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Evaluation of the functional and radiologic outcomes in talus fractures following surgery

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Abstract. – OBJECTIVE: The long-term outcome of talus fractures is not yet sufficiently favorable despite improved resources and growing experience. With increasing fracture severity, the complication rate increases. This study aimed to evaluate the mid-to-long-term clinical and radiologic outcomes using the scoring system and imaging archive in patients with talus fractures who were surgically treated in our hospital.

PATIENTS AND METHODS: The mid- to long-term outcomes of patients with talus fractures admitted to Aydın Adnan Menderes University Faculty of Medicine Hospital between January 2010 and December 2020 and treated surgically were analyzed using satisfaction and functional scoring systems.

RESULTS: Demographic data of the patients enrolled in our study indicated that talus fractures primarily developed in young males ($p<0.05$). The scores obtained from American Orthopaedic Foot & Ankle Society (AOFAS) scoring were consistent with patients' long-term consequences, such as avascular necrosis and post-traumatic arthritis ($p<0.05$). The rates of avascular necrosis and post-traumatic arthritis were lower, whereas AOFAS scores were higher in patients in whom the reduction quality was within the exact anatomical limits ($p<0.05$). The Hawkins sign had a positive predictive significance in patients free of avascular necrosis ($p<0.05$). Higher AOFAS scores were observed in patients treated with a single surgical incision ($p<0.05$). The timing of the surgery did not influence the results ($p>0.05$).

CONCLUSIONS: The outcomes of patients treated surgically for talus fracture depended on the quality of reduction. In the mid-to-long term, the satisfaction scores of our patients with talus fractures who had undergone surgical treatment were rated as moderate.

Key Words:
Talar fractures, Avascular necrosis, Post-traumatic arthritis, Reduction quality, Long-term outcome.

Introduction

Although its fracture is rare, the talus is the second most commonly fractured bone in the foot. Talus fractures represent 2% of lower extremity injuries and 5-8% of foot injuries. They present with a frequently complicated post-traumatic healing. Due to its relatively poor blood supply and articulation with multiple bones, complications such as post-traumatic arthritis (PTA), deformities, and avascular necrosis (AVN) are typical in talus fractures[1,2]. Moreover, the long-term results of talus fractures are not yet sufficiently favorable despite improved resources and growing experience. With increasing fracture severity, the complication rate increases proportionally[3]. Factors such as the type of fracture, presence of a dislocation, soft tissue injury, surgical technique, and physiotherapy play a role in long-term outcomes.

Various scoring systems have been reported to evaluate the patient's status regarding return to work, pain, and a plantigrade foot with full plantar landing. These scoring systems are essential for presenting the patients' final status in quantitative data[4-6].

This study aimed to evaluate the mid- to long-term clinical and radiologic outcomes using the scoring system and imaging archive in patients with talus fractures who were surgically treated in our hospital.

Patients and Methods

The present study was retrospectively designed, and approval was granted by the Aydın Adnan Menderes University Clinical Research and Ethics Committee's decision, dated 14.02.2022 (#137285). Patient information was accessed through our hospital's informatics records.

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Patients

Patients with a talus fracture admitted to Aydın Adnan Menderes University Faculty of Medicine Hospital documented between January 2010 and December 2020 were reviewed, and data of 49 patients with talus fractures were retrieved. The study population comprised patients with a talus fracture in all age groups who had surgical treatment indications, underwent open reduction and internal fixation, and had at least one year of follow-up after surgery. Patients who had undergone percutaneous fixation for talus fracture and who were treated conservatively were excluded.

Preoperative radiologic tests and emergency interventions at the time of admission were analyzed. The duration until definitive surgery and the recorded follow-up service results during this period were investigated. The incisions preferred for definitive surgery, the surgical duration and the fixation method for the fracture were obtained from the operative records. X-rays taken on the first postoperative day and other imaging findings obtained in outpatient settings for routine follow-up were analyzed. The weeks in which the patients attended the outpatient clinic were reviewed. Patient evaluation scores and consent forms were designed. Commonly used talus fracture classifications were evaluated, and a chart for patient examination parameters was prepared. Patients' contact information was confirmed, and they were invited to the clinic.

Patients were informed about our study and the American Orthopaedic Foot & Ankle Society (AOFAS) scoring system. They were told the study would be performed with their current physical examination findings, AOFAS scores, and imaging data. Then, their consent was obtained.

