The antiglide plate for distal fibular fixation. A biomechanical comparison with fixation with a lateral plate

JJ Schaffer and A Manoli
J Bone Joint Surg Am. 1987;69:596-604.

The Antiglide Plate for Distal Fibular Fixation

A Biomechanical Comparison with Fixation with a Lateral Plate*

BY JOHN J. SCHAFFER, M.D.†, AND ARTHUR MANOLI, II, M.D.†, DETROIT, MICHIGAN

From the Department of Orthopaedic Surgery, Wayne State University School of Medicine, Detroit

ABSTRACT: Posterior antiglide plates recently have been introduced as a method of fixation for the short oblique fracture (Type B, as defined by the AO Group) of the distal part of the fibula. This method has several advantages over the more commonly used lateral plate for the fixation of this type of fracture, including dissection of a smaller area and less operative time, minimum bending of the plate, and no potential for penetration of a screw into the joint. The system can also be applied without insertion of a screw into the distal fragment. This prompted us to compare the biomechanical properties of fixation with the antiglide and lateral plating systems.

Short oblique fractures of the distal part of the fibula were produced mechanically in cadaveric legs by supination and external rotation of the foot. The torque that was necessary to produce the fracture in each of twenty-four fibulae was recorded. After fracture, each fibula was reduced anatomically and fixed internally with a lateral plate or antiglide plate applied posteriorly. The strength of fixation was measured by restressing the legs until failure of fixation occurred. The stiffness of the fixation system and the amount of energy required to produce failure of fixation were also calculated.

The system using the lateral plate for fixation failed when the torque reached an average of 64.3 per cent of the torque that produced the fracture. For antiglide plates, this value was 77.2 per cent. This difference was significant ($p < 0.01$). The stiffness of the fixation system with the lateral plate (4.8 newton-meters per degree) and the energy that was absorbed until failure (290 newton-meter degrees) were both significantly less ($p < 0.05$) than comparable values that were obtained for the antiglide plate (14.9 newton-meters per degree and 364 newton-meter degrees, respectively).

CLINICAL RELEVANCE: Fixation with an antiglide plate demonstrated superior static biomechanical properties, as compared with fixation with a lateral plate. This, together with the reported clinical advantages, makes it useful for the treatment of short oblique fractures of the distal part of the fibula.

* No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article. Funds were received in total or partial support of the research or clinical study presented in this article. The funding sources were departmental research funds of the Fund for Medical Research and Education, Wayne State University.

† Department of Orthopaedic Surgery, Wayne State University School of Medicine, 4201 St. Antoine 7C, Detroit, Michigan 48201. Please address requests for reprints to Dr. Manoli.

In many recent studies the importance of anatomical reduction and rigid fixation of displaced fractures of the fibula was emphasized[4,8,12,18]. While a number of methods (cerclage wires, single or multiple lag screws, an intramedullary Rush rod, or a single malleolar screw) are avail-

