Talar Neck Fractures: Results and Outcomes

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TALAR NECK FRACTURES: RESULTS AND OUTCOMES

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Background: Talar neck fractures occur infrequently and have been associated with high complication rates. The purposes of the present study were to evaluate the rates of early and late complications after operative treatment of talar neck fractures, to ascertain the effect of surgical delay on the development of osteonecrosis, and to determine the functional outcomes after operative treatment of such fractures.

Methods: We retrospectively reviewed the records of 100 patients with 102 fractures of the talar neck who had been managed at a level-1 trauma center. All fractures had been treated with open reduction and internal fixation. Sixty fractures were evaluated at an average of thirty-six months (range, twelve to seventy-four months) after surgery. Complications and secondary procedures were reviewed, and radiographic evidence of osteonecrosis and posttraumatic arthritis was evaluated. The Foot Function Index and Musculoskeletal Function Assessment questionnaires were administered.

Results: Radiographic evidence of osteonecrosis was seen in nineteen (49%) of the thirty-nine patients with complete radiographic data. However, seven (37%) of these nineteen patients demonstrated revascularization of the talar dome without collapse. Overall, osteonecrosis with collapse of the dome occurred in twelve (31%) of thirty-nine patients. Osteonecrosis was seen in association with nine (39%) of twenty-three Hawkins group-II fractures and nine (64%) of fourteen Hawkins group-III fractures. The mean time to fixation was 3.4 days for patients who had development of osteonecrosis, compared with 5.0 days for patients who did not have development of osteonecrosis. With the numbers available, no correlation could be identified between surgical delay and the development of osteonecrosis. Osteonecrosis was associated with comminution of the talar neck ($p < 0.03$) and open fracture ($p < 0.05$). Twenty-one (54%) of thirty-nine patients had development of posttraumatic arthritis, which was more common after comminuted fractures ($p < 0.07$) and open fractures ($p = 0.09$). Patients with comminuted fractures also had worse functional outcome scores.

Conclusions: Fractures of the talar neck are associated with high rates of morbidity and complications. Although the numbers in the present series were small, no correlation was found between the timing of fixation and the development of osteonecrosis. Osteonecrosis was associated with talar neck comminution and open fractures, confirming that higher-energy injuries are associated with more complications and a worse prognosis. This finding was strengthened by the poor Foot Function Index and Musculoskeletal Function Assessment scores in these patients. We recommend urgent reduction of dislocations and treatment of open injuries. Proceeding with definitive rigid internal fixation of talar neck fractures after soft-tissue swelling has subsided may minimize soft-tissue complications.

Level of Evidence: Prognostic study, Level II-1 (retrospective study). See Instructions to Authors for a complete description of levels of evidence.

Talar neck fractures occur infrequently. Such fractures typically are the result of high-energy trauma and are characterized by displacement, comminution, and soft-tissue injury. These features have an impact on treatment and may have a negative effect on the result. In addition, associated noncontiguous skeletal injuries and/or systemic trauma may delay the diagnosis or definitive care of the talar neck fracture. Urgent reduction and fixation of these fractures has been advocated to protect any remaining blood supply to the talar body and to promote revascularization[1-7]. The blood supply to the talus has been well characterized[8-10] and is primarily localized to the talar neck and the medial part of the talar body. Consequently, fractures of the talar neck that cause subluxation or dislocation of the talar body presumably compromise its blood supply. It has been suggested that initial fracture displacement and delayed fracture fixation are associ-

ated with an increased incidence of osteonecrosis[1,2,4,5,7,8,11-21].

Talar neck fractures often disrupt the congruity of the peritalar joints[22,23]. Restoration and preservation of anatomic alignment may limit the development of posttraumatic arthritis. Sequelae of posttraumatic arthritis and osteonecrosis have been described in previous reports on talar neck fractures[2,5,12,13,16,20,24-27]. These complications frequently have a devastating impact on overall function, cause chronic pain and stiffness, and often lead to secondary procedures[6,11,15,19-21]. The purposes of the present study were to characterize talar neck fractures, to evaluate the early and late complications of such fractures, and to present the functional outcomes after surgical treatment. We also attempted to assess the impact of surgical delay on the development of osteonecrosis and posttraumatic arthritis.

Materials and Methods

We retrospectively reviewed the records of 100 consecutive patients with 102 fractures of the talar neck (classification 72-A1 according to the system of the Orthopaedic Trauma Association[28]) who had been managed operatively at a level-1 trauma center over a sixty-seven-month period. Sixty male patients and forty female patients with an average age of 32.6 years (range, thirteen to seventy-seven years) and an average Injury Severity Score[29] of 15.8 points (range, 9 to 50 points) were identified. The mechanism of injury was a motor-vehicle accident for sixty patients, a fall from a height for twenty-seven, a motorcycle accident for seven, a pedestrian-motor vehicle accident for two, sports-related trauma for two, a plane crash for one, and an industrial accident for one.