Demographic data of the enrolled patients, such as age, weight, height, smoking, and alcohol use, were recorded. Demographic characteristics except for age, the time to definitive surgery, and the follow-up duration of the patients were presented as the mean values. The median value was calculated for age.

Mechanisms of fractures were recorded and classified into five subgroups. The distribution of the mechanisms, such as motorcycle accidents, vehicular traffic accidents, high falls, low falls, and sprains, were determined.

The range of motion of the ankle joint and the foot posture on a flat surface were evaluated on physical examination. Due to the limited number of patients, two groups were established in this study as poor-moderate (<75) and good-excellent (≥75) regarding their AOFAS scores.

Clinical Procedural Algorithms in Patients with Talus Fractures

Preoperative assessment

Patients were admitted to the emergency department, and those with indications for emergency surgical intervention were identified. Patients with an open fracture or fracture-dislocation had a debridement-joint reduction and were followed up with an external fixator in the context of emergency surgical intervention. Other patients were followed up with a short leg splint, and definitive surgery was scheduled following the regression of soft tissue trauma findings. The "wrinkle sign" was frequently monitored to ensure surgical eligibility. Routine foot and ankle radiographs and computed tomography scans were acquired prior to definitive surgery. Patients with a joint displacement of 2 mm or more were considered for surgical indication. A plate and graft support was also considered for patients with a medial talus defect.

Intraoperative assessment

Patients were operated on in a supine position with a tourniquet pressure 2 folds of the systolic pressure. Single anterolateral, single anteromedial, or double incisions were utilized depending on the side of the fracture fragments. After accessing the fracture fragments, they were fixed with less than 2 mm displacement in the joint, prioritizing a total anatomical reduction. Graft and plate-screw support applications were utilized for the patients lacking continuity of the medial margin. Lateral edge reduction was monitored to ensure optimal alignment. The reduction was visualized with anteroposterior ankle radiographs, a Canale radiograph, and an intraoperative fluoroscopy. Patients were then hospitalized in the ward with a short leg splint.

Post-operative assessment

Foot and ankle radiographs of the patients were taken postoperatively, and they were called for wound site control on the 15th postoperative day. Radiographs were taken for early postoperative checks at 1, 2, 3, and 6 months. 1st and 3rd-year follow-ups were done with plain anteroposterior radiographs. Hawkins' sign was sought on plain anteroposterior radiographs between the 8th and 12th postoperative weeks. Patients with a com-

plaint of pain and a negative Hawkins sign were scheduled for an ankle MRI scan in addition to the routine procedures.

Statistical Analysis

The study data were analyzed using the SPSS 21 (IBM Corp., Armonk, NY, USA) statistical software package. The conformity of continuous variables to normal distribution was determined using visual (histogram and probability graphs) and analytical methods (Kolmogorov-Smirnov/Shapiro-Wilk tests). Descriptive statistics of the study were shown by using the mean and standard deviation for data conforming to the normal distribution, whereas median and minimum/maximum for data not conforming to the normal distribution. The Chi-Square test was used to determine whether there was a difference between the study's categorical variables. Student-*t*-test was used to compare continuous variables with parametric properties, whereas the Mann-Whitney U test compared continuous variables without parametric properties in independent groups. A *p*-value lower than 0.05 was considered for statistical significance.

Results

We obtained the information of 49 patients with talus fractures from our hospital records to be evaluated in our study. As 14 patients were treated conservatively and 3 surgically treated patients could not be reached from their registered contact information, 17 were excluded from the study. Thus, 32 surgically managed talus fracture patients were included in the study.

Demographics

Demographic data such as gender, age, height, body weight, body mass index, smoking, and alcohol use, together with surgical timing, follow-up duration, causes, types, and number of fractures in our surgically managed 32 patients with talar fractures, were presented in Table I.

Talar Fracture and its Relationship with the Presence of a Concomitant Fracture

When patients with talus fracture only and those with talus and concomitant fractures were compared regarding age, timing of surgery, the Hawkins sign, AOFAS score, number of surgical

Table I. Demographics such as gender, age, height, body weight, body mass index, smoking, and alcohol use, together with surgical timing, follow-up duration, causes, types, and number of fractures in surgically managed patients with talar fractures (total n=32).