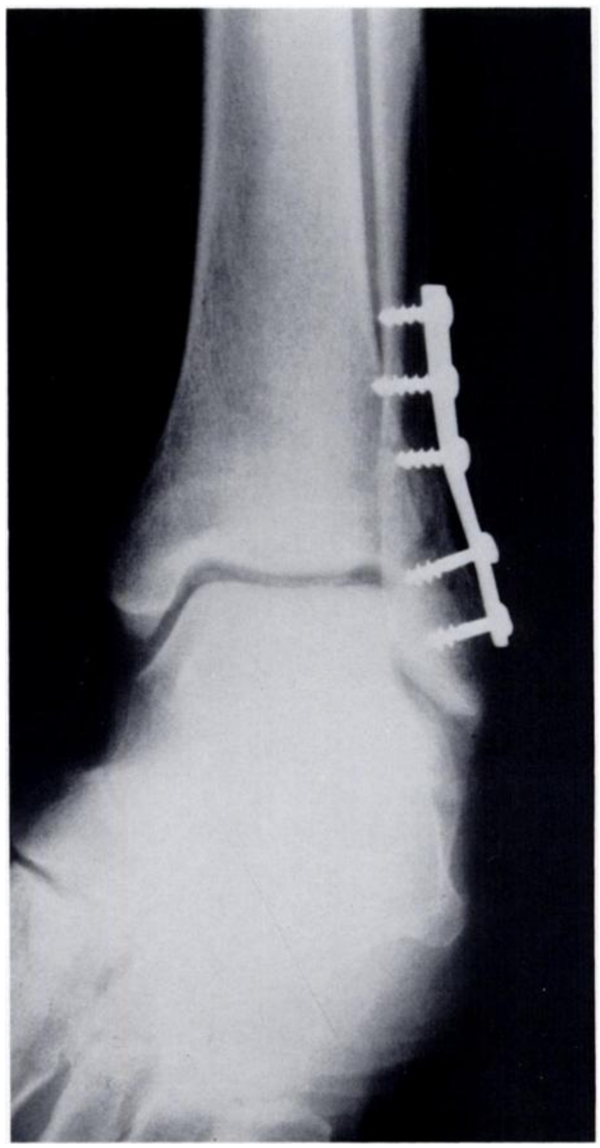

FIG. 1

Anteroposterior roentgenogram of a one-third tubular plate applied to the lateral aspect of the distal part of the fibula. Notice the improper bending of the plate, causing poor seating of the plate on the bone, and the two unicortical screws in the distal metaphysis where penetration into the joint is possible.

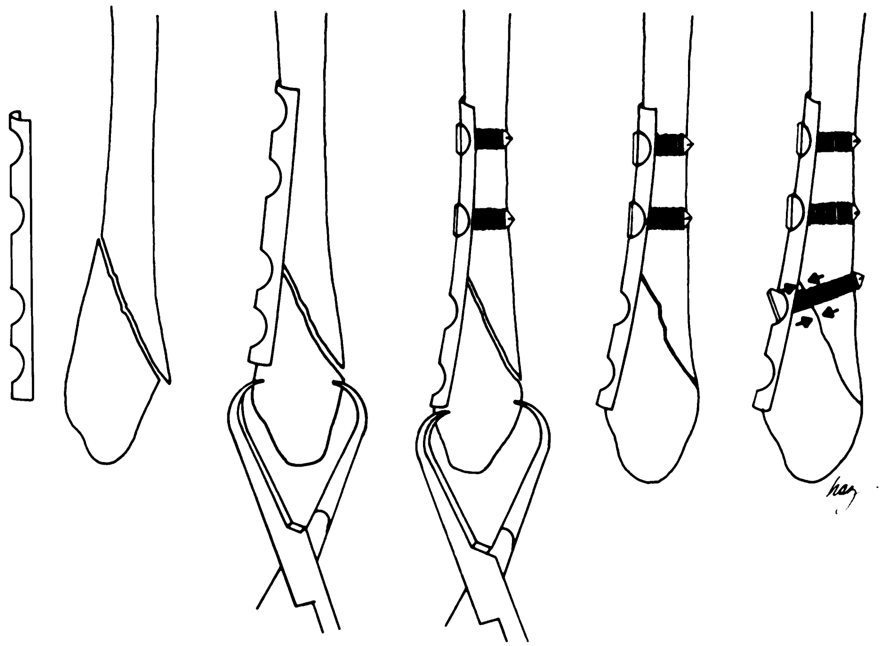

FIG. 2

Application of the antiglide plate to the posterior surface of the distal part of the fibula. The fracture is pulled out to length while a straight or slightly bent plate is applied across the site of the fracture. Two bicortical screws are inserted proximally. This bends the plate to the contour of the fibula and holds the fracture in a reduced position. An optional lag screw may then be inserted across the site of the fracture, if desired. (Redrawn and modified from Brunner, C. F., and Weber, B. G.: Special Techniques in Internal Fixation, p. 125. New York, Springer, 1982.)

able, the lateral plate, as advocated by the AO Group, has become widely accepted for the treatment of the short oblique fracture (Lauge-Hansen supination-external rotation or AO Type B[9]). However, some limitations to the use of the lateral plate exist. Application of the plate requires that it be bent accurately and often twisted along the long axis[3]. The screws in the distal fragment must be unicortical to avoid penetration into the joint, predisposing it to poor fixation in the primarily cancellous bone of the distal fragment (Fig. 1). In addition, the lateral plate is subcutaneous and tends to be painfully prominent under the skin and surgical scar.

In 1982, Brunner and Weber described the antiglide plate for fixation of the short oblique fracture of the distal part of the fibula. With this technique, a short plate is applied posteriorly or slightly posterolaterally, depending on the topography of the fibula, after the fibula is pulled out to length. Screws are placed through the proximal holes in a posterior-to-anterior direction. An optional lag screw may then be placed across the site of the fracture in an oblique direction, either through one of the distal holes in the plate or through the tip of the lateral malleolus (Fig. 2). While this technique was originally illustrated using a compression plate, more recently the use of a one-third tubular plate has been advocated[1,15].

In our brief clinical experience, the use of the antiglide plate appeared to have distinct clinical advantages over the lateral plating system. These advantages include dissection of a smaller area, less operative time, minimum bending of the plate, and no potential for penetration of the screw into the joint. However, with no purchase from a screw in the distal fragment, we questioned the strength of the fixation that is obtained by the antiglide plate. Therefore, a biomechanical study was done to determine the relative static strengths of fixation of the two systems.

