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Original Research

# Factors Affecting Healing of Ankle Fractures

Nicholas B. Dodson, DPM, AACFAS [1], Adrianne J. Ross, DPM [1], Robert W. Mendicino, DPM, FACFAS [2], Alan R. Catanzariti, DPM, FACFAS [3]

[1] Surgical Resident, Division of Foot and Ankle Surgery, Western Pennsylvania Hospital, Pittsburgh, PA
[2] Chief, Division of Foot and Ankle Surgery, Western Pennsylvania Hospital, Pittsburgh, PA
[3] Director of Residency Training, Division of Foot and Ankle Surgery, Western Pennsylvania Hospital, Pittsburgh, PA

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ABSTRACT

Ankle fractures have been widely described in orthopedic and podiatric studies. These injuries have been associated with significant patient morbidity, infection, malunion, nonunion, and arthritis. Avoiding complications and optimizing outcomes demands an awareness of the factors affecting the healing of ankle fractures. The prognosis of surgical treatment of these injuries has varied according to patient factors or injury severity, or a combination. Cigarette smoking, obesity, and diabetes are some of the factors linked to the prognosis of ankle fractures. We conducted a retrospective cohort study of 58 patients treated for an ankle fracture at a single center. The objective of the present study was to comprehensively evaluate the factors affecting the clinical outcome of surgically treated ankle fractures.



Significant fractures of the fibula and/or tibia (excluding small avulsion fractures) can be associated with disruption of the ankle mortise. Ankle fractures are common injuries and often lead to prolonged periods of immobilization, disability, and frustrating delays in returning to normal activities. They comprise a diverse group of injuries that include proximal fibular fractures, syndesmotic injuries, bimalleolar, trimalleolar, and isolated malleolar fractures. The standard treatment of displaced ankle fractures in the general population is open reduction with internal fixation (ORIF) (1,2). Although the short- and long-term complications, as well as other prognostic variables, are generally known to be associated with the outcomes after ankle fractures, we believe that a paucity of data is available pertaining to the relationship between specific patient characteristics and fracture healing. We believe that the existing data have failed to adequately answer the question of which patient factors are significant predictors of ankle fracture healing. Studies have successfully linked cigarette smoking (3), comorbid conditions (4), and osteoporosis (5) to less than optimal results, although a multifactorial analysis would be more useful in predicting the overall clinical outcome. The overall complication rate associated with ankle fractures has been reported to be less than 1% in a level 2 study of 57,183 patients. Open fractures, older age, and medical comorbidities, in particular, diabetes mellitus, were reported to be statistically significant predictors of complications (6). In our experience, recognition of the potential risk factors is important in obtaining an optimal clinical outcome. We undertook a retrospective cohort study to evaluate and characterize the relationship between patient characteristics and clinical outcomes of ankle fractures treated by ORIF.

## Patients and Methods

The institutional review board of the Western Pennsylvania Hospital approved the present study. The charts of 60 patients who had sustained an ankle fracture ("International Classification of Disease, 9th revision," codes 824.0-824.9) and had undergone subsequent ORIF from April 2007 to August 2009 (28 months) were retrospectively reviewed. The potentially eligible patient records included in the cohort had to indicate that the patient had undergone ORIF for the ankle fracture and include the radiographic assessment and the following: age, cigarette smoking (7), presence of diabetic peripheral neuropathy (8), fracture type (9), presence of dislocation (defined as a loss of apposition between the ankle articulations), interval to return to regular activities (defined as the preinjury activity level), interval until radiographic evidence of healing (defined as visible trabeculae across the fracture site), duration of immobilization, and complications (nonunion/malunion [7], infection, or wound dehiscence). We defined infection as a postoperative complication warranting the need for antibiotic treatment. Additional criteria required for inclusion in the cohort were age 20 years or older, history of an ankle fracture with subsequent ORIF, and a minimum follow-up of 6 months. The following criteria excluded patients from inclusion: bilateral fractures and/or a concomitant ipsilateral fracture at a site other than the ankle. Final exclusion from the study was determined on the basis of extreme outliers in any risk factor category of interest or fewer than 50 patients for each variable.

