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An Augmented Fixation Method for Distal Fibular Fractures in Elderly Patients: A Biomechanical Evaluation

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ABSTRACT

This biomechanical investigation compared two fixation techniques for distal fibular fractures. Elderly cadaver lower extremities with simulated fibula fractures underwent fixation either with a plate and intramedullary Kirschner wires (K-wires) with or without the addition of three screws inserted through the four cortices of the fibula and the tibia. The specimens were axially loaded to body weight on a materials testing machine, and the supinated foot was externally rotated to failure. Displacement at the fracture site was monitored with an extensometer. Comparing the augmented technique with the technique without additional screws, mean stiffness was 460 ± 100 and 320 ± 200 N-mm/deg, strength at failure was 31 ± 10 and 19 ± 7 N-m, strength at 30° external rotation was 15 ± 5 and 10 ± 6 N-m, and axial deformation was 0.04 ± 0.06 mm and 0.10 ± 0.04 mm, respectively. All differences were statistically significant.

Key Words: Intramedullary Kirschner Wire Fixation Technique; Osteopenic Fibular Fractures

INTRODUCTION

Displaced ankle fractures show better clinical results after open reduction and internal fixation,[1,5,7,17,24,25] but loss of fixation secondary to osteopenic bone and a higher reported complication rate can occur among the elderly.[13] The preferred treatment for complex ankle fractures, particularly in the young patient, is internal fixation, although severely comminuted fractures can be problematic.[18] In patients over the age of 65 years, weak bone often complicates fracture treatment and increases the risk of delayed union and nonunion.[3,4,11,13,16] Some studies have noted that the incidence of ankle fractures, particularly in women over the age of 50, is increasing and is likely related to osteoporosis.[2,4] Ankle fractures in older women are common.[8] The treatment of ankle fractures can be challenging, particularly in women over 65 years old, who fall twice as often as elderly men.[9] Ankle fractures are the most common nonspinal fracture in women in this age group.[22]

Alternate methods of fibular fixation in the elderly include a posterior antiglide fibular plate, which provides more strength and stiffness than a lateral plate.[19] Orthogonal fibular plating has been described for severely comminuted fibular fractures where distal fixation was limited.[18] The use of axial intramedullary Kirschner wires (K-wires) with a standard lateral plate and screws has been described in comminuted fractures and osteopenic bone.[11] In rare cases where both distal and proximal fixation are tenuous, as in an intraoperative observation of osteopenia with a comminuted fracture, the augmentation of proximal fixation may enhance the strength of the overall fixation.

At our institution, axial fibular K-wires have been used for fractures involving bone clinically assessed as osteopenic by criteria previously described[11] and for fractures where severe comminution precludes fixation with a standard lateral plate. We have had good results with augmented proximal fixation with fibula-to-tibia screws clinically to gain increased bone purchase in fractures involving osteopenic bone, neuropathy, noncompliant patients, and severe comminution.

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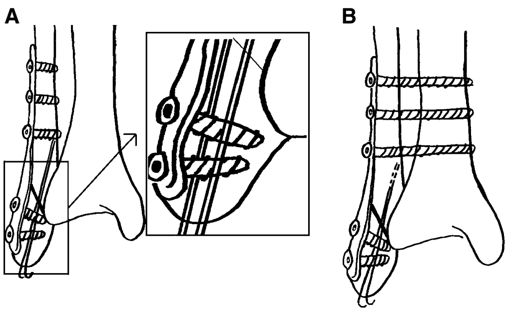

Fig. 1: Plate with intramedullary K-wire fixation (*A*) and fixation augmented with fibula-to-tibia screws technique (*B*).

We hypothesized that further augmentation of the plate and intramedullary K-wires would provide the additional fixation stability for these patients. The purpose of this study was to compare two fixation techniques for fibular fractures in this small subset of elderly patients: 1) AO lateral plate fixation with intramedullary K-wire stabilization and 2) the plate with intramedullary K-wire technique augmented by substituting fibula-to-tibia screws for the standard fibular bicortical screws proximal to the fracture (Fig. 1).