Materials and Methods

Preparation of the Specimens

The experimental specimens were obtained from fresh-frozen cadaveric lower extremities and were prepared for study by thawing them in air for twenty-four hours before dissection. Each extremity was disarticulated at the knee, and all soft tissue except the interosseous membrane was removed from the proximal eight centimeters of the leg. This allowed for insertion of the leg into the testing apparatus.

Testing Equipment

The forces acting on the leg were generated by an Instron Model 1321 biaxial electrohydraulic testing system (Instron, Canton, Massachusetts). This instrument produced an angular displacement of the foot at the base of the limb-mount preparation. The torque that was required to produce the angular displacement was transmitted through the specimen and was sensed by a load cell at the top of the testing column. The data were plotted graphically on a recorder (Hewlett-Packard 7004B, Novi, Michigan), the amount of torque that was generated versus the angular displacement of the foot. Similarly, the instrument can simultaneously produce a displacement to shorten the limb. The required compression load was sensed by a second load cell.

Mounting Apparatus

The proximal end of the leg was held in an eight by

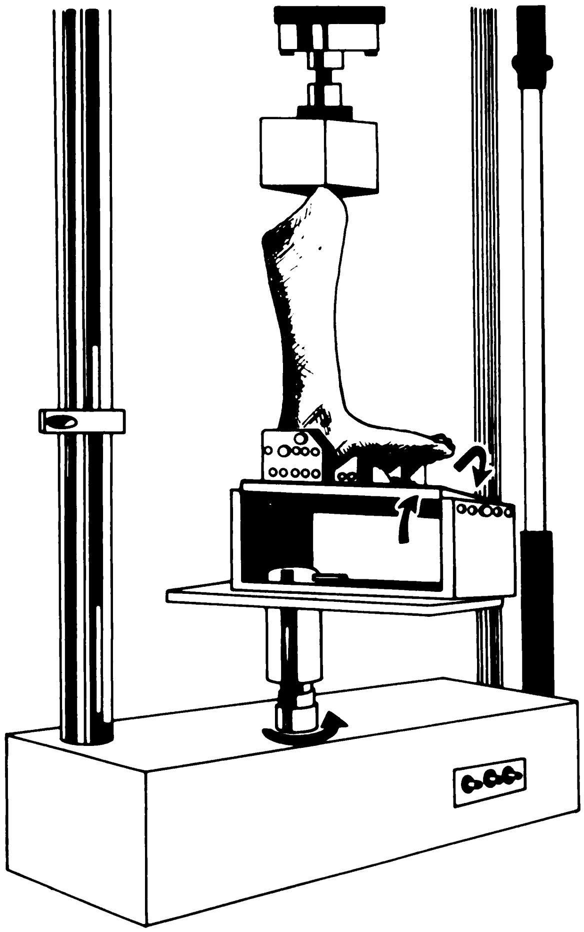

FIG. 3

Diagram of a specimen (left leg) in the testing column before production of the fracture. The foot is fully supinated and dorsiflexed before the platform is externally rotated, as indicated by the arrows.

eight by ten-centimeter aluminum box that was filled with molten potting material (Ostalloy 158; Die Supply, Macedonia, Ohio). With the box sitting on a lab bench, the heated, liquid potting material was poured into the open end. The proximal part of the tibia and the fibula was held upside down and inserted into the box. This position was maintained until the material cooled to a solid state. The specimen, tightly fixed in the box, was inverted and fastened to the load cell at the top of the testing column. The foot was held by a second adjustable aluminum box that was adaptable to the varying dimensions of the specimens. The foot rested on a platform within the box, which could be rotated to provide fixed supination-pronation positions and could be translated medially or laterally. This produced a consistent vertical orientation of the knee-foot axis and minimized any stress on the tibia from bending. Lastly, vertical fins on the surface of the platform, parallel to the long axis of the box, contained holes for four pointed bolts that were screwed into the calcaneus, securely fixing the specimen to the foot holder (Fig. 3).

Test Methods

The box containing the embedded, disarticulated leg was fastened securely to the load cell. The box for the foot was placed on the mobile table of the Instron test machine and was elevated until the heel touched the platform of the box. The foot was then supinated by hand through the subtalar and Chopart joints while the posterior pair of bolts was turned into the body of the calcaneus, securing the supinated position. The platform itself was then forcefully rotated by hand, further supinating the foot. At this point, the foot was brought into maximum dorsiflexion while the pair of anterior bolts was screwed into the calcaneus just inferior to the anterior facet (Fig. 3). A small wooden block was wedged under the first ray of the fore part of the foot to maximize and hold the supination-dorsiflexion position of the foot. Then, 147 newtons of axial load were placed on the system. The fracture was produced by externally rotating the table, which in turn rotated the box containing the foot at a rate of 100 degrees per second up to the maximum excursion of 50 degrees.

