

# EFFECT OF FIBULAR PLATE FIXATION ON ROTATIONAL STABILITY OF SIMULATED DISTAL TIBIAL FRACTURES TREATED WITH INTRAMEDULLARY NAILING

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**Background:** The effect of an intact fibula on rotational stability after a distal tibial fracture has, to the best of our knowledge, not been clearly defined. We designed a cadaver study to clarify our clinical impression that fixation of the fibula with a plate increases rotational stability of distal tibial fractures fixed with a Russell-Taylor intramedullary nail.

**Methods:** Seven matched pairs of embalmed human cadaveric legs and sixteen fresh-frozen human cadaveric legs, including one matched pair, were tested. To simulate fractures, 5-mm transverse segmental defects were created at the same level in the tibia and fibula, 7 cm proximal to the ankle joint in each bone. The tibia was stabilized with a 9-mm Russell-Taylor intramedullary nail that was statically locked with two proximal and two distal screws. Each specimen was tested without fibular fixation as well as with fibular fixation with a six-hole semitubular plate. A biaxial mechanical testing machine was used in torque control mode with an initial axial load of 53 to 71 N applied to the tibial condyle. Angular displacement was measured in 0.56-N-m torque increments to a maximal torque of 4.52 N-m (40 in-lb).

**Results:** Initially, significantly less displacement ( $p \leq 0.05$ ) was produced in the specimens with fibular plate fixation than in those without fibular plate fixation. The difference in angular displacement between the specimens treated with and without plate fixation was established at the first torque data point measured but did not increase as the torque was increased. No significant difference in the rotational stiffness was found between the specimens treated with and without plate fixation after measurement of the second torque data point (between 1.68 and 4.48 N-m).

**Conclusions:** Fibular plate fixation increased the initial rotational stability after distal tibial fracture compared with that provided by tibial intramedullary nailing alone. However, there was no difference in rotational structural stiffness between the specimens treated with and without plate fixation as applied torque was increased.

**Clinical Relevance:** In patients with ipsilateral distal tibial and fibular fractures who are treated with Russell-Taylor intramedullary nailing of the tibia, rotational stability of the tibial fracture can be increased by plate-and-screw fixation of the fibula, which may reduce the risk of valgus malunion.

Conservative treatment of fractures of the tibial shaft has been associated with high rates of nonunion, delayed union, and malunion, leading to the practice of closed intramedullary nailing<sup>1</sup>. Treatment of distal fractures of the tibial shaft is more complicated because such fractures frequently are caused by high-energy trauma that also produces a fibular fracture. To help clarify the role of a concomitant fibu-

lar fracture in the development of malunion of a nailed tibial fracture, we used cadaver specimens to model distal tibial and fibular fractures at the same level. We then analyzed the rotational stability of intramedullary nail fixation of the tibial fracture with and without fixation of the fibular fracture.

## Materials and Methods

Seven matched pairs of embalmed human cadaveric legs and sixteen fresh-frozen human cadaveric legs (Medical Education and Resource Institute, Memphis, Tennessee), including one matched pair, were tested. Each specimen was screened for



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human immunodeficiency virus and examined for gross pathological changes. The average age (and standard deviation) of the donors was  $75 \pm 10$  years. Eight donors were black and fourteen were white. Fourteen were male and eight were female. The prepared specimens were stored frozen at  $-20^{\circ}\text{C}$  until mechanical testing and were thawed to room temperature no more than twenty-four hours before testing.

#### Specimen Preparation

The tibial-fibular interosseous membrane and surrounding muscle were maintained during specimen preparation. To simulate fractures, 5-mm transverse segmental defects were created at the same level in the tibia and fibula, 7 cm proximal to the ankle joint in each bone. The interosseous membrane was preserved and left intact. The length of the segmental defect ensured that no tibial cortical contact would occur during testing. Each tibia was stabilized with a 9-mm Russell-Taylor intramedullary nail (Smith and Nephew Orthopaedics, Memphis, Tennessee) that was statically locked with two proximal and two distal screws. The bending freedom of the distal interlocking screws within the screw holes was found to be  $6^{\circ}$ . The 5-mm gap of the simulated fracture was maintained after stabilization with the Russell-Taylor nail. After the first series of tests, each fibula was fixed with a six-hole semitubular plate

(Smith and Nephew Orthopaedics). All specimens were examined morphologically and radiographically to rule out pathologic fractures and to confirm adequacy of fixation.