Initially, patients were assessed and resuscitated according to Advanced Trauma Life-Support guidelines (American College of Surgeons, Chicago, Illinois). Sterile dressings were applied to open wounds, and intravenous antibiotics and tetanus prophylaxis were administered. Twenty-four fractures were open; of these, one was classified as type I, one was classified as type II, and twenty-two were classified as type IIIA according to the criteria of Gustilo and Anderson[30,31]. Plain radiographs of the foot and ankle were made in all cases. The fractures were classified into groups as described by Hawkins[14] and modified by Canale and Kelly[13]. Four fractures were minimally displaced (group I), sixty-eight were associated with subluxation or dislocation of the subtalar joint (group II), twenty-five were associated with dislocation of the tibiotalar joint (group III), and five were associated with dislocation of the tibiotalar, subtalar, and talonavicular joints (group IV). Twenty-three patients had a contiguous talar body fracture and/or fracture extension, and twenty had an associated lateral talar process fracture. Forty-four patients had additional ipsilateral foot and ankle injuries, and twenty-six had contralateral foot and ankle injuries. Comminution was defined on plain radiographs as a talar neck fracture with more than three fracture fragments.

Although closed, manipulative reduction was attempted at the time of the initial assessment, all fractures subsequently were treated with open reduction and internal fixation with stainless steel small-fragment and/or mini-fragment implants. An attempt was made to perform surgery on an urgent basis. However, associated life-threatening injuries or a delay in diagnosis or presentation to our hospital precluded urgent treatment in some cases. Dual anteromedial and anterolateral surgical approaches were used for ninety-one fractures (Figs. 1-A through 1-D)[17]. The remaining fractures were treated through a single medial approach (eight fractures) or a single lateral approach (three fractures). Eight patients also had an osteotomy of the medial malleolus to enhance the surgical exposure. Six of these osteotomies were performed in patients who had associated fracture extensions involving the talar body.

Postoperative management consisted of immobilization of the ankle in neutral alignment until the wounds were sealed and the swelling had diminished. Range-of-motion exercises for the ankle and foot were then initiated. No weight-bearing on the affected limb was recommended for a total of twelve weeks after surgery or until fracture union had occurred. Progressive weight-bearing, however, was not delayed by radiographic evidence of osteonecrosis. Plain radiographs of the lateral aspects of the foot and ankle, ankle mortise radiographs, and Canale[13] radiographs were made after fixation and at approximately six-week, twelve-week, six-month, and twelve-month intervals postoperatively. Computerized tomography was not used to assess fractures preoperatively or to evaluate alignment postoperatively. Osteonecrosis was defined on plain radiographs as any area of increased density of the talar dome relative to the adjacent structures. Magnetic resonance imaging was not routinely used to diagnose osteonecrosis or to follow its progression. Posttraumatic arthritis was defined as any loss of joint space, formation of osteophytes, or development of subchondral sclerosis or cysts.

Functional outcome measurements included the Foot Function Index (FFI) and the Musculoskeletal Function Assessment (MFA). These measurements were collected at the most recent clinic visit or by means of a questionnaire that was administered over the phone or by mail. The FFI is a specific lower-extremity outcome index consisting of scores for pain (81 points), disability (81 points), and activity (45 points)[32]. The total score is the average of these three scores, with higher scores indicating greater impairment of function. The MFA is a general-health-status outcome index consisting of ten categories, from which a total score can be calculated[33]. MFA values range from 0 to 100, with higher scores indicating a lower level of overall function. Both the FFI and MFA instruments have been determined to be valid, reliable, and consistent[32-36]. The FFI has been validated for the evaluation of individuals with systemic arthritis and measures activity specific to the foot and ankle in individuals with a low level of function. The MFA has been validated for the evaluation of trauma patients with greater activity levels but includes the entire musculoskeletal system.

Statistical analysis was performed with the SAS statistical package (SAS Institute, Cary, North Carolina). The possible predictive variables included the type of fracture (open or closed), fracture comminution, Hawkins' classification, and

age (less than forty years or forty years or more). The clinical outcomes included osteonecrosis, collapse of the talar dome, and arthritis of the tibiotalar or subtalar joint. Bivariate analysis and Fisher's exact test were used to test the association between the possible predictive variables and these clinical outcomes. With use of chi-square analysis, the timing of fixation was analyzed as a continuous variable (within six hours, eight hours, twelve hours, twenty-four hours, or more than twenty-four hours) to test the association between surgical timing and osteonecrosis. The Student t test was used to identify the associations between the functional outcomes (as indicated by the FFI and MFA scores) and the possible predictive variables as well as to identify the associations between functional and clinical outcomes.