After removing the specimen, both the medial and the lateral malleolar regions were inspected and the deltoid ligament was examined visually. The fibular fractures were reduced and plated. Each specimen was reinserted and reloaded in the Instron test machine in an identical manner.

Application of the Plate

The plates were applied to the fibulae in a manner that is used routinely at our institution[9]. AO one-third tubular, four and five-hole plates were used. The five-hole plates were placed on the lateral side of ten fibulae. We found that it was necessary to use this longer plate, as a four-hole plate did not provide adequate purchase of the proximal fragment. Three bicortical 3.5-millimeter screws in the proximal fragment and two 4.0-millimeter cancellous screws in the distal fragment held the plate to the bone. The latter screws were inserted just deep enough to abut against the medial aspect of the cortex of the distal part of the fibula, thereby avoiding the joint. The plates were bent to conform to the contours of the lateral part of the fibular shaft, and the fixation system was loaded. The original protocol called for reloading the plated fibulae after the addition of a lag screw across the site of the fracture, as recommended by the AO Group[9]. However, the mechanisms of failure associated with the first test caused destruction of the distal part of the fibula such that the specimen could not be used further. Therefore, our lateral plating system for this fracture did not meet strict AO guidelines. However, we believe that our data are still relevant, since many examples of this plating method are found in the literature[8,14,17].

For all fourteen fibulae that were repaired with the antiglide system a four-hole plate was placed on the posterior surface of the fibula. The technique incorporated a subperiosteal dissection around the posterior and lateral portions of the distal part of the fibula. The peroneal tendon sheaths were then retracted posteromedially to allow for application of the plate. Preliminary studies comparing three and four-hole plates in this application showed four-hole plates to be necessary. Three-hole plates did not extend an adequate

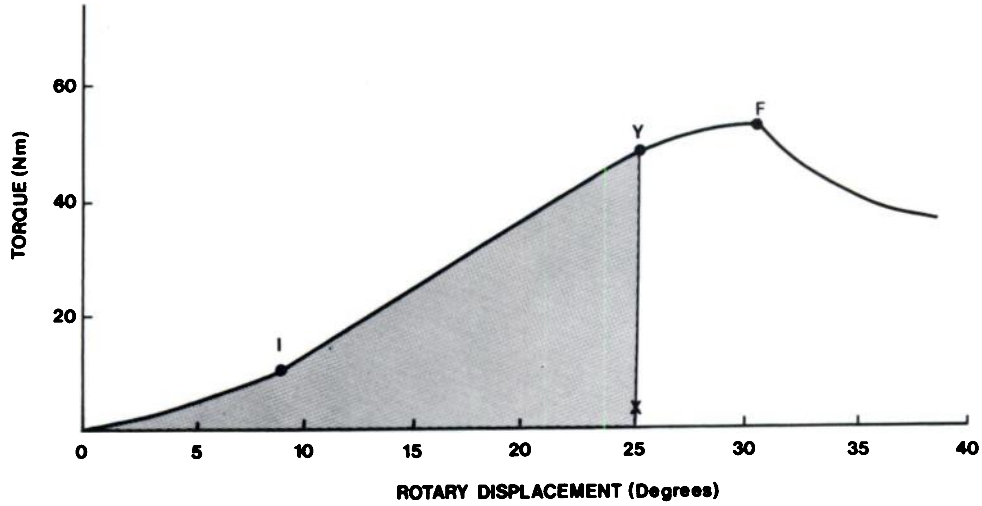

FIG. 4

The type of curve that was obtained as the foot was rotated. The plots were similar in appearance when the fracture was originally created, or when the fixation system was stressed. The portion of the curve, zero to I, represents the resistance of the soft tissue around the ankle. The portion I to Y is the segment when the stresses are directed against the distal part of the fibula before fracture, or against the fixation system before failure. The stiffness of the intact fibula and the entire system was calculated by finding the slope of the line in this section and was expressed as newton-meters per degree. Point Y marked the onset of fibular fracture or failure of fixation. The energy absorbed by the fixation system is the shaded area under the curve within the points zero, Y, and X. It is expressed as newton-meter degrees. F indicates the point at which the torque caused fracture or ultimate failure of the fixation.

distance distal to the fracture line, and as the system was reloaded the distal fragment of the fracture would roll out from under the end of the plate. Adequate reduction and fixation were produced by using a straight plate, or a plate that had been slightly underbent (radius of curvature of the plate greater than that of the adjacent fibula), and inserting two bicortical screws into the proximal fragment from a posterior to anterior direction.

