

# Are Hook Plates Advantageous Compared to Antiglides Plates for Vertical Shear Malleolar Fractures?

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## Abstract

This study was designed to evaluate the biomechanical properties of a hook plate (HP) vs an antiglide (AG) plate for supination-adduction (SAD)-ankle fractures. Identical polyurethane tibial models were obtained and vertical fractures were created. The fractures were stabilized with 1 of the following: one-third tubular plate in an AG fashion with 2 screws proximal to the fracture; an AG plate with an additional screw perpendicular to the vertical shear fragment (MAG), or an HP.

Ten models were randomly assigned to each of the 3 groups. The constructs were tested in offset-axial loading and were evaluated for construct stiffness and load-to-failure. The MAG construct yielded better stiffness compared with the AG plate ( $P < .05$ ) and the HP ( $P < .05$ ). The plate stiffness of the HP construct compared with the AG was not significant ( $P = .350$ ). In regards to load-to-failure, the difference between MAG and AG was 638 N, and MAG and HP was 530 N (both  $P < .05$ ). The HP had a load-to-failure that was, on average, 108 N more than the AG but was not significant ( $P = .063$ ). A one-third tubular plate in the MAG fashion provided a stable, strong construct for fixation of vertical shear medial malleolus fractures.

describes, this fracture is caused by forceful adduction of the supinated foot. There are 2 stages of the fracture pattern: the injury usually occurs first on the lateral side of the ankle with injury to the soft tissues or a low transverse fracture of the distal fibula. With continued force, in the second stage, the talus causes a shearing of the medial malleolus, creating the vertical shear fracture pattern.<sup>4,7</sup> The vertical shear medial malleolus fracture pattern is the subject of this investigation.

Several techniques have been traditionally recommended for fixation of SAD-type ankle fracture, including: a 2-screw construct without plate fixation, oriented perpendicular to the fracture; and an AG plate construct with variable positioning and numbers of screws for fixation. There have been, however, only 2 published articles about the biomechanical properties of fixation of vertical shear medial malleolar fractures, which reported conflicting results.<sup>8,9</sup> The most recent of these studies argued that one-third tubular plate fixation offers significant mechanical advantage over screw-only fixation, supporting the use of AG plates for fixation of SAD ankle fractures.<sup>8</sup>

An additional design for fixation of medial malleolus fractures has been introduced, consisting of a hook plate (HP) contoured for the medial malleolus. To our knowledge, no studies have investigated HP's biomechanical properties. Thus, the objective of this study was to investigate and compare the biomechanical properties of 3 constructs for fixation of SAD-ankle fractures: an antiglide (AG) plate, an AG plate with an additional lag-screw across the fracture, and a precontoured HP.

## Materials and Methods

Thirty 4th-generation-composite polyurethane models of the left tibia were obtained (Sawbones,

**S**upination-adduction (SAD)-type fractures of the ankle comprise approximately 5% to 20% of ankle fractures.<sup>1-3</sup> As the name

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Pacific Research Laboratories, Inc.). Largely, our methods accorded with the precedent set by other studies on these fracture types.<sup>8,9</sup>

Prior to creation of the fractures, each model was individually evaluated for pretest stiffness by using the slope of the linear portion of the load-displacement curve during offset-axial loading. This demonstrated the baseline elasticity of the models during loading. Assessing pretest stiffness was performed to reduce potential variables in the stiffness of individual models in the analysis of the testing data.

The models were numbered 1 through 30 on the shaft and on the medial malleolus. A custom jig was constructed with a table saw to create identical vertical shear medial malleolar fracture patterns in each model. The jig created the vertical shear SAD fracture described by Lauge-Hansen.<sup>7</sup> All models were randomly assigned to 1 of 3 groups; each group consisted of 10 models (**Figures 1A, 1B**).

