuperscript{1}. Vallier et al.\textsuperscript{3} recently reported one deep infection among eleven open talar body fractures treated operatively\textsuperscript{3}. Two patients in our study had an infection. One occurred despite removal of most of the talus and arthrodesis of the calcaneus to the tibia acutely. No other patient in this series had an infection within the first three months, although of the six remaining patients lost to follow-up, more (excluding the patient with the below-the-knee amputation) could have had an infection develop. An additional infection occurred at nineteen months in the calcaneus of a patient who had had a total of seven surgical procedures, including a calcaneal osteotomy for the treatment of talar collapse.

In what we believe is the largest reported series of high-energy talar fractures, Marsh et al. included eighteen open injuries, of which twelve were complete or partial talar extrusions\textsuperscript{1}. The overall rate of infection in that series was 38%, with seven infections occurring early (within twenty-three days after the injury). The authors found an association between function and the presence of infection, which, in turn, was associated with extrusion. In that series, infection necessitated late excision of the talar body in two of the seven infected ankles. Our series demonstrated a lower infection rate. Possible explanations for this include our use of staged procedures, multiple débridements, early soft-tissue closure, and rigid fixation. In the previous series, although all patients were treated operatively in a timely fashion, no mention was made of serial débridements and nine wounds were closed in a delayed fashion, or were allowed to granulate secondarily. Vigorous attention to meticulous soft-tissue handling and the use of external fixation either to temporize or stabilize the soft-tissue envelope may have contributed to the relatively low infection rate we encountered.

Reported rates of osteonecrosis after talar fractures have ranged widely in the literature, from nearly 80% to 90% of Hawkins type-III and IV injuries\textsuperscript{8,17} to as low as 11% (five) of forty-four operatively repaired talar fractures as recently reported by Sanders et al.\textsuperscript{21,24}. Talar collapse was noted in seven of our patients, six of whom had fractures. Vallier et al. recently reviewed two large series of talar body and talar neck fractures treated operatively, demonstrating that osteonecrosis always occurs within ten months with subsequent collapse or revascularization within another thirty-six weeks. That series also showed a high association between osteonecrosis and open injuries\textsuperscript{8,17}. Three of our patients had clinically important arthritis develop in either the ankle or the subtalar joint. Thus, ten of the thirteen patients with radiographic follow-up had radiographic changes that were due to collapse, osteonecrosis, or osteoarthritis. This rate is similar to the findings of Vallier et al.\textsuperscript{4,5}, in that arthritis developed in all of the patients with an open fracture of the talar body but only in half of those with a closed fracture. Three of our patients had normal findings on radiographs made after one year; none of them had a fracture. Interestingly, one of our patients had sclerosis radiographically at thirteen months, but the radiographs showed collapse only after three years. Additionally, two of the patients with radiographic evidence of collapse had not required a secondary procedure despite the radiographic findings at the time of the latest evaluation. Of these two patients, one was sixty-three years old at the time of the latest evaluation at two and one-half years after the injury, was able to walk, had an MFA score of 18 points, and did not desire any more surgery. The other patient was forty-four years old at the time of the latest evaluation at five years after the injury, did not want any additional procedures, and had an MFA of 13 points. Both had osteonecrosis demonstrated on radiographs made within ten months after the injury.

The need for subsequent procedures is another concern after talar reimplantation. Some authors have suggested that if the talus develops osteonecrosis, fusion between the sclerotic talus and the tibia or calcaneus is more difficult to achieve\textsuperscript{24}. In a recent retrospective study of eighty talar fractures, Schulze et al. successfully performed an arthrodesis in three ankles, five combined ankle and subtalar joints, and one talonavicular joint despite talar necrosis\textsuperscript{15}. Reimplantation of the extruded talus imparts the theoretical advantage of retained height and bone stock, even in the face of some collapse. In our patients who were followed for greater than one year, seven of nine required an additional surgical procedure, including successful total ankle replacement and tibiotalar arthrodesis, both of which benefited from the additional bone stock of the retained talus. This rate of subsequent major reconstructive procedures may be acceptable with this severe injury, as some patients (twelve of nineteen) required no further procedures, and the alternative of discarding the extruded talus is not an attractive one. In the series described by Marsh et al.\textsuperscript{3}, even patients who required major reconstructive procedures thought that the reconstructions had benefited them. Even those with late excision of the talus had good functional results. Our study adds to the increasing number of patients who have had successful reimplantation of the talus and suggests that the procedure can be done in a safe manner and that it may enhance functional outcome by preservation of the joint mechanics and bone stock, even if subsequent procedures become necessary.

The average MFA for our fourteen patients for whom it was available was 29.8 points (range, 5 to 59 points), reflecting some degree of permanent disability. This rate is similar to that in the study by Vallier et al., who reported an average MFA score of 29.4 points for thirty patients with a talar body fracture and 24.6 points for forty-five patients after a talar neck fracture\textsuperscript{4,5}. Certainly more functional data are necessary.
in order to make concrete conclusions regarding the utility of talar reimplantation. The long-term data in the study by Marsh et al. strongly indicated that function is associated with infection, and the ability to achieve a low infection rate may enhance functional outcome. Furthermore, we advocate cautious use of reimplantation in patients with a fracture as the presence of a fracture does appear to be associated with radiographic sequelae.

An alternative approach to the extruded talus, in which a metal prosthesis is fashioned on the basis of the dimensions of the lost talus, has also recently been described. Originally designed for replacement of a collapsed, avascular, or painful non-unioned talus, this prosthesis has been implanted in a small number of patients. A single report in the literature has described the fabrication of such a custom implant and its use in the acute setting of an unreconstructible extruded talus. Although we have no experience with such a prosthesis, it should be considered in the options for treatment of an extruded talus.

In conclusion, reimplantation of the traumatically extruded talus in our series did not result in a prohibitively high infection rate. While multiple surgical procedures, both acute and delayed, are often necessary to treat this injury and its sequelae, the talus frequently survives. Radiographic changes occur commonly, but the talar body does not always collapse and not all patients with talar body collapse require subsequent surgical procedures. Therefore, reimplantation should be strongly considered whenever possible as it may restore the most normal joint mechanics, hindfoot height, and bone stock for future function and reconstructive procedures.

### Appendix

Tables showing detailed clinical information on all patients and a list of other reports in the literature of this injury are available with the electronic versions of this article, on our web site at jbjs.org (go to the article citation and click on “Supplementary Material”) and on our quarterly CD-ROM (call our subscription department, at 781-449-9780, to order the CD-ROM).

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### References