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Comparison of Pullout Strength between 3.5-mm Fully Threaded, Bicortical Screws and 4.0-mm Partially Threaded, Cancellous Screws in the Fixation of Medial Malleolar Fractures

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ABSTRACT

Displaced medial malleolus fractures are considered unstable and typically require open reduction and internal fixation for anatomic reduction and early joint range of motion. These fractures are usually fixated with either compression lag screws or tension band wiring depending on the fracture pattern, size of the distal fragment, and bone quality. When fracture fixation fails, it is typically in pullout strength. Failure of primary bone healing can result in nonunion, malunion, and need for revision surgery. The current study wished to explore a potentially stronger fixation technique in regard to pullout strength for medial malleolar fractures compared with traditional cancellous screws. This was a comparative study of the relative pullout strength of 2 fully threaded 3.5-mm bicortical screws versus 2 partially threaded 4.0-mm cancellous screws for the fixation of medial malleolar fractures. Ten fresh-frozen limbs from 5 cadavers, mean age 79 years (range of 65–97 years), were tested using the Instron 8500 Plus system. The median force recorded at 2 mm of distraction using unicortical partially threaded cancellous screws was 116.2 N (range 70.2 to 355.5N) compared with 327.6 N (range 117.5 to 804.3 N) in the fully threaded bicortical screw ($P = .04$). The unicortical screw fixation displayed only 64.53% of the median strength noted with the bicortical screw fixation at clinical failure. The current study demonstrated statistically significantly greater pullout strength for 3.5-mm bicortical screws when compared with 4.0-mm partially threaded cancellous screws used to fixate medial malleolar fractures in a cadaveric model.

Displaced medial malleolus fractures are considered unstable fractures. These fractures typically require open reduction and internal fixation to allow for anatomic restoration and early joint range of motion. Herscovici et al (1) devised a classification scheme for medial malleolus fractures based on the level of the fracture (Figure 1). The mechanism of injury for Type B and C fractures is external rotation or abduction. These fractures are usually fixated with either compression lag screws or tension band wiring. The method of fixation is often dictated by the fracture pattern, size of the distal fracture fragment, and quality of the bone.

Ankle fractures have also been increasing in incidence and severity among the elderly population (2, 3). Valtola et al (4) associated smoking, fracture history, obesity, and multipharmacy with the increased incidence of ankle fractures in this patient population. There is much debate over conservative versus surgical treatment of geriatric ankle fractures. Certain comorbidities like osteoporosis, diabetes, peripheral vascular disease, and skin problems have been associated with poorer surgical outcomes (5–7). The best treatment, whether it is conservative or surgical, should provide the elderly patient with a functionally stable ankle joint, allowing him or her to return to normal activity.

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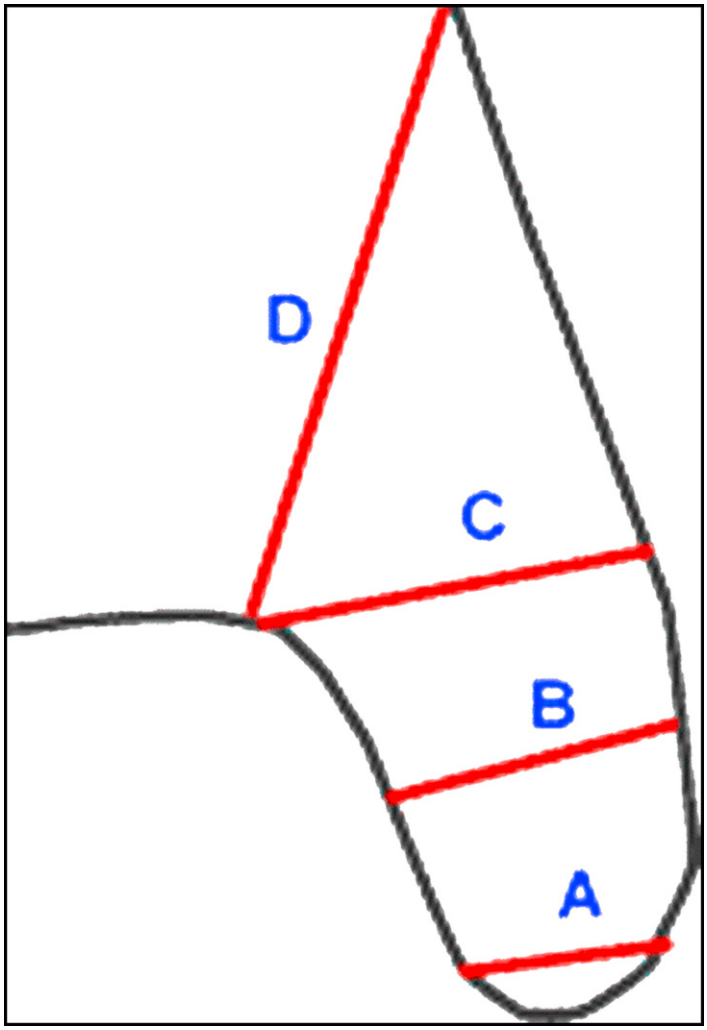

Fig. 1. Diagram showing Herscovici classification for isolated fractures of the medial malleolus (reproduced from Herscovici et al [1] with permission from the *Journal of Bone and Joint Surgery*).