#### Mechanical Testing

Specimens were tested on a biaxial mechanical testing machine (series-3300 test frame; Interlaken Technology, Eden Prairie, Minnesota) with the machine operating in torque control mode. For mechanical testing, the specimens were held proximally at the tibial condyles and distally at the foot and ankle with specially designed grips. The foot and ankle were fixed to minimize the angular displacement measurement error due to movement distal to the fracture site. The proximal part of the tibia was attached firmly to the actuator by a cylindrical fixture with six stainless-steel screws with sharpened ends penetrating the tibial condyles. Before each mechanical test, a final check was made to ensure that the prepared specimen was positioned in the test frame with the tibia nailed in its normal anatomical alignment and with no cortical contact between the proximal and distal tibial fragments at the simulated fracture site. An initial axial load of 53 to 71 N (approximately 10% of body weight) was applied to the tibial condyle of each specimen and was maintained throughout the test. Only static loads (torques) were applied to the specimens

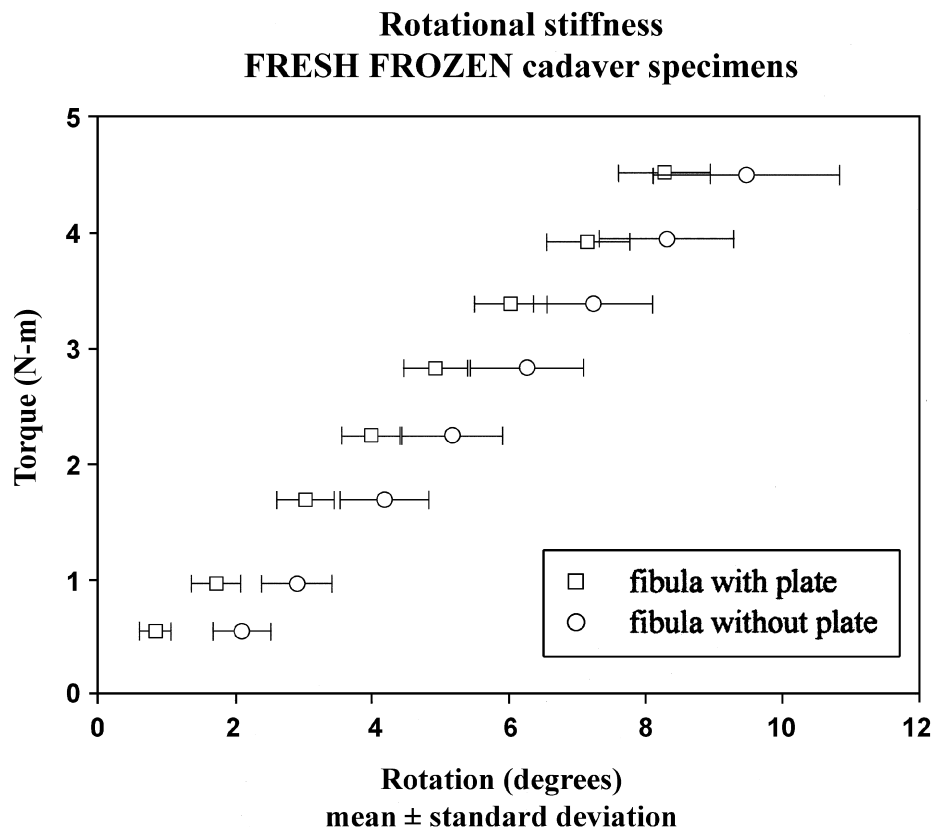


Fig. 1  
Rotational stiffness of fresh-frozen specimens with and without plate fixation of the fibular fracture, tested first without the plate.

in this study. A static testing method was selected to address only the initial stability of the fracture.

A dial indicator (Mitutoyo, Boston, Massachusetts) mounted on a magnetic base was used to approximate angular displacement at the fracture site. A 4.5-mm-diameter, 50-mm-long cortical bone screw was drilled 1 cm proximal to the fracture site and advanced until the top of the screw made contact with the nail. The dial indicator was then positioned so that clockwise rotation of the leg caused the cortical bone screw to displace the indicator. Linear displacements of the dial indicator were converted into angular displacement at the fracture site (degrees of rotation) for 0.56-N·m torque increments (applied to the proximal part of the tibia) to a maximal torque of 4.52 N·m (40 in-lb). The linear translation of the dial indicator, which was converted into an angle of rotation, depended on the applied torque from roughly 1 to 6 mm. Because of the small amount of displacement, we were able to calculate the angle of rotation by approximating the arc swept with a right triangle (i.e., small-angle approximation). The error for measuring angles of rotation with such an approximation was found to be small (see Appendix).