Gender	
Male	29
Female	3
Age (years) [mean-(min-max)]	34.7 (15-67)
Height (cm) [mean-(min-max)]	173.1 (160-188)
Body weight (kg) [mean-(min-max)]	81.87 (58-110)
Body mass index [mean-(min-max)]	27.14 (20.0-40.4)
Active smokers (n)	14
Alcohol use	11
Timing of surgery (days) [mean-(min-max)]	10.4 (0-27)
Follow-up duration (months) [mean-(min-max)]	52 (14-102)
Cause of the fracture	
Falling from a height	15
Vehicular traffic accident	7
Motorcycle accident	7
Low fall	2
Sprain	1
Type of fracture	
Closed	27
Open	5
Number of fractures	
Talus only (n)	20
Talus + concomitant fractures (n)	12

incisions, and AVN development, no statistically significant difference was found ($p>0.05$).

When the relationships of the age parameter with talar neck and corpus fractures were evaluated based on the cut-off median age of the patients, which was 35.5 years, patients below this cut-off value had a statistically significantly higher neck fracture rate ($p=0.013$). In contrast, those over 35.5 years had a significantly higher corpus fracture rate ($p=0.033$).

Classifications of Talar Fractures

Of the 32 patients, 15 had neck fractures (Hawkins classification), 11 had corpus fractures, and 6 had peripheral process fractures (Marti-Weber classification). When the AOFAS score, Hawkins sign, and AVN variables were evaluated according to Hawkins classification, no statistically significant correlation was found in Hawkins subtypes regarding AOFAS score, Hawkins sign, and AVN development ($p>0.05$).

When the AOFAS score, Hawkins finding, age, and AVN variables were evaluated based on the Marti-Weber classification, it was found that Hawkins sign and AVN variables were statistically significantly different among the Marti-Weber subtypes. Those who did not develop AVN and had positive Hawkins signs were statistically significantly higher in the Type 1 group ($p=0.006$), and those who developed AVN and had negative Hawkins signs were statistically significantly higher in the Type 4 group ($p=0.008$) (Table II).

When the AOFAS score, Hawkins sign, and AVN variables were evaluated following the Sneppen classification, no statistically significant difference was found among the subtypes ($p>0.05$).

Hawkins Sign

The Hawkins sign was assessed in 31 of 32 patients. Early post-operative radiographs of one patient could not be obtained. In 18 patients, the Hawkins sign was positive, whereas in 13 patients, it was negative. Patients' sociodemographic data and the timing of surgery were compared between patients with positive and negative Hawkins signs, and the two groups were similar ($p>0.05$).

When the associations of the Hawkins sign with AOFAS score, post-traumatic arthritis (PTA), number of surgical incisions, reduction quality, and AVN development were investigated, it was observed that the AOFAS score was statistically significantly above 75 ($p=0.048$) and fracture reduction quality was good in the group with positive Hawkins sign ($p=0.007$). On the other hand, post-traumatic arthritis and AVN rates were higher in the Hawkins negative group ($p=0.000$ and $p=0.000$, respectively) (Table III).

Avascular Necrosis

Two patients without late follow-up were excluded, and 30 were analyzed for avascular necrosis (AVN). Of the 13 patients with AVN, nine had neck fractures, and four had corpus fractures. The mean AOFAS score of patients with AVN was 58.2, whereas that of patients without AVN was 77.6. The two patients who could not be evaluated for AVN were in the poor reduction group and developed post-traumatic arthritis in less than one year.

AVN associations with concomitant fractures and fractures at different locations (talar neck/corpus) were analyzed. A statistically significant relationship was determined between neck

Table II. Evaluation of the variables of AOFAS score, Hawkins sign, age, and avascular necrosis according to the Marti-Weber classification.

		Marti-Weber Classification				p
		Type 1	Type 2	Type 3	Type 4	
AOFAS score	**<75**	4 (50.00)	5 (62.50)	4 (36.36)	3 (75.00)	0.515
	≥75	4 (50.00)	3 (37.50)	7 (63.64)	1 (25.00)	
Hawkins sign	**Negative**	0 (.00)	5 (62.50)	4 (40.00)	4 (100.00)	**0.006**
	Positive	8 (100.00)	3 (37.50)	6 (60.00)	0 (.00)	
Age (median=35.5)	**<35.5**	3 (37.50)	4 (50.00)	6 (54.55)	3 (75.00)	0.668
	≥35.5	5 (62.50)	4 (50.00)	5 (45.45)	1 (25.00)	
Avascular necrosis	**Absent**	8 (100.00)	3 (42.86)	5 (50.00)	0 (.00)	**0.008**
	Present	0 (.00)	4 (57.14)	5 (50.00)	4 (100.00)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

Table III. Evaluation of the association of the Hawkins sign with AOFAS score, post-traumatic arthritis, number of surgical incisions, reduction quality, and avascular necrosis.