MATERIALS AND METHODS

Eight matched pairs of human cadaver lower extremities were obtained (average age, 73 years; range, 65–82 years) and stored at −20°C. The specimens were thawed at room temperature for 24 hours. All specimens appeared grossly normal before use. Osteopenia of the specimens was presumed based on their age and was supported by radiographic evidence. The matched limbs were considered their own controls for the purposes of the study. We simulated a supination–external rotation ankle injury (Danis-Weber type B fracture, or Lauge-Hansen supination–external rotation type 4 injury) by creating an oblique osteotomy 4 cm proximal to the distal tip of the lateral malleolus and dividing the anterior tibiofibular ligament via a lateral incision. As in another fracture model previously described,[11] a 2-mm gap was left at the osteotomy site to simulate a comminuted fracture with no osseous support. The limbs were amputated 12 cm distal to the knee, and 6 cm of soft tissue was removed proximally to facilitate potting for the load frame. The interosseous membrane and all ligaments except the anterior tibiofibular ligament were left intact. After the osteotomy was created via a lateral exposure, the two fixation techniques were randomly assigned by coin toss to the right or left limb in each pair. Each fibular fracture was stabilized with two axial 0.062-inch K-wires. A seven-hole, one-third tubular plate (Synthes, Paoli, PA) was used in all specimens, and distal fixation was accomplished in all specimens with two 3.5-mm cancellous screws interdigitating with the axial K-wires as described previously.[11] For proximal fixation, three 3.5-mm fibula-to-tibia cortical screws were used through the plate, each engaging four cortices proximal to the fracture. Proximal fixation with the plate and intramedullary K-wire technique was accomplished in one specimen from each pair by manually inserting three standard bicortical screws in the fibula proximal to the fracture site. The ankle was at 10° of dorsiflexion when the proximal screws were inserted.

Each specimen was securely mounted on a load frame (MTS Mini Bionix, MTS Systems Corp., Eden Prairie, MN) for biomechanical testing. An extensometer with pins (0.062-inch unicortical K-wires) located on either side of the osteotomy was used to measure axial displacement across the osteotomy site with preloading. Specimens were axially preloaded to body weight of 720 N, and the supinated foot was externally rotated to failure at a torque of 60°/min, assumed to simulate the conditions that create this type of fracture. Torque versus angular deformation curves were generated for each specimen. The slope of the linear portion of these plots was defined as stiffness in Newton-millimeters per degree.

The Students *t* test was used, with the level of significance set at $p < .05$.

RESULTS

The augmented fixation construct was stiffer, stronger, and more resistant to axial deformation than the unaugmented plate and intramedullary K-wire technique in our tested specimens (Table 1). All differences were statistically significant (paired Student *t* tests, $p < .05$).

All 16 specimens generated similar curves of torque versus angular deformation. The fibula-to-tibia technique provided stiffer and stronger fixation than the unaugmented plate and K-wire technique in all eight pairs of specimens. This augmented fixation was also more resistant to axial compression at the fracture gap when preloaded to body weight in all eight matched pairs. Six of the specimens stabilized by the unaugmented method failed early in external rotation by gapping at the osteotomy site, and ultimate failure occurred at the screws proximal to the fracture where the screws did not interdigitate with the K-wires. None of the specimens stabilized with the augmented technique failed at the osteotomy site. They instead failed distally by creating a longitudinal fracture in the sagittal plane, splitting the lateral cortex and hardware from the medial cortex of the distal fibular fragment.

Table 1: Comparison of results with plate and intramedullary K-wire procedure and augmented technique

Method	Stiffness (N-mm/deg ± SD)	Strength at 30° External Rotation (N-m ± SD)	Strength at Failure (N-m ± SD)	Axial Deformation (mm ± SD)
Unaugmented[a]	320 ± 180	10 ± 6	19 ± 7	0.10 ± 0.04
Augmented[b]	460 ± 140	15 ± 5	31 ± 13	0.04 ± 0.06

All differences between unaugmented and augmented were significant ($p < .05$).
[a]Plate and intramedullary K-wires.
[b]Plate and intramedullary K-wires augmented with three tetracortical fibula-to-tibia screws.