The 10 specimens in group 1 were fixed with a 5-hole, 3.5-mm, one-third tubular plate (Smith & Nephew) in a traditional AG fashion. The plates were placed at the same location on all tibiae. The proximal hole and the hole closest to the fracture line were filled with 3.5-mm cortical screws, which were long enough to achieve bicortical fixation. No lag screws were placed in this specimen group. In group 2, specimens were fixed with the same plate used in group 1 (Smith & Nephew). In this modified AG (MAG) construct, specimens were fixed identically to group 1 for plate placement and fixation of the 2 proximal screws. In this group, an additional screw was placed perpendicular to the fracture and parallel to the distal tibial articular surface. In both groups (AG and MAG), the plates were not bent before application.

Group 3 consisted of specimens fixed with a 5-hole, precontoured medial malleolar HP (Arthrex). This HP construct was fixed with two 3.5-mm cortical screws long enough to achieve bicortical fixation. The plate also engaged the bone at the tip of the medial malleolus by using 2 sharp prongs. The screws were placed in the most proximal hole and the hole just proximal to the fracture line. No lag screws were placed in the HP construct.

All models were tested in offset-axial loading to replicate a SAD moment similar to previous studies. To test offset-axial loading, a vice held each model identically with a 17° angle from the longitudinal axis (**Figure 2**). Loading was performed with a material testing system; a material testing system plunger was directed at the inferior articu-



**Figure 1.** Two views (A, B) of the models after fixation with the 3 different constructs. From left to right: 2-screw construct, 3-screw construct, and hook plate.



**Figure 2.** Offset-axial loading at 17° from vertical.

lating cartilage surface of the medial malleolus. The specimens were loaded at a rate of 1 mm/sec until 2 mm of displacement was reached (**Figure 3**) or catastrophic failure occurred. The raw data analyzed consisted of the initial stiffness of the construct and the overall load-to-failure. The slope of the linear portion of the load-displacement curve of stiffness determined stiffness of the construct.

One-way analysis of variance with post hoc Tukey HSD data analysis was performed to determine if there were statistical differences among the different fixation constructs during load-to-failure. To prevent skewing of results by different

values of model elasticity, pretest stiffness was accounted for by calculating a ratio of construct stiffness as a function of pretest model stiffness. Total force-to-failure was the recorded maximum force (in N) to cause failure. A *P* value of  $< .05$  was set for significance. All data were analyzed using SPSS software (SPSS Version 15.0; SPSS Inc.).

## Results

Analysis of pretest stiffness showed no significant difference among models ( $P = .490$ ). All models failed by a gap of 2 mm at the distal fracture site except for 3 models in the MAG group. These 3 models failed at a much higher load than the remainder of the models and failed by fracture of the models.

The MAG group demonstrated significantly superior stiffness to the 2 other models tested (**Figure 4**). On average, this group required 753.5 N of force before failure. This was 530 N higher than the HP ( $P < .05$ ) and 638 N higher than the AG constructs, respectively ( $P < .05$ ). The HP and AG groups required forces of 223.2 N and 115.5 N for failure, respectively. These numbers were not significant ( $P = .063$ ).

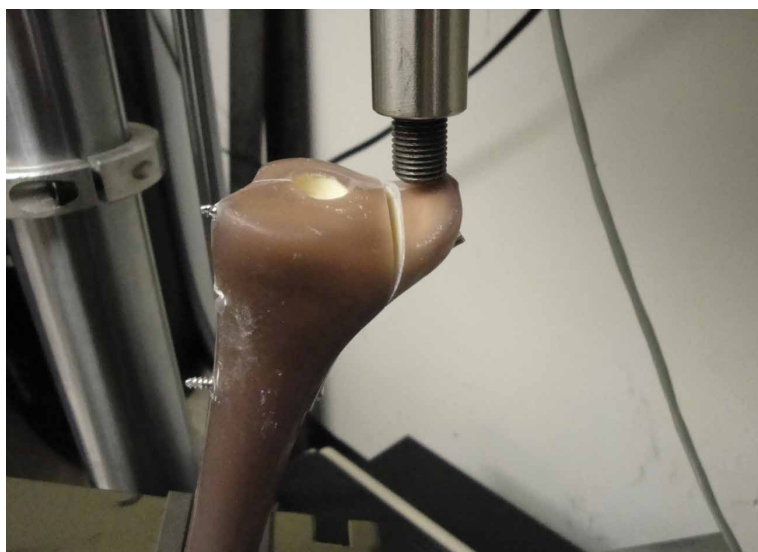
The absolute construct stiffness and construct stiffness as a function of pretest stiffness of the MAG group was the highest of all groups, 271.7 N/mm and 57.2%, respectively (**Figure 5**). These numbers showed significance when compared with the values of the HP group ( $P < .05$  for both) and the AG group ( $P < .05$  for both). The average stiffness of the HP group was 159.7 N/mm, which was 36.8% of pretest stiffness.