Each specimen was tested twice, once with the fibula fixed

with a plate and once with no fixation of the fibula. The order of testing was reversed from one specimen to the next.

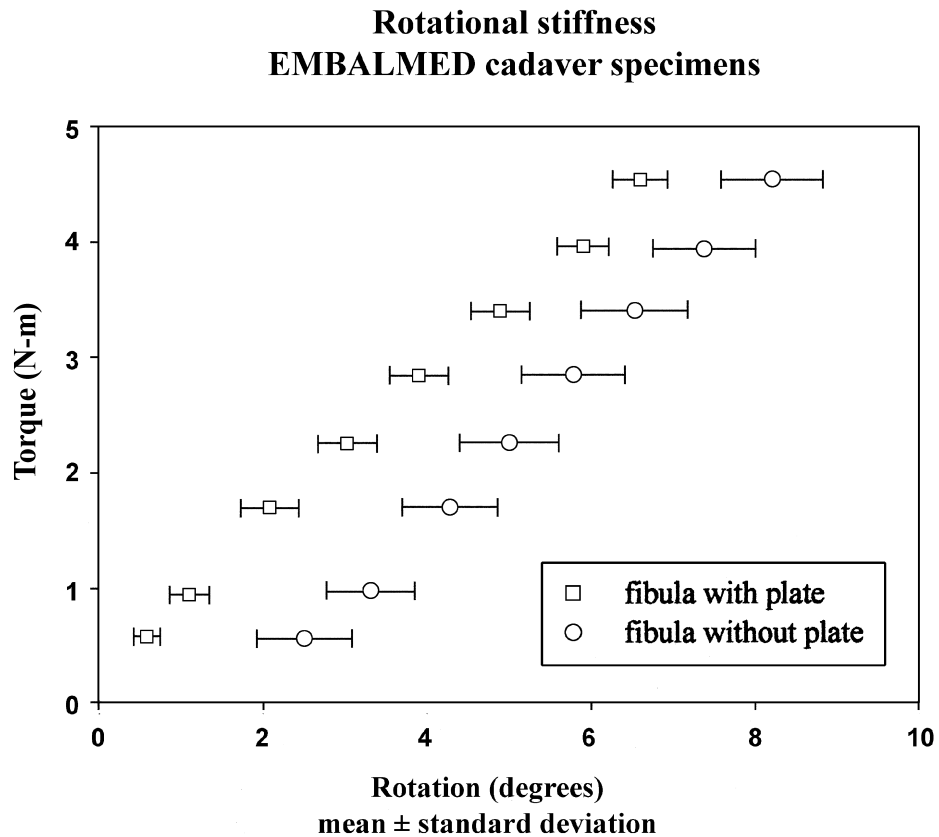
#### Data Analysis

Two-way analysis of variance with post hoc tests and paired Student t tests were used to evaluate the effects of plate fixation; type of cadaveric specimen; donor age, sex, and race; and order of testing (whether the leg was first tested with or without fibular plate fixation). Nonpaired tests were used to make other comparisons. Fresh-frozen and embalmed specimens were examined separately. A total of eight data points were measured. When a significant difference was found, the data points are referred to according to the order in which they were obtained (e.g., as the first torque data point measured). The results of the analysis of variance and t tests were considered significant when  $p$  was  $<0.05$ .

#### Results

Because of the experimental design and the differences in the cadaveric specimens used in this study, it was necessary to group the results by the type of cadaveric specimen and by whether the specimen was first tested with or without fibular plate fixation (Figs. 1 and 2). The disparity between me-

Fig. 2  
Rotational stiffness of embalmed specimens with and without plate fixation of the fibular fracture, tested first without the plate.



chanical test data derived from human fresh-frozen cadaveric specimens and those derived from embalmed cadaveric specimens is well known and has been reported in the literature<sup>2</sup>. Accordingly, we compared the mean angular displacements in each respective specimen-preparation group to account for such differences.

#### *Effect of Fibular Plate Fixation on Angular Displacement*

Local rotation at the simulated fracture site was measured with increasing amounts of torque applied at the proximal end of the tibia. Both the embalmed and the fresh-frozen cadaver specimens with plate fixation of the fibula had significantly less displacement initially (at the first torque point [0.56 N-m]) than did the specimens without fibular plate fixation (plate fixation compared with no fixation in the embalmed group,  $p = 0.004$ ; plate fixation compared with no fixation in the fresh-frozen group,  $p = 0.030$ ). The difference in angular displacement between the specimens with and without fibular plate fixation was established at the first torque data point but did not increase as torque was increased. No significant difference in rotational stiffness (newton-meters per degree rotation) was found between the specimens with and without fibular plate fixation after the second torque data point (between 1.68 and 4.48 N-m) (plate fixation compared with no fixation in the embalmed group,  $p = 0.106$ ; plate fixation compared with no fixation in the fresh-frozen group,  $p = 0.881$ ).