Each specimen was then reloaded in the testing apparatus to obtain the strength of fixation. Additionally, the last ten consecutive fibulae that were repaired with the antiglide plate were reloaded one additional time to study the effect of adding a lag screw to the antiglide system. In these ten fibulae, a new antiglide plate was applied in a slightly more proximal position, utilizing new screw-holes in the fibular shaft. The lag screw was inserted through the plate, across the site of fracture, and into the anterior aspect of the cortex of the distal part of the fibula in a posterior-distal to an anterior-proximal direction.

Acquisition and Analysis of Data

The data were plotted as the amount of torque that was produced at the load cell versus the rotational displacement of the table. All plots were similar in appearance. A representative graph is shown in Figure 4.

Torque increased rapidly with rotation of the foot until the instant of fracture or failure of the fixation. At this point, the torque decreased sharply. Thus, these plots directly illustrate both the amount of torque and the amount of external rotation that were required to produce fracture or failure of the fixation. From these plots, both the stiffness of the intact fibula and the entire system and the energy that was absorbed until the onset of failure were measured. The stiffness of the intact fibula and the entire system was determined by obtaining the slope of the linear portion of the plot. With this data, the stiffness of the fixation system was calculated using the formula for series elastic elements (the reciprocal of the stiffness for the entire system = the stiffness of the intact fibula + the reciprocal of the stiffness of the fixation system). The energy that was absorbed until the onset of failure of the fixation was determined by measuring the area under the curve, as seen in Figure 4. Statistical analysis was done using the two-tailed Student t test.

Results

Medial Malleolus and Deltoid Ligament

All legs were carefully inspected for fracture of the medial malleolus or tears of the deltoid ligament. After examination of the malleolus and probing of the ligament under direct vision, none of the twenty-four legs were noted to have any pathological change on the medial aspect of the joint of the ankle.

Fibular Fracture

All fibulae exhibited a fracture line that began anteriorly at the level of the joint of the ankle or one millimeter distal to it (Fig. 5). The fracture line propagated directly posterior for a distance of approximately one-third of the diameter of the bone. From there the fracture line propagated in a posterior-superior direction at an angle of approximately 45 degrees to the long axis of the bone. Minimum comminution occurred occasionally at the point where the fracture line emerged through the posterior part of the cortex. With termination of the deforming force, the lateral malleolus was externally rotated and displaced both laterally and posteriorly, and slightly proximally.

Anterior Tibiofibular Ligament

Two of the twenty-four ankles had a pattern of injury that included avulsion of a portion of the fibular insertion of the anterior tibiofibular ligament in addition to the fracture of the fibular shaft. The ankles of the remaining twenty-two

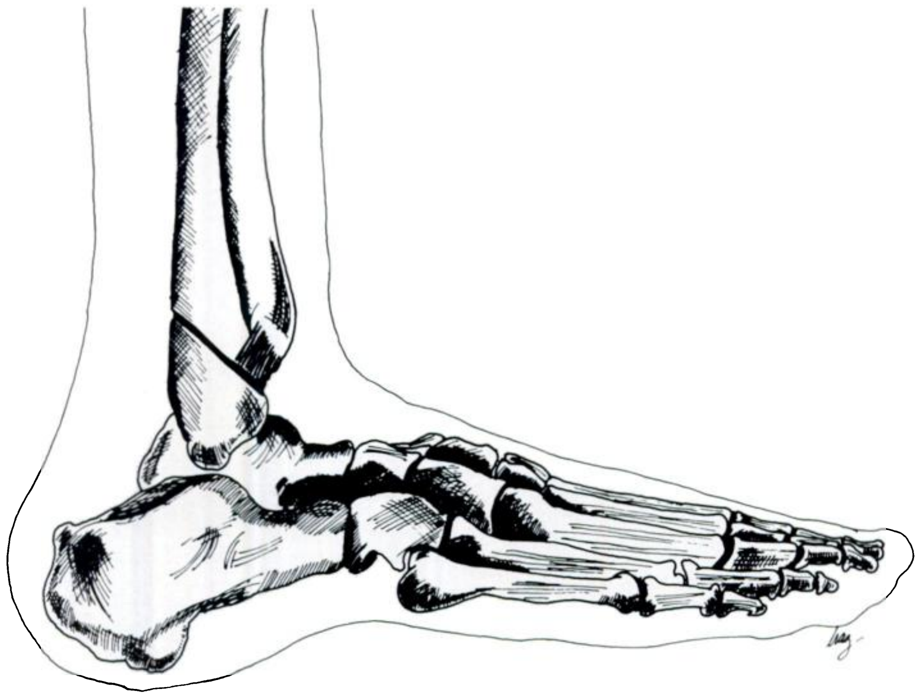

FIG. 5

The lateral side of the ankle, demonstrating the typical fracture that was produced. In this specimen, the fracture began anteriorly at the joint line distal to the insertion of the anterior tibiofibular ligament.

legs did not demonstrate any avulsion of bone or ligamentous disruption during the production of the fracture of the fibular shaft. In these legs the fracture line began on the anterior part of the cortex of the fibular shaft just distal to the insertion of the anterior tibiofibular ligament.