		Hawkins Sign		
		Negative	Positive	p
AOFAS Score	**<75**	9 (69.23)	6 (33.33)	**0.048**
	≥75	4 (30.77)	12 (66.67)	
Post-traumatic arthritis	Absent	2 (15.38)	15 (83.33)	**0.000**
	Present	11 (84.62)	3 (16.67)	
Number of surgical incisions	Single Incision	3 (23.08)	10 (58.82)	**0.050**
	Double Incision	10 (76.92)	7 (41.18)	
Reduction quality	Good	3 (23.08)	13 (72.22)	**0.007**
	Bad	10 (76.92)	5 (27.78)	
Avascular necrosis	Absent	0 (.00)	17 (94.44)	**0.000**
	Present	12 (100.00)	1 (5.56)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

fracture and AVN (p=0.03). On the other hand, there were no statistically significant associations of AVN with the presence of another concomitant fracture or a corpus fracture (p=0.88 and p=0.078, respectively).

When the associations of the talar fracture classifications with AVN prediction were analyzed, no statistically significant relationship was determined between the severity of the fracture and AVN in Hawkins and Sneppen classifications (p=0.36 and p=0.19, respectively). However, a statistically significant relationship was found between the fracture subtype and AVN in the Marti-Weber classification (p=0.008).

When examining the associations between AVN and various factors such as the Hawkins sign, AOFAS score, post-traumatic arthritis (PTA), and reduction quality, it was found that AVN did not occur in patients with a positive Hawkins sign (p=0.00), and it was less prevalent in patients with an AOFAS score ≥75 (p=0.03), while it was more likely to develop in patients with PTA (p=0.00). Regarding the effect of reduction quality on AVN development, it was found that AVN development was less in the good-quality reduction group than in the poor reduction group, with a statistically significant difference (p=0.004) (Table IV).

AOFAS Score

The overall mean AOFAS score was 67.7, with a minimum value of 25 and a maximum of 100. Furthermore, the mean AOFAS score of the neck fracture group was 68.5, whereas that of those with corpus fractures was 65. Sociodemographic

Table IV. The associations of avascular necrosis with Hawkins sign, AOFAS score, post-traumatic arthritis, and reduction quality.

		Avascular Necrosis		
		Absent	Present	p
Hawkins Sign	**Negative**	0 (.00)	12 (92.31)	**0.00**
	Positive	17 (100.00)	1 (7.69)	
AOFAS Score	**<75**	5 (29.41)	9 (69.23)	**0.03**
	≥75	12 (70.59)	4 (30.77)	
Post-traumatic arthritis	**Absent**	15 (88.24)	2 (15.38)	**0.00**
	Present	2 (11.76)	11 (84.62)	
Reduction quality	**Good**	13 (76.47)	3 (23.08)	**0.004**
	Poor	4 (23.53)	10 (76.92)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

and bone variables were compared between those with AOFAS scores below and above 75, revealing no statistically significant inter-group differences (age-p=0.286; smoking-p=0.476; alcohol use-p=0.710; concomitant fracture-p=0.465).

When the groups with AOFAS scores below 75 and above 75 were compared regarding the variables of reduction quality, number of surgical incisions, Hawkins sign, PTA, and AVN, it was found that there were statistically significant differences between the two groups for all variables. The proportion of patients with a good reduction quality and positive Hawkins sign was statistically significantly higher in the group with an AOFAS score above 75 (p=0.000 and p=0.048, respectively). Moreover, the proportion of patients with double surgical incisions, PTA, and AVN was statistically significantly higher in those with an AOFAS score below 75 (p=0.045, p=0.000, and p=0.030, respectively) (Table V).

Post-Traumatic Arthritis

Fifteen patients had post-traumatic arthritis (PTA). While six patients had isolated subtalar arthritis, six patients had combined subtalar and tibiotalar arthritis, two patients had tibiotalar arthritis, and two had talonavicular arthritis. The mean AOFAS score of the patient group with PTA was 53.4, whereas that of patients without PTA was 82.