#### *Effect of Donor Age, Sex, and Race*

The age, sex, and race of the donor and the initial fracture displacement had no significant effect on rotational stiffness or angular displacement after fixation.

### **Discussion**

The role of the fibula in maintaining stability after fixation of distal tibial fractures has not been clearly defined<sup>3-5</sup>. Gotzen et al.<sup>6</sup> and Morrison et al.<sup>7</sup> showed that fibular plate fixation increased both torsional and longitudinal stability of mid-diaphyseal tibial fractures treated with external fixation; fibular fixation made the construct 2.2 times stiffer than that produced by tibial fixation alone. Weber et al.<sup>4</sup>, testing the effects of varus, valgus, and flexion stresses, found that, although fibular plate fixation increased the stability of external fixation of mid-diaphyseal tibial fractures, it did not affect the stability of tibial fractures treated with intramedullary nailing. Their study did not, however, include torsional stress testing. Also, it included only fractures of the midpart of the diaphysis, where intimate contact with the nail greatly increases stability.

In an unpublished clinical series of sixty tibial fractures, we noted valgus deformity at the sites of anatomically nailed distal tibial fractures when fibular plate fixation had not been used. Because the anatomic flare of the distal part of the tibial canal does not allow cortical contact with the nail, mechanical stability after fixation of distal tibial fractures is provided only by the cross-screw static locking of the nail. Intramedullary nail fixation in this area has been shown to be strongest in resisting

valgus and varus flexion loads and weakest against torsional loads<sup>8</sup>. An intact fibula increases the stability of these fractures by moving distally during weight-bearing, thereby deepening the ankle mortise<sup>9</sup>. More load is transmitted to the tibia when the foot is dorsiflexed and everted because of the greater contact of the talus with the ankle mortise. The reported percentage of body weight borne by the fibula has ranged from 6.4% to 17%<sup>10</sup>. In a cadaver study, Goh et al.<sup>9</sup> found that resection of the proximal part of the fibula reduced its load-bearing to <1%, resulting in most of the load being transmitted through the tibia.

The importance of the interosseous membrane in fibular stress transmittal also has been a subject of debate<sup>11-13</sup>. Although Lambert<sup>11</sup> determined that the interosseous membrane did not affect the weight-bearing function of the fibula, later studies refuted this. For example, Vukicevic et al.<sup>13</sup> found that sectioning the interosseous membrane decreased the amount of stress borne by the fibula by 30%, and Skraba and Greenwald<sup>12</sup> found stresses on the fibula to be reduced to almost zero after sectioning of the interosseous membrane. These findings indicate that a distal fibular fracture with damage to the interosseous membrane results in almost all of the weight-bearing stresses being borne by the tibia.

The weight-bearing mechanical axis may shift as a result of translation of the nail due to loosening of the distal screws at the bone-screw interface. We determined that the distal interlocking holes in the Russell-Taylor nail allow 6° of varus-valgus movement of the screw. Because of the so-called windshield wiper effect, this could result in loosening at the bone-screw interface and nail translation along the axis of the screw, ultimately exaggerating a varus or valgus deformity. This potential complication might be avoided by reducing the freedom at the screw-nail interface by changes in screw design, divergent screw placement, or addition of an anteroposterior screw. The fibular plate fixation technique investigated in this study may be used to minimize varus or valgus motion, in addition to providing rotational stability.

In our unpublished clinical series of sixty tibial fractures stabilized with proximally and distally locked Russell-Taylor nails, all valgus malunions occurred gradually, without evidence of a precipitating traumatic event, and all occurred in patients without fixation of the fibular fracture at the same level as the tibial fracture. Initial tibial fixation was anatomic in all patients, and valgus malunion appeared to result from normal stresses to the ankle joint with activities such as walking. During the gait cycle, sequential internal and external rotation torque is transmitted across the ankle joint to the tibia<sup>14,15</sup>. Because fixation of same-level fibular fractures appeared to reduce the risk of malalignment of distal tibial fractures, we designed this biomechanical study, which confirmed that initial rotational stability of distal tibial fractures treated with intramedullary nailing is increased by plate-and-screw fixation of an accompanying fractured fibula.

### **Appendix**

**eA** A description of the method used to measure rotational angles with use of small-angle approximation is avail-

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