The AG group had the lowest construct stiffness and percent of pretest stiffness (128.1 N/mm and 29.6%). The HP and AG groups were not statistically different in these comparisons,  $P = .350$  for construct stiffness and  $P = .395$  for percent of pretest stiffness.

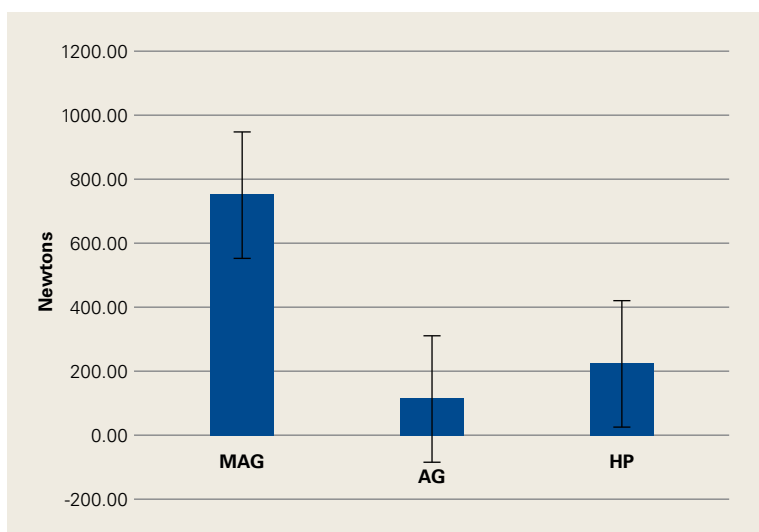
## Discussion

These results support the use of a one-third tubular plate and lag-screw construct for fixation of vertical shear medial malleolus fractures. This is clinically important because one-third tubular plates with 3.5-mm screws are readily available and cost significantly less than a precountoured anatomic-specific type of fixation. These results are based on the biomechanical properties of the constructs tested in this study.

The previous 2 studies<sup>8,9</sup> showed conflicting results about the most biomechanically sound fixa-



**Figure 3.** Representative failure at 2-mm displacement.



**Figure 4.** Load-to-failure of all 3 constructs. Abbreviations: AG, antiglide; HP, hook plate; MAG, modified antiglide.

tion for SAD medial malleolar fractures. The study by Toolan and colleagues<sup>9</sup> reported that 2 screws placed perpendicular to the fracture demonstrated the strongest overall construct. This study compared 3 separate types of 2-screw-only fixations and 2 plate-and-screw fixations. One construct was similar to the AG group in our study, and the other construct had a lag screw at the apex of the fracture. This previous study,<sup>9</sup> however, did not investigate a similar construct to the MAG group that was tested in our study.

According to Dumigan and associates,<sup>8</sup> a construct that consisted of a 4-hole plate with 2 screws proximal to the fracture and 2 lag screws showed the strongest fixation. This study, however, did not include a group like our study's AG group, which is the traditional AG form of fixation.

In our study, we examined the biomechanical properties of a traditional fixation (AG construct), a commonly used fixation (MAG construct), and a newer construct (HP construct). The HP group is unique to this study and, to our knowledge, there is no literature on its use as fixation for this fracture. We did not include a 2-screw-only group, which is a limitation, because this fixation type is not common for the SAD fracture. This study also did not include an HP construct with an additional lag screw, which is an available option as well.