Posterior Tibiofibular Ligament

None of the ankles that were tested had any evidence of avulsion of bone or ligamentous damage to the posterior tibiofibular ligament.

Capsule of the Joint

The pathological changes that were noted in the capsule of all ankles were limited to the portion that attached to the anterior aspect of the distal part of the fibula. Here the capsular pathology varied from just attenuation of its fibers to complete separation of the capsule from the fibula.

Qualitative Analysis of Failure of the Fixation System

On reloading of the specimens, both the antiglide and the lateral plating systems demonstrated two distinctly different modes of failure that were related to the bone strength of the specimens. We defined bone strength as the amount of torque that was needed to produce fracture in each specimen.

The use of the lateral plate on bones with lower strength resulted in a distinct pattern of failure on reloading. A shearing force was created between the distal fragment and the plate. The distal fragment displaced posteriorly with external rotation and two distal screws pulled out of the cancellous bone of the lateral malleolus. Some minimum bending of the plate was seen in fibulae that had this type of failure, designated as Type I (Fig. 6-A).

With stronger bone, the pattern of failure was quite different when the lateral plate was used. These failures were designated as Type II. On loading, as the foot was rotated externally, the screws held in the denser bone of the distal fragment; however, a vertical fracture line was created through the screw-holes in the proximal fragment (Fig. 6-B).

Failure of fixation with the antiglide plate also differed in both the specimens with bone of low strength and those with bone of high strength. Although some bending of the plate was seen in both groups as the distal part of the fibular fragment rotated against the antiglide plate, the amount of bending was modified by varying degrees of pullout of the screw from the proximal fibular fragment. This deformation of the plate occurred at the location of the most distal bicortical screw in the proximal fragment. The amount of pullout of the screw was indirectly proportional to the strength of the bone. Therefore, in bone of low strength, failure of fixation was attributable primarily to pullout of a screw, with minimum bending of the plate. In bone of high strength, there was no pullout of a screw and failure of fixation was due solely to bending of the plate. Failure of the antiglide plating system with any amount of pullout of a screw was designated as Type III (Fig. 7-A). The remainder, without pullout of a screw, were called Type IV (Fig. 7-B).

Quantitative Analysis

The data on fibular fractures that were repaired with

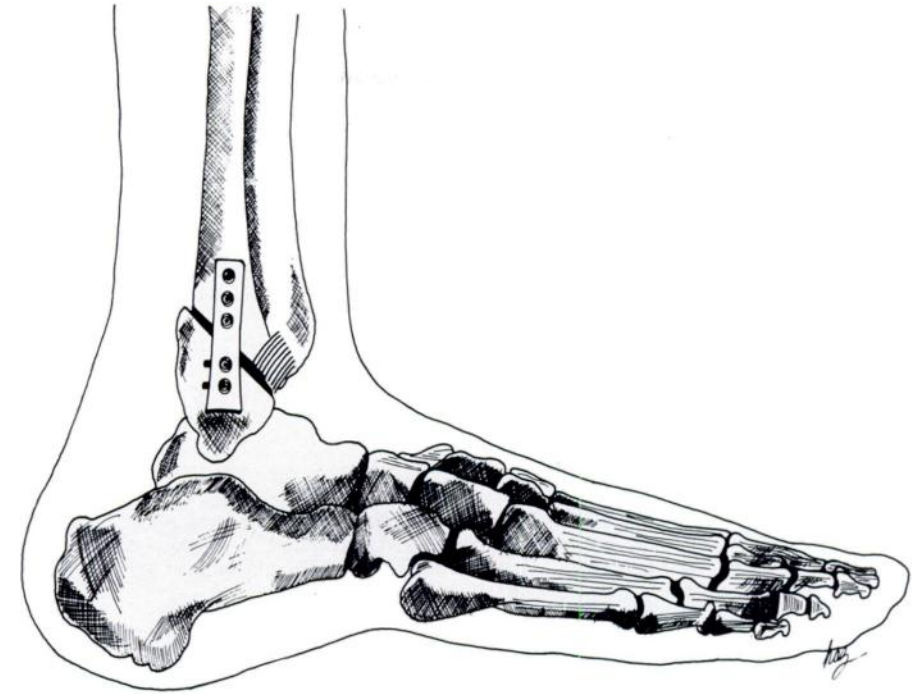

FIG. 6-A

Type-I failure. As the distal fragment is rotated and displaced posteriorly, the two screws in the distal fragment pull out.