DISCUSSION

The technique described in the current study initially evolved through clinical difficulty encountered by the senior author in obtaining rigid fixation of neuropathic fibular fractures. Because of weightbearing noncompliance issues among these patients, we observed postoperative loss of reduction of fibular fractures with standard fixation techniques. Results were improved with the use of three fibula-to-tibia tetracortical screws to augment the plate and intramedullary K-wire technique in these patients.

Fibula-to-tibia screws are commonly used for syndesmotic disruptions, though the use of tetracortical fibula-to-tibia screws in the absence of syndesmotic disruption has been described in neuropathic ankle fractures.[20] To our knowledge, the use of tetracortical fibula-to-tibia screws to enhance fixation in osteopenic bone has not been described previously. Biomechanical evidence suggests that the use of fibula-to-tibia tetracortical screws alters the biomechanics of the ankle by changing the stiffness of the syndesmosis,[15,21] but this result has not been noted clinically.[10] Fibula-to-tibia transfixation is routinely done with the ankle in dorsiflexion to deliver the widest portion of the talus into the mortise during screw insertion, though this common practice has been questioned.[23] There is concern that the screws may break if they resist the natural motion at the tibiofibular syndesmosis,[15] but this risk may be acceptable in light of the stability gained. The use of fibula-to-tibia screws for syndesmotic fixation seems fairly well tolerated because ambulation progressively restores motion between the tibia and fibula in spite of fixation.[10]

In the current biomechanical study, the results with the augmented technique support the theory that the interdigitation of the screws with the K-wires is the reason for improved fixation with the plate and K-wire technique, as compared with plate fixation alone.[11] A decrease in axial compression with body weight may transfer stress to the proximal fibular fragment and transiently prevent the physiologic fibular descent with weightbearing.[21] Although fatigue resistance was not tested, we would expect that a stronger and stiffer construct would show increased resistance against fatigue stress.

The current study is limited in that we did not attempt to quantify osteopenia but presumed a high probability of osteopenic bone in our fresh-frozen specimens based on age and radiographic osteopenia. Our fracture model with fresh-frozen tissue did not fully recreate the degree of comminution that can be encountered clinically. Fixation techniques were stressed to failure by recreating the mechanism of original injury and were not subjected to cyclic loading. A longer lateral plate has been shown to enhance fixation,[14] but we considered the plate and K-wire technique the best benchmark for comparison because it was described for this clinical situation and we have clinical experience with it. We noted variations between the limb pairs though the trend was consistent in all pairs. We attributed these differences to variations in bone quality among the pairs and possible minute differences in technique. Similar limitations have been found in the few other reported biomechanical comparisons of fibular fixation methods.[6,11,19] We randomized the treatments in each pair by a coin toss to minimize the impact of slight discrepancies from side to side and to avoid favoring one technique over the other by using the better specimens for a particular technique.

Bearing these limitations in mind, the information obtained in the current study is consistent with our clinical observations, which suggest that this method of fixation can tolerate more immediate postoperative weightbearing in a cast. Variations would be expected with larger patient size or other variables, which may cause the clinician to avoid aggressive weightbearing. Better fixation may translate to improved ability to bear weight clinically, but the current results are relative and the clinical extrapolation is not certain.

We created a reproducible fracture model using an osteotomy because of difficulty in consistently reproducing short oblique fractures of the distal fibula in our laboratory, a difficulty that likely resulted from the presumed high incidence of osteopenic bone in our specimens and from the lack of specimen flexibility for appropriate foot positioning in cadaver specimens.[12] This is not a truly posttraumatic situation, and the nature of the model makes it possible to assess values only relative to the contralateral specimen in the pair and not in absolute terms. We simulated a comminuted fracture by making a gap, which is rarely encountered clinically. A gap is worse than a comminuted fracture in that a gap has absolutely no stability, whereas a comminuted fracture is considered unstable but often has some bone-to-bone contact. We believed that this scenario reflects a worst-case scenario with no load sharing through the bone. The model was reproducible without introducing additional random variables, and to date it is the best model we have found.

Stable fixation is especially challenging to achieve among the elderly in general, and even more so where bone is weakened. An improvement in fixation stability could have substantial benefit in this patient group. The method of fibula-to-tibia screw fixation may help improve stiffness, strength, strength to failure, and axial deformation (Table 1). This may permit better clinical fixation stability and improve results.

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