Results

Forty-one patients with forty-two fractures were unavailable for follow-up. Two patients died of unrelated causes, two patients had severe closed head injuries and were unable to walk or to communicate, one patient was in jail, one patient did not speak English, and thirty-five patients could not be located. Seventeen of the thirty-five patients who could not be located had been followed for six to twelve months, and none of them had had any clinical problems or symptomatic radiographic abnormalities at the time of the most recent follow-up. The remaining fifty-nine patients (sixty fractures) were evaluated at an average of thirty-six months (range, twelve to seventy-four months) after surgery. Forty-five of these patients had complete functional outcome data, and thirty-nine had complete radiographic data. Six of the sixty fractures were associated with early complications (Table I). Two patients had development of a superficial infection, and one had partial medial wound dehiscence. These three patients were successfully managed with oral antibiotics and dressing changes. Another patient with wound dehiscence had development of a deep wound infection that required serial irrigation and débridement and intravenous administration of antibiotics. After two years, there had been no recurrence

TABLE I Incidence of Early and Late Complications After Open Reduction and Internal Fixation of Talar Neck Fractures

	Incidence
Superficial infection	3.3% (2 of 60)
Wound dehiscence	3.3% (2 of 60)
Deep infection	5.0% (3 of 60)
Delayed union	1.7% (1 of 60)
Nonunion	3.3% (2 of 60)
Osteonecrosis and dome collapse	31% (12 of 39)
Ankle osteoarthritis	18% (7 of 39)
Subtalar osteoarthritis	15% (6 of 39)

Fig. 1-A

Fig. 1-B

Figs. 1-A through 1-D A twenty-one-year-old man who sustained a Hawkins' Group-III talar neck fracture with associated tibiotalar and subtalar dislocations in a motor-vehicle accident. **Figs. 1-A and 1-B** Preoperative anteroposterior (Fig. 1-A) and lateral (Fig. 1-B) radiographs.

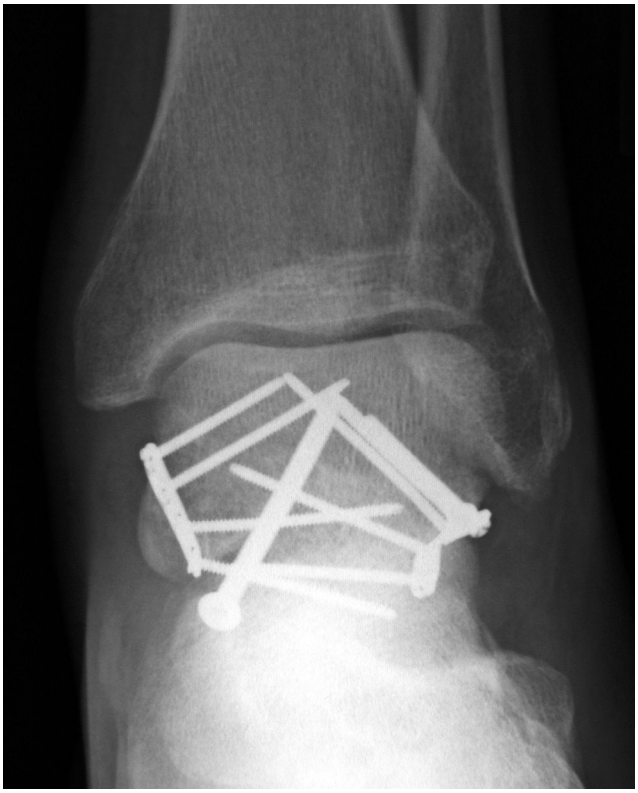

Fig. 1-C

Fig. 1-D

Figs. 1-C and 1-D Anteroposterior (Fig. 1-C) and lateral (Fig. 1-D) radiographs made after open reduction and internal fixation through anteromedial and anterolateral approaches.

of infection. Two other patients had development of a deep infection within the first three months postoperatively. Both of these patients underwent serial irrigation and débridement procedures, and both were managed with intravenous administration of antibiotics for several weeks. Neither patient had had a recurrence of infection at the time of the most recent follow-up.