Regarding the relationship between post-traumatic arthritis and age, AVN, reduction quality, and fractured bone variables, no statistically significant correlations of PTA with age and fractured bone variables were found (p=0.601 and p=0.647, respectively). On the other hand, PTA was found to have statistically significant associations with AVN and reduction quality variables. PTA was significantly more common in the presence of AVN and poor reduction quality (p=0.000 and p=0.000, respectively) (Table VI).

Table V. Comparison of patients with AOFAS scores below and above 75 regarding reduction quality, number of surgical incisions, Hawkins sign, post-traumatic arthritis, and avascular necrosis.

		AOFAS Score		
		<75	≥75	p
Reduction quality	**Good**	2 (12.50)	14 (87.50)	**0.000**
	Poor	14 (87.50)	2 (12.50)	
Number of surgical incisions	**Single-incision**	4 (26.67)	10 (62.50)	**0.045**
	Double incisions	11 (73.33)	6 (37.50)	
Hawkins Sign	**Negative**	9 (60.00)	4 (25.00)	**0.048**
	Positive	6 (40.00)	12 (75.00)	
Post-traumatic arthritis	**Absent**	3 (18.75)	14 (87.50)	**0.000**
	Present	13 (81.25)	2 (12.50)	
Avascular necrosis	**Absent**	5 (35.71)	12 (75.00)	**0.030**
	Present	9 (64.29)	4 (25.00)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

Table VI. Evaluation of the associations of post-traumatic arthritis with age, avascular necrosis, reduction quality, and fractured bone variables.

		Post-traumatic Arthritis		
		Absent	Present	p
Age		33.53±12.54	36.00±13.91	0.601
Avascular necrosis	**Absent**	15 (88.24)	2 (15.38)	**0.000**
	Present	2 (11.76)	11 (84.62)	
Fractured bone	**Talus only**	10 (58.82)	10 (66.67)	0.647
	Talus + concomitant fracture	7 (41.18)	5 (33.33)	
Reduction quality	**Good**	15 (88.24)	1 (6.67)	**0.000**
	Poor	2 (11.76)	14 (93.33)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

The Quality of the Reduction

The mean AOFAS score of the poor reduction group was 45.8. The reduction quality obtained was positively correlated with our clinical and radiologic results. Evaluation of the relationships of reduction quality with the variables of Hawkins sign, AVN, AOFAS score, post-traumatic arthritis, neck and corpus fractures revealed statistically significant positivity of Hawkins sign (p=0.007), absence of PTA (p=0.000), absence of AVN (p=0.004), and AOFAS scores of 75 and above (p=0.000) in those with good reduction quality. Moreover, better reduction results were statistically more common in patients with double surgical incisions (p=0.02). On the other hand, the presence of neck or corpus fractures had no statistically significant effect on the reduction results (Table VII).

Timing of Surgery

When the effects of the duration between the patient's presentation to the emergency service and the day of definitive surgical treatment on the development of avascular necrosis and post-traumatic arthritis and the final reduction quality were analyzed, no statistically significant effect of the time was determined on the presence of avascular necrosis (p=0.418), post-traumatic arthritis (p=0.738), and reduction quality (p=0.367).

Discussion

Considering all orthopedic traumatology admissions, the proportion of talus fractures constitutes a small fraction. Hence, it is challenging to generalize from the results obtained[7]. We compared our demographic data to a comprehensive study[8] of 25,615 patients with talus fractures, of whom 61% were male and most were young. Furthermore, Elgafy et al[9], in their demographic data of 60 patients with talus fractures, reported a clear majority of the male gender. Our study's demographic data were similar to the above studies, and the male gender constituted the majority.

In the literature, no study exists on which regions of the talus are more commonly fractured according to age groups. In our study, neck fractures were more common below the median age of 35.5 years, whereas corpus fractures were more common above the median age. Sakaki et al[7], in their study of 23 patients, reported the incidence of central (neck and corpus) fractures as 87%. Comparable studies[1,10] have also supported the low incidence of peripheral fractures. They suggested this might have been due to the possibility of overlooking peripheral (process, tubercle, and head) fractures. Our results supported the literature.

Table VII. Evaluation of the associations of reduction quality with the variables of Hawkins sign, avascular necrosis, AOFAS score, post-traumatic arthritis, surgical incisions, neck fracture, and corpus fracture.