When bone screws are used for fracture stabilization there are several factors that can influence screw performance (Figure 2). Typically, cancellous screws have a greater difference between major and minor diameter, deeper threads, and a larger pitch compared with cortical screws to provider greater holding power in porous materials such as metaphyseal or epiphyseal bone. Also, the length of screw thread engagement has been shown to increase the pullout strength (8–10).

The goal of the current study was to explore a potentially stronger construct for medial malleolar fixation, which has not been examined in the foot and ankle. The hypothesis of this study was that 3.5-mm fully threaded, bicortical screws have greater pullout strength than the 4.0-mm partially threaded cancellous screws for medial malleolar fracture stabilization.

Materials and Methods

Preparation of Specimens

The research was conducted in conjunction with the Department of Biomedical Engineering at Wayne State University. Ten paired fresh-frozen cadaveric specimens from 5 bodies were used in the study. The average age of the specimens was 79 years with a range of 65 to 97 years. No specimen had any evidence of previous operative treatment or grossly abnormal motion. After thawing, the specimens were dissected proximally down to bone exposing the tibia and fibula. Mid-shaft amputations were then performed through the tibia and fibula.

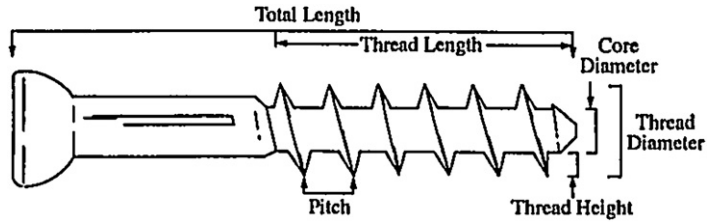

Fig. 2. Basic design parameters of a screw. Thread diameter is synonymous with major diameter and thread height is used interchangeably with thread depth (reproduced with permission from Walters Kluwer Health).

Bone density was measured on each limb by calculating the cross-sectional geometry of the cortical bone (11, 12). The bone densitometry measurements were used to set parameters for inclusion into the study. The criterion for inclusion was defined as greater than 40% cortical area for each specimen.

All cadavers underwent a transverse osteotomy of the medial malleolus at the level of the ankle joint simulating the Muller type B medial malleolar fracture seen in bi-malleolar and tri-malleolar ankle fractures. Care was taken to ensure that the ankle joint capsule and surrounding ligamentous attachments were preserved. For each of the paired specimens, bicortical or unicortical fixation was randomly assigned to each leg. The order in which the specimens were prepared was at random, based on their location in the storage facility. The bicortical group was fixated with two 3.5 × 70.0- to 75.0-mm solid core screws inserted perpendicular to the simulated fracture line that purchased the far cortex. The unicortical group was fixated with the typical arrangement of 2 partially threaded 4.0 × 40.0-mm cancellous solid core screws purchasing 1 cortex. All fixation was performed according to Arbeitsgemeinschaft fur Osteosynthesfragen (AO Foundation, Davos, Switzerland)/Association for the Study of Internal Fixation (AO/ASIF) technique with Synthes (Synthes, Inc, West Chester, PA) implants and instrumentation. Radiographs were taken of each specimen to confirm accurate placement of the screws (Figure 3).

Specimen Loading and Measurements

After fixation of the simulated fracture, a pilot hole was drilled through the mid-body of the talus and a threaded steel rod was inserted from medial to lateral. Five 0.09-inch diameter round metallic markers were then glued parallel to each side of the fracture to assist with video tracking. The specimen was then mounted on an Instron 8500 Plus (Canton, MA) system (Figure 4). A wire cable was attached to the steel rod 3.5 cm from the medial surface of the talus, and the other end was connected to the Instron 8500 Servohydraulic Test Fatigue System (Instron Worldwide Headquarters, Norwood, MA) crosshead. The wire cable was tensioned resulting in an eversion force applied to the foot and a distraction across the medial malleolar osteotomy, recreating the force of an avulsion fracture. The crosshead moved at a rate of 1.0 mm/s and the load was recorded at a rate of 1000 Hz. A Redlake HG 2K high-resolution camera (Cheshire, CT) captured the motion at a rate of 125 Hz. The load and high-speed video data were triggered simultaneously. This allowed the distraction, measured by the Tema 2.6 Motion-Tracking Software (Photo-sonics, Burbank, CA), to be correlated to the load for the duration of the test. Before testing and in accordance with our previous study, the authors determined that a 2-mm gap at the osteotomy site would constitute the clinical definition of fixation failure (13). A gap of 2 mm or more has been previously established as the standard threshold of displacement to indicate surgical intervention of an intra-articular fracture and to alter the joint contact surfaces (14). At this failure point, the force in Newtons was captured and recorded.

Statistical Analysis

Statistical analyses were performed using SPSS Statistic 17.0 software (Chicago, IL). A nonparametric paired Wilcoxon 2-tailed signed rank statistical analysis was performed for the variable force measured as 2 mm of displacement. Statistical significance was defined at the 5% ($P \leq .05$) level.

Results

All specimens met the inclusion criteria and the bone density analysis results are described in Tables 1 and 2. The cadaveric specimens did not demonstrate any statistically significant difference in respect to noncortical area (mm^2), total cross-sectional area (mm^2), percentage of cortical area, and cortical area (mm^2) when comparing the unicortical fixation group to the bicortical group as demonstrated by *P* values. The median force recorded at 2 mm of distraction using