Three of the sixty fractures did not demonstrate radiographic evidence of union within the first three months. One of the patients with a deep infection had development of a nonunion. This patient also had osteonecrosis of the talar dome, which progressed to collapse. The talar fracture united following a subtalar arthrodesis and revision of fixation. One other nonunion united successfully three months after iliac-crest bone-grafting. One patient had a delayed union and was followed with plain radiographs until fracture union occurred at twenty-four weeks after surgery.

Radiographic evidence of osteonecrosis was identified in nineteen (49%) of thirty-nine patients. Osteonecrosis occurred within the first ten months after the injury (at a mean of nineteen weeks) in all cases. Osteonecrosis was seen in association with nine (39%) of twenty-three Hawkins' II fractures (five of which progressed to collapse of the talar dome), nine (64%) of fourteen Hawkins' III fractures (six of which progressed to collapse), and one Hawkins' IV fracture (which progressed to collapse). Overall, osteonecrosis with collapse of the talar dome occurred in twelve (31%) of thirty-nine patients. Collapse occurred at a mean of thirty-nine weeks (range, twenty-six to sixty-five weeks) after osteonecrosis was detected on plain radiographs. Seven (37%) of the nineteen patients with osteonecrosis demonstrated revascularization of the talar dome on plain radiographs with no evidence of collapse. Revascularization occurred an average of thirty-five weeks (range, twenty-five to sixty-five weeks) postoperatively. All of these patients were followed for at least eighteen months after the return of normal bone density. None of them demonstrated subsequent evidence of osteonecrosis or collapse.

The average time from injury to fixation was 3.7 days (range, four hours to forty-eight days). With the numbers available, chi-square analysis of fixation within six hours, eight hours, twelve hours, twenty-four hours, or more than twenty-four hours did not demonstrate a correlation between surgical delay and the development of osteonecrosis or collapse. The mean time from injury to fixation was 3.4 days (range, four hours to twenty days) for patients who had development of osteonecrosis and 5.0 days (range, four hours to forty-eight days) for those who did not (Figs. 2-A, 2-B, and 2-C). The mean time between injury and fixation was 12.9 hours for patients who had development of osteonecrosis and 13.0 hours for those who did not. Time was also analyzed as a continuous variable and, with the small numbers available, no correlation was observed between the timing of surgery

Fig. 2-A

Fig. 2-B

Figs. 2-A, 2-B, and 2-C A thirty-eight-year-old man who sustained a talar neck fracture with dislocation of the subtalar joint in a motorcycle accident. The patient presented to our hospital more than twelve hours after the injury with severe soft-tissue swelling and fracture blisters. **Fig. 2-A** Lateral radiograph made at the time of presentation. **Fig. 2-B** Lateral radiograph made after closed reduction, which was facilitated with percutaneous insertion of a calcaneal pin. Seventeen days later, after some improvement in the soft-tissue injury, the patient underwent open reduction and internal fixation.

and the development of osteonecrosis with or without collapse. This test was performed on the entire group of patients and was repeated for just those patients who had received fixation within twenty-four hours.

Osteonecrosis occurred in eighteen of thirty-one patients with comminution of the talar neck ($p < 0.03$). Twelve of these eighteen patients had collapse of the talar dome; a significant association was noted between comminution of the talar neck and osteonecrosis with collapse ($p = 0.02$). Nine of thirteen patients with an open fracture also had development of osteonecrosis; osteonecrosis occurred significantly more frequently in patients with open fractures than in patients with closed fractures ($p < 0.05$). Eight of nine patients who had an open fracture with development of osteonecrosis had progression to collapse of the talar dome ($p < 0.02$). With the numbers available, neither osteonecrosis nor collapse was associated with the age of the patient, Hawkins' classification, or the presence of an associated talar body fracture. However, our data showed a trend toward increased rates of osteonecrosis and collapse in association with greater initial fracture displacement according to Hawkins' classification.

Twenty-one (54%) of thirty-nine patients had radiographic findings consistent with posttraumatic arthritis of the ankle joint and/or the subtalar joint. End-stage arthritis with complete loss of the joint space was identified in the subtalar joint of six patients and in the ankle joint of seven patients. Six of twenty-three patients with Hawkins' II fractures and six of fourteen patients with Hawkins' III fractures

Fig. 2-C

Anteroposterior radiograph, made nineteen months postoperatively, demonstrating a viable talar dome without evidence of osteonecrosis or collapse.