		Reduction Quality		
		Good	Poor	p
Hawkins sign	**Negative**	3 (18.75)	10 (66.67)	**0.007**
	Positive	13 (81.25)	5 (33.33)	
Avascular necrosis	**Absent**	13 (81.25)	4 (28.57)	**0.004**
	Present	3 (18.75)	10 (71.43)	
AOFAS Score	**<75**	2 (12.50)	14 (87.50)	**0**
Post-traumatic arthritis	**Absent**	15 (93.75)	2 (12.50)	**0**
	Present	1 (6.25)	14 (87.50)	
Number of surgical incisions	**Single-incision**	10 (66.67)	4 (25.00)	**0.02**
	Double incision	5 (33.33)	12 (75.00)	
Neck fracture	**Absent**	10 (62.50)	7 (43.75)	0.288
	Present	6 (37.50)	9 (56.25)	
Corpus fracture	**Absent**	6 (37.50)	8 (50.00)	0.476
	Present	10 (62.50)	8 (50.00)	

AOFAS: The American Orthopaedic Foot & Ankle Society.

The majority of talus fractures are caused by high-energy trauma[11]. The high prevalence of high-energy trauma in the male population may result in a similar prevalence of talus fractures in the male population. A trauma-related injury was seen in the majority of our patients. Elgafy et al[9] reported that the most common injury mechanism was motor vehicle injury. However, in our study, unlike Elgafy's study results, falling from a height was the most common injury mechanism.

Talus fractures may be accompanied by ankle and calcaneus fractures. In the literature, concomitant ankle fractures have been reported[8] in 42.7% of patients with talus fractures and calcaneus fractures in 27.8%. Our study found no correlation between age and concomitant adjacent fractures. Likewise, we did not find any correlations between the presence of isolated or multiple fractures and prognostic factors (AOFAS score, AVN, Hawkins sign), the number of incisions made, and the time to surgery.

Classifications

The Hawkins classification covers only neck fractures and is inadequate in corpus and peripheral fractures[12]. In Sneppen's classification[6], the subtypes are not established standardized, which may restrict the classification. The Marti-Weber classification's coverage of peripheral and corpus fractures might make it more advantageous, but its inability to categorize complex fractures constitutes a limitation for the Marti-Weber classification[4,13].

In medical history, there was a long time between when these classifications were introduced and when computed tomography became widely used[7]. The debate regarding the inclusion of fracture configurations in specific classifications has persisted. Studies[9,14-18] have emphasized avascular necrosis, focusing primarily on neck fractures. After talus corpus fractures, the most severe complications, such as avascular necrosis and arthritis, have been reported[18,19] with considerable rates. Outside of the traditional classifications, the most detailed classification is that of the Arbeitsgemeinschaft für Osteosynthesefragen/Orthopedic Trauma Association (AO/OTA), which also does not include combined fractures, and intraobserver and interobserver reliability studies[12] have shown that this classification is not functional. This classification was also reported as inadequate in determining prognosis in two published studies[14,20].

Only one patient (complex fracture consisting of a corpus and neck fracture) was excluded from the classification when we subdivided our current patient's sample into subtypes according to the Marti-Weber classification. A comparison of predicting avascular necrosis showed that the Marti-Weber classification was more favorable than others. We believe the classification will be more responsive to practical use once the classification is revised. Our study failed to detect a correlation between the Hawkins classification and AVN rates. Potential explanations may be that the number of patients in the subgroups was reduced, and isolated corpus fracture patients could not be included in the classification. Even though no statistical correlation was found, the number of patients developing AVN increased gradually from type I to type IV.

Hawkins Sign

Described by Hawkins in 1970, the 'Hawkins sign' helps us to understand the prognosis of talar fractures[5]. A subchondral radiolucent appearance is seen in the talus dome after 6-8 weeks. The literature[16,17,21] agrees that the presence of a complete Hawkins sign is relatively reliable for the 'radiologic warning sign' of AVN. Some authors[22] have clinically judged it as partially positive and entirely positive, showing that partially positive patients have also developed AVN. However, a negative Hawkins sign is not conclusive that AVN will develop[23-25]. Tezval et al[24] evaluated 41 patients in their study and identified 11 patients with a negative Hawkins sign on radiographs in 25 patients without AVN development. As a result, a positive Hawkins sign is more significant than a negative Hawkins sign in predicting prognosis. The fact that none of the patients with a positive Hawkins sign in our study developed AVN is supportive of the literature. However, the fact that almost all of the patients with a negative Hawkins sign manifested increased sclerosis (a finding favoring AVN) on direct radiographic examinations was not compatible with the literature. The negativity of this sign should not mislead the clinician, and as Lindvall et al[26] pointed out in their study, it is not appropriate to consider the negativity of the Hawkins sign as a criterion for prognosis prediction due to its false negativity.

