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Predicting syndesmotic injuries in ankle fractures: a new system based on the medial malleolar focus

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KEYWORDS

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medial malleolus
Lauge–Hansen
medial crural–focal angle
tibiofibular clear space

ABSTRACT

The early establishment of the diagnosis of a syndesmotic injury is essential for treatment selection. However, such injuries may not be apparent radiographically. Previous studies have attempted to describe correlations between medial malleolar fracture geometry and syndesmotic disruption. The main objective of this study was to create predictive models for assessing syndesmotic injuries based on an originally described angle, i.e., the medial crural–focal angle (MCFA).

This study included 138 ankle fractures involving the medial malleolus. Any measure from the plain radiograph that could potentially lead to the suspicion of a syndesmotic disruption was recorded, and the newly described MCFA (formed by the main line of the medial malleolus fracture and a line perpendicular to the bearing surface of the tibial plafond) was also recorded. The inter- and intraobserver reliabilities were obtained using Krippendorff's alpha coefficients. To examine the predictive abilities of every parameter, several statistical methods were applied including logistic regression, an *ad hoc* clinical rule, and discriminant analysis.

After variable selection, we obtained the best possible logistic model. The variables that were found to be statistically significant were the MCFA, the tibiofibular clear space (TFCS) and the type of injury in the Lauge–Hansen (L–H) classification. This model was tested by cross validation, which revealed a mean percentage of correctly classified patients of 88%. A simpler and more intuitive alternative model was sought that was based solely on the influences of the MCFA and the TFCS. Our study revealed that an absence of syndesmotic disruptions when the MCFA was under 60°, and there were no uninjured patients with tibiofibular clear space values over 6 mm. Cross-validation revealed that the mean percentage of patients who were correctly classified with this model was 86%. The application of discriminant analysis to this combination of variables resulted in a function was able to correctly classify a mean of 84% of patients.

In conclusion, three models that can predict syndesmotic injury using parameters from preoperative plain radiographs were obtained and validated. The MCFA measurement was in these models and found to be a reliable technique.

Introduction

The treatment of ankle fractures may considerably change depending on the state of the syndesmosis [1–8], but the ability to determine with certainty the presence of the lesion is limited [9–11]. Therefore, objective data that help to predict or identify preoperative syndesmotic damage are appreciated. There are four radiological measures that should be highlighted: tibiofibular clear space (TFCS), tibiofibular overlap, medial clear space, and talocrural angle [12,13].

Numerous recent studies have demonstrated the difficulty of making the diagnosis of syndesmotic injury without the use of expensive or invasive studies such as MRI or arthroscopy, respectively [14–16]. Due to the difficulty of diagnosis with conventional means, intraoperative assessments with routine stress tests are important for discovering latent injuries [17–22].

The Denis–Weber classification of ankle fractures is the most widely used and takes the level of the fibular fracture relative to syndesmosis

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as its main reference; however, this classification makes no reference to the medial malleolus. The Lauge–Hansen (L–H) classification is based on the position of the foot and the direction of the damaging force and thus results in the following four types that are divided into subtypes: supination-adduction (SAD), supination-external rotation (SER), pronation-abduction (PABD), and pronation-external rotation (PER) [23,24]. Based on Lauge–Hansen morphological descriptions of medial malleolar fractures and recent studies that have attempted to correlate the geometry of this fracture with syndesmotic disruption, we propose that vertical fracture lines in the medial malleolus are less likely to be associated with syndesmotic injury.

The main objective of this study was to create a predictive model to assess syndesmotic injury based on the description of an original angle, i.e. the medial crural–focal angle (MCFA), formed by the main line of the fracture of the medial malleolus with a line perpendicular to the bearing surface of the tibial plafond based on which syndesmotic injury should be suspected.

Patients and methods

We identified all of the record numbers of patients with ankle fractures who were treated by the Orthopaedics Department of the University Hospital 12 de Octubre (Madrid) between 1/1/2011 and 3/31/2014. We obtained 651 records, and 138 of these included medial malleolus fractures. Every step of the protocol was approved by the ethics committee. Each patient was retrospectively studied by four researchers to record the presence (injured) or absence of syndesmotic damage (uninjured) and to obtain the radiological data from the emergency room plain radiographs including the following: type of injury according to the Lauge–Hansen system, number of affected malleoli, talocrural angle, anteroposterior tibiofibular ratio [25], TFCS, tibiofibular overlap, talar tilt angle, continuous or discontinuous Shenton line, medial clear space, and MCFA. To analyze the MCFA, a line perpendicular to the plafond articular surface was drawn, then a second line was drawn between two reference points, i.e. the most lateral and medial fracture origin points on the tibia. The MCFA was taken as the angle formed by this line and the line perpendicular to the tibial articular surface and is reported within the range of possible values of 0–180° (Figures 1 and 2).