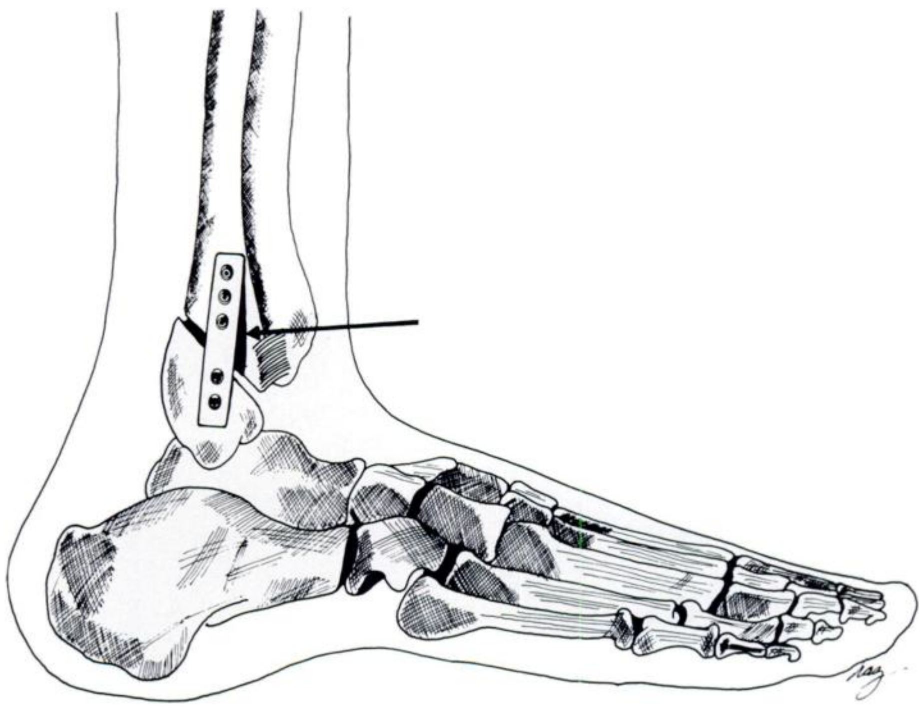

FIG. 6-B

Type-II failure. As the distal fragment is rotated and displaced, a longitudinal fracture is produced in the proximal fragment. The fracture occurs along the line of the screws in the proximal fragment and is seen here as the shaded area anterior to the plate, denoted by the arrow.

the lateral or with the antiglide plate are shown in Table I.

Observations on the Application of the Plates

A well contoured lateral plate achieved and maintained an anatomical reduction. Use of the plate required accurate bending in both the sagittal and the coronal planes to conform it to the lateral surface of the fibula, adding some difficulty to its application[3].

In contrast, the antiglide plate was applied easily to the posterior surface of the distal part of the shaft. In this position, the use of a straight plate or a plate slightly bent in the sagittal plane produced a congruous plate-bone in-

TABLE

BIOMECHANICAL PROPERTIES OF FIXATION OF FIBULAE

	Torque at Fracture (Nm)	Angle at Fracture (Degrees)	Stiffness of Intact Bone (Nm/Degree)	Torque at Failure† (Nm)
Failure‡				
Type I (n = 7)	40.3 ± 3.8	27 ± 2	1.8 ± 0.3	24.6 ± 4.6
Type III (n = 9)	40.9 ± 3.9	30 ± 3	1.9 ± 0.2	31.2 ± 4.1/31.3 ± 4.9
Type II (n = 3)	60.1 ± 9.3	29 ± 10	2.7 ± 0.2	42.8 ± 2.4
Type IV (n = 5)	60.5 ± 8.7	36 ± 5	2.7 ± 0.1	45.9 ± 2.3/46.5 ± 1.2
Fixation				
Lateral plates (n = 10)	46.2 ± 8.7	28 ± 5	2.1 ± 0.5	30.2 ± 9.5
Antiglide plates (n = 14)	47.9 ± 11.3	32 ± 5	2.2 ± 0.4	36.4 ± 8.2/35.9 ± 8.2

* All values are expressed as mean ± standard deviation.

† The numbers after the slashes are the results of retesting the system after the insertion of a lag screw across the site of fracture.

‡ Type-I failure — lateral plate: pullout of a screw from the distal fragment; Type-II failure — lateral plate: a longitudinal crack through the screw-holes in the proximal fibular fragment; Type-III failure — antiglide plate: pullout of a screw from the proximal fragment and bending of the plate; and Type-IV failure — antiglide plate: bending of the plate only.