Like Tezval et al[24], we did not detect any significant correlation between the Hawkins sign and age, timing of surgery, smoking, and number of fractured bones in our study. On the other hand, our study found significant associations between the Hawkins sign and the AOFAS score, post-traumatic arthritis, number of surgical incisions, and the quality of reduction. Unfortunately, we found no study in the literature making a similar comparison. Hawkins sign's high sensitiv-

ity and low specificity might explain this[11]. Even though Tezval et al[24] did not identify a correlation between the number of incisions and the results of their study, our study detected that patients operated on with a single surgical incision had a higher rate of positive Hawkins sign. Nevertheless, we believe it would be incorrect to conclude that patients with a negative Hawkins sign will necessarily experience a poor outcome.

Avascular Necrosis

Numerous studies[5,26,27] have pointed out that the essential risk for AVN development was the initial degree of fracture deviation. Hawkins reported that among neck fractures, osteonecrosis may develop in 0-24% of type I neck fractures, 0-50% of type II, and 33-100% of type III and IV[5]. AVN has been reported[11,28-30] to occur in 5-44% of Marti Type I corpus fractures and 50% of displaced Marti Type III and IV fractures. We have not found a similar proportional study with Sneppen classification in the literature. It has also been reported[28] that the risk of AVN is increased in open corpus and neck fractures. Consistent with the literature, AVN was detected in two of our patients with open fractures in our study.

Our study found no statistically significant increase in AVN risk with increasing Hawkins classification grade of neck fractures. This result may be because of the limited number of patients in the group. However, the literature supports the proportional increase in AVN frequency from Hawkins Type I to IV in our study. Studies[19] have shown that AVN development would very likely lead to future post-traumatic arthritis and cause a decline in AOFAS scores. We obtained similar results in our study.

AOFAS Score

In our study, AOFAS scores were divided into two groups, poor-moderate (<75) and good-excellent (≥75), owing to the limited patient numbers. The results of our study were that patients with AOFAS scores of 75 and above had good reduction quality, a positive Hawkins sign, and lower rates of PTA and AVN. Our inconsistent result with the literature[26] was that the AOFAS score was higher in patients with a single surgical incision. The prevailing literature opinion is that the incision's number and side do not impact the results[24,26,31]. The number of patients involved in our study appears to be similar to the studies in the literature. The relationship between the AOFAS score and the number of incisions can be demonstrated more strongly in more extensive case series.

Post-Traumatic Arthritis

Post-traumatic arthritis remained proportionally inferior to avascular necrosis for many years[17]. However, later studies[6,9,16,26,32] have shown that the rates were much higher; they have reported 50% to even 100% rates of post-traumatic arthritis. Lindvall et al[26], in their study, stated that chronic pain and PTA could develop even if AVN did not occur after a good-quality reduction. Some studies[26] have reported no difference between neck and corpus fractures regarding the development of PTA, but there are also studies[11] reporting a higher rate of PTA following corpus fracture. In our patient series, with at least a 12-month follow-up, we identified PTA in 15 of 32 patients. In our study sample, there was a significant difference regarding PTA development between the group with good-quality reduction and the group with a reduction outside the limits of acceptability[26]. Fracture line staging was assessed on early post-operative radiographs, and the acceptable level was determined as anatomical or almost anatomical (suboptimal) reduction. Total anatomical reduction has been shown to stimulate neo-angiogenesis in previous studies[33,34]. PTA was encountered, and AOFAS scores were lower in our patients with a displacement beyond acceptable limits. Buza and Leucht[29] reported that even a mild displacement could lead to arthritis. In our study, a significant PTA rate was present in the AVN group, and we concluded that the age factor was not a significant criterion for PTA. We found that PTA was the factor that greatly influenced the patients' well-being, pain level, and functionality. We suggest that all therapeutic interventions should be aimed at preventing PTA development. When PTA develops, arthrodesis is widely proposed to patients. We planned this procedure for one of our patients.