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Address correspondence to: Robert W. Mendicino, DPM, FACFAS, Division of Foot and Ankle, Western Pennsylvania Hospital, 4800 Friendship Avenue, N1, Pittsburgh, PA 15224.
*E-mail address:* rmendicino@faiwp.com (R.W. Mendicino).

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The patient characteristics were collected from the medical records by 2 of us (N.D., A.R.). The original data collection process gathered an extensive list of variables. However, for a more comprehensive statistical analysis of 60 patients, the variables were limited to 5 independent variables (i.e., age, smoker status, presence of peripheral neuropathy, fracture type, and presence of dislocation) and 5 dependent (outcome) variables (i.e., interval to return to regular activities, duration of immobilization, interval to radiographic evidence of healing, presence of nonunion/malunion, and wound/fracture healing complications).

After consideration of the clinical, operative, and radiographic reports, the ankle fractures were classified as isolated fibular, proximal fibular, bimalleolar, or trimalleolar. Comorbidities were considered present if reported in the patient's history or records from other services that pertained to the patient's medical status at the ankle fracture. The follow-up examinations recorded the interval to return to regular activities, radiographic evidence of healing, duration of immobilization, evidence of wound healing complications, and evidence of nonunion/malunion.

*Statistical Analysis*

A statistical description of the cohort was undertaken, and tests of the null hypothesis were also performed. The initial analysis used multiple contingency table Fisher's exact chi-square nonparametric tests to analyze 20 different variables. The results did not offer a comprehensive analysis for the cohort size; therefore, additional analysis was undertaken of the 5 independent and 5 dependent (outcome) variables. The revised analyses were performed using SPSS, version 17 (SPSS, Chicago, IL). The independent variables (i.e., age, smoker status, presence of diabetic peripheral neuropathy, fracture type, presence of dislocation) and outcome variables (interval to until return to regular activities, duration of immobilization, interval to radiographic evidence of healing, presence of nonunion/malunion, and wound healing complications, including infection) were analyzed (Table 1).

## Results

The original data set (using the "International Classification of Disease, 9th revision," codes 824.0-824.9) yielded 97 potentially eligible patients. However, only 60 patients met the inclusion criteria. Final exclusion from the present study was determined on the basis of extreme outliers in the category and fewer than 50 patients for each variable. The patient demographics and the numbers for each subcategory are listed in Table 1. The final cohort consisted of 60 patients who had an ankle fracture with subsequent ORIF. The present retrospective cohort analysis evaluated the influence of age, cigarette smoking, presence of peripheral neuropathy, fracture type, and presence of dislocation on multiple measures of recovery from injury. Three outcome variables were considered in regard to days until healing benchmarks and were analyzed using a multivariate approach. Two outcome variables (i.e., the presence of malunion/nonunion and the presence of healing complications) were both coded dichotomously and each analyzed using a logistic regression approach. The sample included 41 females (68%) and 19 males (32%), with a mean age of 49.43 ± 15.36 years.

**Table 1**
Summary of independent and dependent variables (n = 60 ankle fractures in 60 patients)

| Variable | Value* |
|---|---|
| Independent variable (risk factor) | |
| Age (y) | 49.43 ± 15.36 |
| Gender | |
| Male | 19 (32%) |
| Female | 41 (68%) |
| Dislocation | 33 (55%) |
| Peripheral neuropathy | 8 (18%) |
| Cigarette smoker | 20 (33%) |
| Trimalleolar fracture | 19 (32%) |
| Bimalleolar fracture | 23 (38%) |
| Other fracture (i.e., isolated) | 18 (30%) |
| Outcome variable | |
| Nonunion/malunion | 5 (8%) |
| Complications (wound/fracture healing, infection) | 10 (17%) |

* Continuous variables listed as mean ± standard deviation, and categorical variables as n count (%).