The current investigation used synthetic bone models constructed for biomechanical testing. The models were thought to provide a consistent model for fixation as opposed to using potentially osteopenic cadaveric bone. Each model was the same size and laterality. The stiffness as determined by pretest stiffness was not significantly different among models. Because all models were similar in composition and size, this allowed for more consistent osteotomies and similarly sized malleolar fragments. Theoretically, this allowed a more uniform comparison of all specimens and constructs.

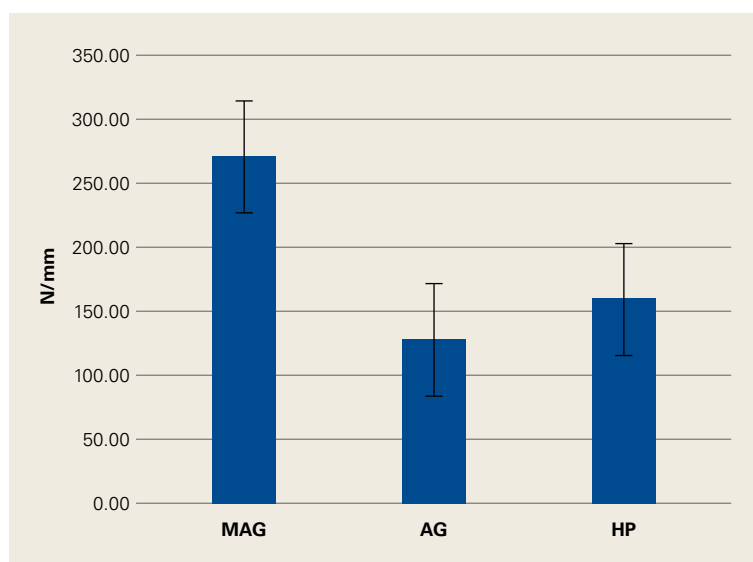
Using models, however, is a limit of this study. While the models were of similar biomechanical quality, it is possible that a model may not reproduce the biology of a cadaveric specimen or the physiology of a construct in vivo. Of the 2 studies that investigated SAD fractures, the Dumigan study<sup>8</sup> used cadaveric specimens. The fact that these models were all mildly osteoporotic and were embalmed specimens were study limits. The Toolan study<sup>9</sup> used synthetic models. Although these models were consistent, they were models of bones and not intended for biomechanical studies,

thereby increasing the potential for skewed results.

Our study investigated loading only in the offset-axial direction, a difference when compared to the Dumigan and colleagues<sup>8</sup> and Toolan and colleagues<sup>9</sup> studies. The offset transverse loading previously investigated would most likely represent an external rotation moment. While fixation in vivo could experience an external rotation moment, the specific fracture pattern of interest fails in offset-axial loading. In the original description of the SAD fracture, Lauge-Hanson<sup>7</sup> stated that the talus causes the vertically oriented medial malleolar fracture in the extreme of ankle supination with an adduction moment. Considering this, we investigated failure with a force in the direction that causes this type of fracture.

There are some additional limitations. This study demonstrated superiority of a one-third tubular plate with 2 screws proximally and 1 lag screw. While this was shown in the laboratory under pure offset-axial loading conditions, this may not reproduce daily forces experienced by the constructs. Additionally, this study examined load-to-failure of the constructs and did not investigate cyclic loading that a construct would experience in vivo. Because the testing is not recognizably consistent with day-to-day stresses of these constructs in vivo, this confounds the clinical application of our study.

The stiffness required for clinical healing is undetermined and, therefore, all 3 types of fixation could be adequate clinically. Patients are typically instructed to adhere to weight-bearing limitations



**Figure 5.** Construct stiffness among the 3 groups. Abbreviations: AG, antiglide; HP, hook plate; MAG, modified antiglide.

on the affected extremity, and casts or splints are applied postoperatively for extended periods of time. Clinical studies would have significant benefit in the evaluation of fixation of vertical shear medial malleolar fractures.

## Conclusion

AG plating technique with lag-screw placement is biomechanically superior to the other 2 constructs investigated. The clinical applications of these results are not known, and clinical trials are suggested to determine the best type of fixation for SAD-type medial malleolar fractures.

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