TABLE II Mean Foot Function Index and Musculoskeletal Function Assessment Scores

	Foot Function Index Scores*				Musculoskeletal Function Assessment Score*
	Pain	Activity	Disability	Total	
Comminution					
No	13.3	11.4	25.3	16.7	11.2
Yes	24.6	22.4	36.4	27.8	26.9
P value	0.02†	<0.05†	0.14	<0.03†	0.03†
Type of fracture					
Closed	21.0	18.3	32.2	23.9	25.3
Open	27.6	26.5	40.9	31.7	21.8
P value	0.24	0.19	0.28	0.15	0.60
Hawkins classification					
Group II	24.5	20.3	32.7	25.9	19.9
Group III	26.4	19.8	37.3	27.8	18.7

*The mean scores according to the Foot Function Index and Musculoskeletal Function Assessment questionnaires were calculated on the basis of the presence of talar neck comminution, the presence of an open fracture, and the Hawkins' classification. †Significant.

had end-stage arthritis involving one or both of these joints. Trends were observed toward an association between posttraumatic arthritis and a history of open fracture (nine of thirteen patients, $p = 0.09$) and between posttraumatic arthritis and talar neck comminution (nineteen of thirty-one patients, $p < 0.07$).

Seventeen patients underwent twenty-five secondary procedures. Eleven patients had removal of symptomatic hardware. Five patients had an isolated subtalar arthrodesis because of severe posttraumatic arthritis. One patient had a Blair tibiotalar arthrodesis twelve months after the injury because of symptomatic osteonecrosis and collapse. Another patient underwent a Blair arthrodesis thirteen months after the injury and achieved partial relief of symptoms. Several months later, she underwent a subtalar arthrodesis that was complicated by nonunion. She recently had a revision of the subtalar arthrodesis. Another patient had a subtalar arthrodesis for the relief of end-stage subtalar arthritis. The ankle arthritis subsequently progressed, and the patient underwent total ankle arthroplasty, with relief of pain. Another patient underwent total ankle arthroplasty twenty-one months after the injury. Subsequently, she reported no ankle or foot pain. Two other patients had a triple arthrodesis. These procedures were performed twelve and thirteen months after the injury. Both of these patients had continued pain and limitation because of tibiotalar arthritis. At the time of the most recent follow-up, at least three other patients were considering secondary procedures for pain relief.

Of the forty-five patients who completed functional outcome questionnaires, thirty-two (71%) had returned to work. Five were employed in jobs involving heavy construction or industrial work. Six patients who had returned to work had modified their work duties because of the injury. Two patients had been unemployed before the talar fracture, and one of them was working at the time of the most recent follow-up. The other patient was not employed outside of the home; however, he reported that he did not feel limited by the injury. Two women who were more than sixty-five years of age had not been employed before the talar fracture. Both of them reported that they felt severely limited because of the foot injury. Eleven patients never returned to any form of employment. One of these patients was not capable of working because of a severe closed head injury that had been sustained during the same accident.

Functional outcomes were assessed with the Foot Function Index (FFI) and Musculoskeletal Function Assessment (MFA) questionnaires (Table II). The FFI specifically addresses the foot and ankle, and the MFA is a general-health-status index. Reference FFI values have been published previously for patients without foot or ankle pathology[34,35]. Comparison of the mean FFI scores for our patients with these reference values (pain, 25.3 compared with 11; disability, 34.4 compared with 15; and activity, 20.1 compared with 10) indicated increased impairment after talar neck fracture. Worse outcomes were noted in association with comminuted fractures ($p < 0.03$). With the numbers available, the age of the patient, Hawkins' classification, and the presence of associated talar body fractures did not have an effect on the FFI scores.

Similarly, the mean standardized MFA score in our series was 24.6. Comparison of the mean score for our patients with published reference values for uninjured patients (9.3), patients with hindfoot injuries (22.1), and patients with ankle or leg injuries (19.3) suggested a greater level of disability after talar neck fracture ($p < 0.001$)[36,37]. Fracture comminution adversely affected the MFA score ($p = 0.03$). However, with the numbers available, the age of the patient, the Hawkins classification, a history of open fracture, and extension of the

fracture into the talar body had no discernable effect on the MFA score.

Discussion

Fractures of the talar neck have been associated with high rates of early and late complications[2,4-6,12,13,16,20,21,24-27,38]. The high-energy nature of the majority of these injuries produces not only fracture displacement and comminution but also severe soft-tissue damage, frequently in association with open wounds. These characteristics often portend a poor prognosis. Early complications such as skin necrosis, wound dehiscence, and infection have occurred in as many as 77% of cases[14,16,38]. Reports of late problems such as osteonecrosis, posttraumatic arthritis, and osteomyelitis with associated stiffness, pain, and loss of function also have been common[2,5,12,13,16,20,24-27]. Treatment strategies initially evolved from reduction and immobilization[6,24,26,27] to limited, often temporary, fixation[14,16,27,38]. Currently, open reduction and internal fixation is performed for most talar neck fractures[1,3-5,7,11,12,15,17,18,20,39]. The goals of surgical treatment have been to restore overall alignment of the talus in order to maximize function of the limb.