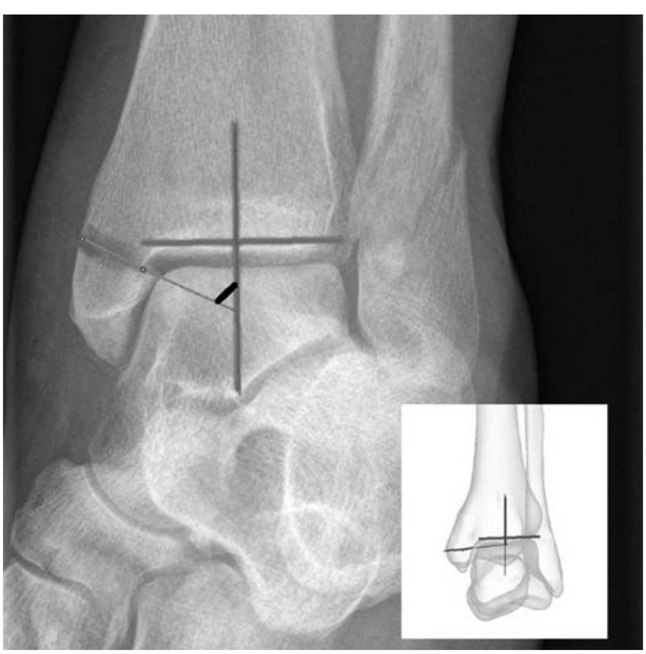

Fig. 1. Schematic illustrations of the MCFA measurement.

To eliminate the possibility of false-positive results due to interpersonal anatomical variations, in the second phase of the study, new X-rays were requested from the patients with syndesmotic injuries to enable comparisons with the uninjured sides and to obtain the inter- and intraobserver reliabilities and reproducibilities of the measurement. Each researcher measured the MCFAs again in subjects with syndesmotic injuries. These data were processed for analysis with the web service ReCal OIR, which calculates the Krippendorff's alpha coefficient for two or more encoders [26].

Other utilized non-parametric inferential statistical methods included the Kruskal–Wallis/Wilcoxon test for continuous variables and Fisher's exact test for categorical data. Three different models were developed to predict syndesmotic injury. The prediction ability of each model was assessed as the proportion of the number of correct assignments (true injured and true uninjured) of the proposed model to the total number of patients, i.e. the so-called accuracy. These models included a logistic regression, an *ad hoc* clinical rule and a discriminant analysis. The logistic regression was fit according to the minimum *Akaike's Information Criteria* (AIC) [27]. A receiver operating characteristic (ROC) curve was calculated for the logistic model. Because one of the aims of this work was prediction, we implement a fourfold cross-validation scheme with 100 replicates with the same proportion of syndesmotic injuries as observed in the original population [28]. Finally, we calculated the means and standard

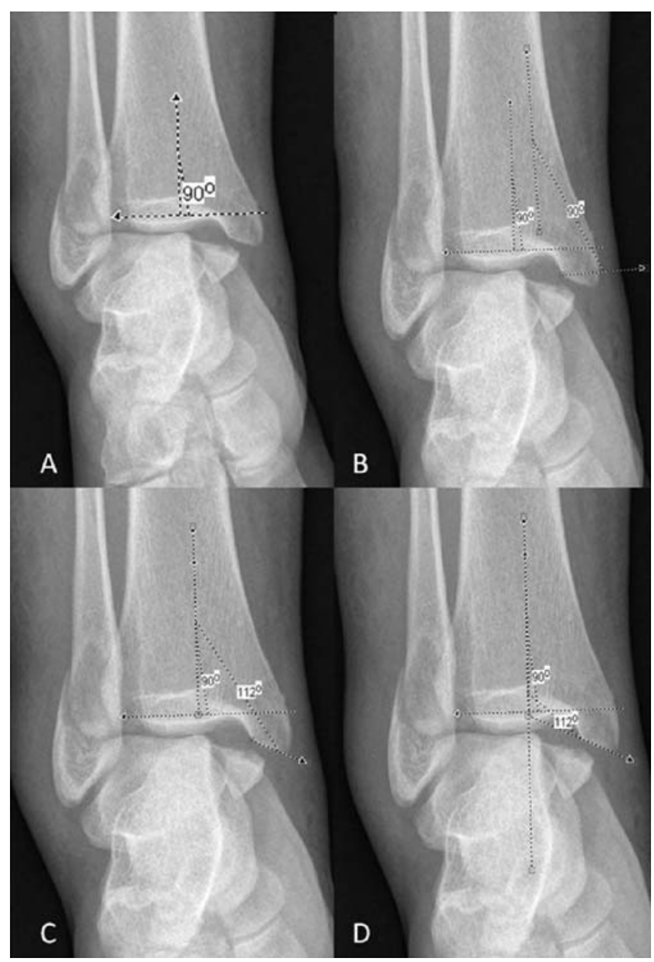

Fig. 2. Measuring the MCFA. (A) The line perpendicular to the tibial plafond articular surface is obtained. (B) An overlapping second angle measure to the previously obtained perpendicular line is obtained. (C) The goniometer is placed on a line obtained between two reference points, i.e., the most lateral and medial fracture origin points in the tibia. (D) The MCFA is the angle formed by this line and the line perpendicular to the tibial articular surface.