The $p$ values (probabilities of the null hypothesis) for the variables of interest are listed in Table 2. The interval in days until radiographic evidence of healing was not recorded for 8 patients, and the data from 1 patient was removed, because it was an extreme outlier ($z = 5.7$), leaving data for 51 patients for use in the final subgroup analyses. A main effect was observed for fracture type [$F(2, 35) = 5.91$, $p < .01$, partial $\eta^2 = 0.252$]. No other main effects were observed. Tukey's post hoc tests were conducted among the specific fracture types. Trimalleolar fractures exhibited a mean difference of 22.06 ± 8.36 fewer days until radiographic evidence of healing than did fractures not categorized as either trimalleolar or bimalleolar fractures ($p < .05$). Bimalleolar fractures exhibited a mean difference of 17.82 ± 7.40 fewer days until radiographic evidence of healing than did the other fracture types ($p < .10$). No statistically significant difference was seen between bimalleolar and trimalleolar fractures with regard to the interval to radiographic evidence of healing.

The duration of immobilization was not recorded for 2 patients, and the data from 1 patient was excluded because it was an extreme outlier ($z = 6.3$), leaving the data from 57 patients for this final subgroup analysis. A main effect was observed for the occurrence of dislocation, with patients who experienced a dislocation ($m = 54.29 \pm 15.61$) requiring longer immobilization than patients who did not experience a dislocation [$m = 43.96 \pm 11.82$; $F(1, 40) = 9.95$, $p < .01$, partial $\eta^2 = 0.199$]. A main effect was also observed for cigarette smoking, with smokers ($m = 53.00 \pm 16.63$) exhibiting a longer duration of immobilization than did nonsmokers [$m = 47.87 \pm 13.75$; $F(1, 40) = 4.75$, $p = .11$, partial $\eta^2 = 0.106$].

The interval to return to everyday activities was not recorded for 7 patients, leaving 53 patients for the final subgroup analysis. A main effect was observed for fracture type [$F(1, 36) = 5.12$, $p < .05$, partial $\eta^2 = 0.221$]; no other main effects were observed. Tukey's post hoc tests were conducted regarding the individual fracture type. Trimalleolar fractures exhibited a mean difference of 34.29 days longer to return to regular activities than did bimalleolar fractures ($p < .10$). No other significant differences were observed among the fracture types with regard to the interval to return to everyday activities.

Binomial logistic regression analysis was conducted to determine the extent to which age, cigarette smoking, neuropathy, fracture type, and dislocation predicted for suboptimal union. A total of 58 patients were included in this final subgroup analysis, after removal of

**Table 2**
Summary of variable analysis* (n = 51 ankle fractures in 51 patients)

| Risk factor | Outcome | F-statistic | Adjusted $p$ Value | Partial $\eta^2$ |
|---|---|---|---|---|
| Fracture type | | | | |
| | Evidence of healing† | 5.91 | .018 | 0.252 |
| | Immobilization | 0.658 | .523 | 0.032 |
| | Activities† | 5.12 | .022 | 0.221 |
| Dislocation | | | | |
| | Evidence of healing | 0.043 | .838 | 0.001 |
| | Immobilization† | 9.954 | .009 | 0.199 |
| | Activities | 3.21 | .162 | 0.082 |
| Cigarette smoking | | | | |
| | Evidence of healing | 0.757 | .390 | 0.021 |
| | Immobilization‡ | 4.752 | .105 | 0.106 |
| | Activities | 1.86 | .362 | 0.049 |
| Neuropathy | | | | |
| | Evidence of healing | 0.305 | .584 | 0.009 |
| | Immobilization | 0.034 | .854 | 0.001 |
| | Activities | 2.189 | .444 | 0.057 |

* Holm's method of correcting for family-wise error rate used for each family of tests.
† Significant at $p < .05$ level after Holm's correction.
‡ Significant at $p < .10$ level after Holm's correction.