Reduction Quality

Minimizing the likelihood of arthrodesis is essential when treating young and active individuals. Considering these individuals' active working lives, minimizing the sequelae is also essential. For this reason, a total anatomical reduction is crucial. The fact that the talus is the most load-bearing bone further increases the complication risk. In general orthopedic surgical practice, anatomical reduction for joint restoration is accepted as a maximum of 0-2 mm step limit. In their study, Gomes de Sousa et al[19] evaluated patient groups based on the limits determined by Lindvall et al[26]. They divided the patients into

three groups: complete anatomical reduction, almost anatomical reduction, and poor reduction, and reported that AOFAS scores significantly declined[19]. Our study revealed a significant correlation between good-quality reduction and high AOFAS scores. Good-quality reduction indirectly decreased the AVN and PTA rates. AVN did not develop in one of our patients with a Hawkins Type III neck fracture (with tibiotalar dislocation) due to the complete reduction of the fracture. There were no signs of PTA, and the patient had a high AOFAS score. This situation has been explained in previous studies[33,34] as "good-quality reduction can stimulate neo-angiogenesis even in severe fractures". For this reason, the best reduction should be tried to be achieved. Our patient's outcome supported the literature.

Timing of Surgery

Numerous studies on the timing of fixation are available in the literature. The consensus from these studies[14,26,35] is that the timing of surgery does not change the rates of late complications such as AVN and PTA. Under emergency conditions, no additional surgical intervention is recommended except for joint reduction and wound debridement in open fractures. Some authors[11,19,27,30,35-37] advocated follow-up of soft tissue swelling, suggesting the time when the swelling subsided and the wrinkle sign developed was appropriate for surgery. However, the common point of these studies was that the surgeons tried to operate on talus fractures as early as possible. On the other hand, in our study, we concluded that the operative timing did not affect avascular necrosis and post-traumatic arthritis development, nor did it affect the quality of reduction.

Outcome in General

Various factors can influence the outcomes of surgically treated talus fractures. Fractures classified as type I or II generally result in better outcomes compared to type III or IV fractures. Fractures that are exposed or associated with vascular or neurological injuries can lead to additional complications. Achieving accurate anatomical reduction of the fracture is crucial for restoring joint alignment and ensuring proper functioning of the talus joint during surgery. The methods employed must prioritize stability, as it can impact the final results. Soft tissue damage is often present in conjunction with talus fractures and requires proper treatment to maintain joint stability and function. Outcomes can be influenced and complications reduced by patients following postoperative instructions, including using braces and engaging in physical therapy. Managing these complications in a timely manner is of utmost importance. An important aim in surgical treatment is to attain stable osteosynthesis, which serves as a strong foundation for bone healing and facilitates the recovery of normal joint function. A balance must be achieved between stability and mobility, considering fracture characteristics, patient age, activity level, and functional needs, as excessive stability can cause joint stiffness.

It is the responsibility of doctors to notify patients about the potential risks and benefits of the procedure. Part of their responsibility is to inform patients about the risks, benefits, and various alternatives associated with a procedure during the consent process. It is important to discuss alternatives, as patients may have difficulty grasping risks without a reference point. It supports patients in making well-informed choices[38].

Conclusions

Talus fractures are more common in young males compared to other patients. The rates of complications, such as AVN and PTA, are consistent with the AOFAS scoring results. AOFAS scores are high, and AVN and PTA rates are low in talus fractures managed with total anatomical reduction. Time to definitive surgery does not affect the favorability of the scores and radiologic outcomes. Patients with talus fractures surgically approached with a single incision have higher AOFAS scores. PTA is present in most patients who developed AVN. The outcomes of patients managed surgically for talus fractures mainly depend on the reduction quality. We concluded that current classification systems should be revised by combining them with tomography data, and all therapeutic interventions should be aimed at preventing the development of post-traumatic arthritis.

Conflict of Interest
The authors declare no potential conflict of interest.

Ethics Approval
The approval of the Ethics Committee of Aydin Adnan Menderes University, Faculty of Medicine, was obtained on 14.02.2022 (#137285) when the study's project was submitted to Aydin Adnan Menderes University, Faculty of Medicine.

Authors' Contributions
Ridvan Oner designed and conducted the research and wrote and revised the manuscript.
Ferit Tufan Ozgezmez supervised Ridvan Oner while conducting and writing this research and revised the manuscript when necessary.

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Informed Consent
The study protocol was explained to every subject before the study. In addition, written informed consent was obtained from participants prior to enrollment.

Availability of Data and Materials
Data are available upon request from the corresponding author.

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