Surgical treatment is necessary to restore and to maintain alignment after a displaced talar neck fracture. Most fractures are associated with some subluxation or dislocation of the talar body. As direct exposure permits accurate reduction in these cases, we advocate dual anteromedial and anterolateral approaches for most talar neck fractures[1,3,7,11,17]. An adjunctive osteotomy of the medial malleolus may be performed to enhance visualization of the talar body[40]. The anterolateral exposure, along with intraoperative radiographs, greatly aids in establishing an anatomic reduction. The Canale view[13] is particularly helpful for assessing deformity. Medial comminution of the talar neck may otherwise be underestimated, and varus malalignment can result[22,23]. Once an accurate reduction has been achieved, strategic, rigid internal fixation with plates and/or screws usually will provide adequate stability to permit early mobilization of the adjacent joints[3], which may reduce ankle and foot stiffness and may maximize overall function[2,5,7]. The effect of dual surgical approaches on the blood supply of the talus is unknown. It is possible that this technique could further compromise the vascularity of fracture fragments or that of the talar body. As 91% of the patients in the present study had both anteromedial and anterolateral surgical approaches, we could not assess whether this method has an advantage compared with other surgical techniques in terms of vascular compromise.

Osteonecrosis occurs frequently after talar neck fractures. It also has been proposed that surgical treatment may promote revascularization of the talar body[1-7]. Hawkins developed a classification scheme that was based on the fracture displacement that is observed on the initial plain radiographs[14]. He also provided treatment recommendations and presented prognostic information that was based on this classification system. In his study, osteonecrosis was identified in no Group-I patients, in 42% of Group-II patients, and in 91% of Group-III patients. Canale and Kelly later modified this classification scheme, describing a fourth type of talar neck fracture with associated talonavicular dislocation[13]. Studies in the literature to date have demonstrated the occurrence of osteonecrosis in association with as many as 13% of Hawkins' I fractures, as many as 50% of Hawkins' II fractures, as many as 84% of Hawkins' III fractures, and as many as 100% of Hawkins' IV fractures[2-4,18,25,38]. Our data showed a trend toward an increased rate of osteonecrosis in association with greater initial fracture displacement as described with Hawkins' classification. Comminution of the talar neck and open fractures were associated with an increased risk of osteonecrosis in our study.

Some authors have advocated the use of protected weight-bearing to reduce the possibility of collapse of the talar dome in patients with osteonecrosis[1,6,13,16,18,24,27]. This recommendation remains controversial, however, and other authors have recommended the progression of weight-bearing regardless of the presence of osteonecrosis[14,25,38]. We agree that once fracture union has been achieved, weight-bearing as tolerated may be started. In the present study, 37% of the patients with radiographic evidence of osteonecrosis showed a return to normal talar dome density on plain radiographs. No collapse of the talar dome was detected in these patients despite weight-bearing as tolerated without bracing. Thus, we believe that the effect of weight-bearing on the progression of osteonecrosis remains unknown. Additional studies are needed to resolve this issue.

Talar neck fractures often are treated urgently to reduce the risk of osteonecrosis[1,4-7,20] because urgent reduction of dislocations may help to preserve any remaining blood supply to the posterior portion of the talus. However, to our knowledge, surgical timing has not been previously shown to impact the development of osteonecrosis. Although the numbers in the present study were small, no correlation was found between the timing of reduction and fixation and the development of osteonecrosis. Because we did not have consistent information about the duration of dislocation in our patients, we were unable to determine the impact of prolonged dislocation on the development of osteonecrosis. Other characteristics of the initial injury and its treatment, such as the presence of comminution or an open fracture, may have a greater influence on whether or not osteonecrosis will occur[7,12].

We advocate urgent fracture reduction through either closed or percutaneous manipulation, and we recommend resorting to open reduction only when the fracture is not reducible through closed means. Once a reduction of the talar neck fracture has been achieved, we speculate that a delay in fixation of the fracture will not affect the development of osteonecrosis. In some cases, internal fixation cannot be safely undertaken on an urgent basis. This may be because of life-threatening trauma or because of severe soft-tissue damage and swelling of the ankle and foot. It has been suggested that a surgical delay will allow improvement in the associated soft-tissue injury and will decrease the rates of wound complications and infection after fractures of the

tibial plafond or calcaneus[41-46]. Previous reports have demonstrated skin necrosis, wound dehiscence, and infection in association with as many as 77% of talar neck fractures[14,16,38]. Perhaps these complications could be minimized by achieving a closed reduction but delaying definitive fixation in order to allow for improvement in the soft-tissue injury before proceeding with the dual surgical approach that we favor.

In conclusion, it has been suggested that early operative intervention protects the already tenuous blood supply to the posterior portion of the talus after a fracture of the talar neck. Although the numbers in this series were small, no correlation was found between the timing of fixation and the development of osteonecrosis. Osteonecrosis was associated with talar neck comminution and open fractures, confirming that higher-energy injuries are associated with more complications and a worse prognosis. This concept is further strengthened by the poor FFI and MFA scores in patients with comminuted fractures. We continue to recommend urgent treatment of open injuries and reduction of dislocations. Proceeding with definitive fixation when there is minimal soft-tissue swelling will provide rigid fracture stability to promote fracture-healing and to achieve an earlier return to weight-bearing function. ■

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References

1. **Berlet GC, Lee TH, Massa EG.** Talar neck fractures. *Orthop Clin North Am.* 2001;32:53-64.
2. **Elgafy H, Ebraheim NA, Tile M, Stephen D, Kase J.** Fractures of the talus: experience of two level 1 trauma centers. *Foot Ankle Int*. 2000;21: 1023-9.
3. **Fleuriau Chateau PB, Brokaw DS, Jelen BA, Scheid DK, Weber TG.** Plate fixation of talar neck fractures: preliminary review of a new technique in twenty-three patients. *J Orthop Trauma.* 2002;16:213-9.
4. **Frawley PA, Hart JA, Young DA.** Treatment outcome of major fractures of the talus. *Foot Ankle Int*. 1995;16:339-45.
5. **Inokuchi S, Ogawa K, Usami N, Hashimoto T.** Long-term follow up of talus fractures. *Orthopedics.* 1996;19:477-81.
6. **Mindell ER, Cisek EE, Kartalian G, Dziob JM.** Late results of injuries to the talus. Analysis of forty cases. *J Bone Joint Surg Am*. 1963;45:221-45.
7. **Smith PN, Ziran BH.** Fractures of the talus. *Operative Tech Orthop*. 1999; 9:229-38.
8. **Gelberman RH, Mortensen WW.** The arterial anatomy of the talus. *Foot Ankle.* 1983;4:64-72.
9. **Haliburton RA, Sullivan CR, Kelly PJ, Peterson LF.** The extra-osseous and intra-osseous blood supply of the talus. *J Bone Joint Surg Am*. 1958;40: 1115-20.
10. **Mulfinger GL, Trueta J.** The blood supply of the talus. *J Bone Joint Surg Br.* 1970;52:160-7.
11. **Archdeacon M, Wilber R.** Fractures of the talar neck. *Orthop Clin North Am.* 2002;33:247-62.
12. **Canale ST.** Fractures of the neck of the talus. *Orthopedics.* 1990;13: 1105-15.
13. **Canale ST, Kelly FB Jr.** Fractures of the neck of the talus. Long-term evaluation of seventy-one cases. *J Bone Joint Surg Am.* 1978;60:143-56.
14. **Hawkins LG.** Fractures of the neck of the talus. *J Bone Joint Surg Am*. 1970; 52:991-1002.
15. **Higgins TF, Baumgaertner MR.** Diagnosis and treatment of fractures of the talus: a comprehensive review of the literature. *Foot Ankle Int*. 1999;20: 595-605.
16. **Kenwright J, Taylor RG.** Major injuries of the talus. *J Bone Joint Surg Br.* 1970;52:36-48.
17. **Mayo KA.** Fractures of the talus: principles of management and techniques of treatment. *Tech Orthop.* 1987;2:42-54.
18. **Pajenda G, Vecsei V, Reddy B, Heinz T.** Treatment of talar neck fractures: clinical results of 50 patients. *J Foot Ankle Surg.* 2000;39:365-75.
19. **Santavirta S, Seitsalo S, Kiviluoto O, Myllynen P.** Fractures of the talus. *J Trauma*. 1984;24:986-9.
20. **Schulze W, Richter J, Russe O, Ingelfinger P, Muhr G.** Surgical treatment of talus fractures: a retrospective study of 80 cases followed for 1-15 years. *Acta Orthop Scand*. 2002;73:344-51.
21. **Szyszkowitz R, Reschauer R, Seggl W.** Eighty-five talus fractures treated by ORIF with five to eight years of follow-up study of 69 patients. *Clin Orthop*. 1985;199:97-107.
22. **Daniels TR, Smith JW, Ross TI.** Varus malalignment of the talar neck. Its effect on the position of the foot and on subtalar motion. *J Bone Joint Surg Am*. 1996;78:1559-67.
23. **Sangeorzan BJ, Wagner UA, Harrington RM, Tencer AF.** Contact characteristics of the subtalar joint: the effect of talar neck misalignment. *J Orthop Res*. 1992;10:544-51.
24. **Coltart WD.** Aviator's astragalus. *J Bone Joint Surg Br.* 1952;34:545-66.
25. **Grob D, Simpson LA, Weber BG, Bray T.** Operative treatment of displaced talus fractures. *Clin Orthop*. 1985;199:88-96.
26. **Kleiger B.** Fractures of the talus. *J Bone Joint Surg Am*. 1948;30:735-44.
27. **Pennal GF.** Fractures of the talus. *Clin Orthop*. 1963;30:53-63.
28. **Orthopaedic Trauma Association Committee for Coding and Classification.** Fracture and dislocation compendium. *J Orthop Trauma*. 1996;10(Suppl 1): v-ix,1-154.
29. **Baker SP, O'Neill B, Haddon W Jr, Long WB.** The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. *J Trauma*. 1974;14:187-96.
30. **Gustilo RB, Anderson JT.** Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: retrospective and prospective analyses. *J Bone Joint Surg Am*. 1976;58:453-8.
31. **Gustilo RB, Mendoza RM, Williams DN.** Problems in the management of type III (severe) open fractures: a new classification of type III open fractures. *J Trauma*. 1984;24:742-6.
32. **Budiman-Mak E, Conrad KJ, Roach KE.** The Foot Function Index: a measure of foot pain and disability. *J Clin Epidemiol.* 1991;44:561-70.
33. **Martin DP, Engelberg R, Agel J, Snapp D, Swiontkowski MF.** Development of a musculoskeletal extremity health status instrument: the Musculoskeletal Function Assessment instrument. *J Orthop Res.* 1996;14:173-81.
34. **Coester LM, Saltzman CL, Leupold J, Pontarelli W.** Long-term results follow-

ing ankle arthrodesis for post-traumatic arthritis. *J Bone Joint Surg Am.* 2001;83:219-28.

35. **Domsic RT, Saltzman CL.** Ankle osteoarthritis scale. *Foot Ankle Int.* 1998; 19:466-71.
36. **Engelberg R, Martin DP, Agel J, Obremsky W, Coronado G, Swiontkowski MF.** Musculoskeletal Function Assessment instrument: criterion and construct validity. *J Orthop Res.* 1996;14:182-92.
37. **Engelberg R, Martin DP, Agel J, Swiontkowski MF.** Musculoskeletal Function Assessment: reference values for patient and non-patient samples. *J Orthop Res.* 1999;17:101-9.
38. **Gilquist J, Oretop N, Stenstrom A, Rieger A, Wennberg E.** Late results after vertical fracture of the talus. *Injury.* 1974;6:173-9.
39. **Sangeorzan BJ, Mayo KA, Hansen ST.** Intraarticular fractures of the foot. Talus and lesser tarsals. *Clin Orthop.* 1993;292:135-41.
40. **Ziran BH, Abidi NA, Scheel MJ.** Medial malleolar osteotomy for exposure of complex talar body fractures. *J Orthop Trauma.* 2001;15:513-8.
41. **Barei DP, Bellabarba C, Sangeorzan BJ, Benirschke SK.** Fractures of the calcaneus. *Orthop Clin North Am*. 2002;33:263-85.
42. **Egol KA, Wolinsky P, Koval KJ.** Open reduction and internal fixation of tibial pilon fractures. *Foot Ankle Clin*. 2000;5:873-85.
43. **Folk JW, Starr AJ, Early JS.** Early wound complications of operative treatment of calcaneus fractures: analysis of 190 fractures. *J Orthop Trauma.* 1999; 13:369-72.
44. **Patterson MJ, Cole JD.** Two-staged delayed open reduction and internal fixation of severe pilon fractures. *J Orthop Trauma.* 1999;13:85-91.
45. **Sirkin M, Sanders R, DiPasquale T, Herscovici D Jr.** A staged protocol for soft tissue management in the treatment of complex pilon fractures. *J Orthop Trauma.* 1999;13:78-84.
46. **Sirkin M, Sanders R.** The treatment of pilon fractures. *Orthop Clin North Am.* 2001;32:91-102.