§ NSD = no statistical difference.

terface. Occasionally, application of the antiglide plate to the posterior surface caused a small forward rotation of the distal fragment in the sagittal plane, which produced a one to two-millimeter gap at the posterior aspect of the fracture line. However, this gap was reduced easily by insertion of the lag screw. Thus, while the lag screw did not enhance strength of fixation, it did improve the reduction produced by the antiglide plate.

Discussion

The pathomechanics of an injury by supination and external rotation are controversial. The sequence of injury, as postulated by Lauge-Hansen, is marked by a disruption of the integrity of the anterior tibiofibular ligament before the fibular fracture. In his original description, all seventeen ankles that were subjected to this force showed avulsion of a bone insertion or intraligamentous tearing before the fibula fractured. This idea was mentioned widely by others[7,16]. This sequence has been questioned, however, by those who believe that the short oblique fracture of the distal end of the fibula can be produced with no injury to the anterior tibiofibular ligament[9,10]. Using our experimental model,

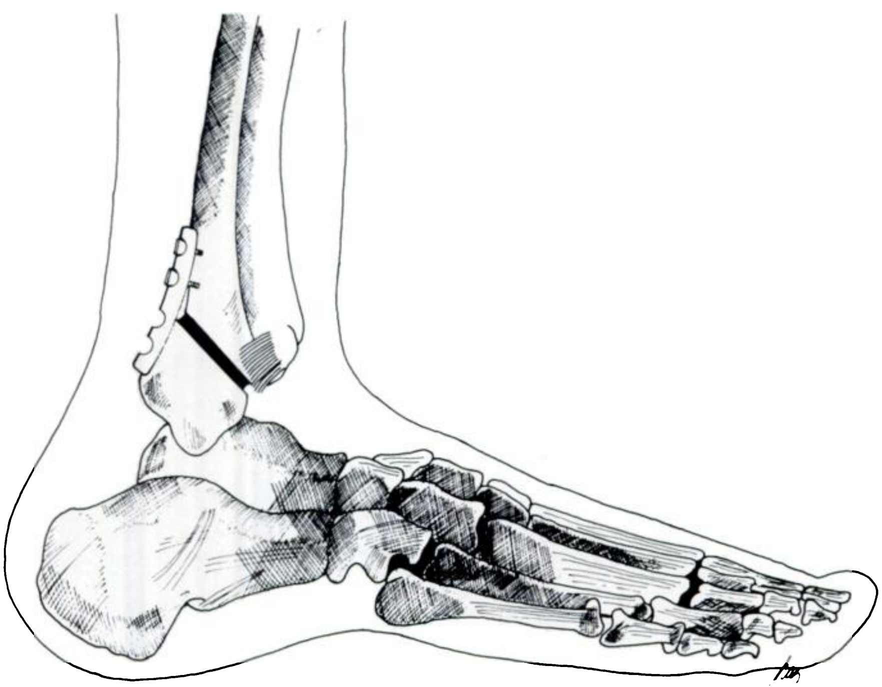

FIG. 7-A

Type-III failure. The screws in the proximal fragment pull out as the distal fragment is rotated against the antiglide plate. Minimum bending of the plate is seen here.

I

USING LATERAL AND ANTIGLIDE PLATING SYSTEMS*

Angle at Failure† (Degrees)	Per Cent Strength		Stiffness of Entire System (Nm/Degree)		Energy Absorbed (Nm-Degrees)		Stiffness of Fixation System (Nm/Degree)	
30 ± 2	61.1 ± 7.0	$p < 0.01$	1.1 ± 0.2	$p < 0.05$	240 ± 53	$p < 0.01$	2.8 ± 1.2	$p < 0.01$
32 ± 2/33 ± 2	77.4 ± 9.6		1.4 ± 0.2		322 ± 44		6.0 ± 1.6	
31 ± 3	71.9 ± 6.8	NSD§	2.0 ± 0.3	$p < 0.05$	405 ± 40	NSD§	9.6 ± 6.2	$p < 0.05$
31 ± 4/32 ± 3	76.8 ± 7.7		2.5 ± 0.2		440 ± 57		30.0 ± 11.4	
30 ± 2	64.3 ± 8.4	$p < 0.01$	1.3 ± 0.4	$p < 0.05$	290 ± 93	$p < 0.05$	4.8 ± 4.4	$p < 0.05$
32 ± 3/33 ± 3	77.2 ± 8.7		1.8 ± 0.4		364 ± 74		14.9 ± 14.0	

twenty-two of the twenty-four ankles had no ligamentous injury associated with the fibular fracture. The other two did have tearing of the anterior tibiofibular ligament. This discrepancy suggests that there may be several variants of the short oblique fracture of the lateral malleolus.

Exact anatomical reduction of the lateral malleolus is desirable in treating fractures of the fibula. Poor reduction of the distal part of the fibula by persistent lateral displacement[13,17] or residual shortening[8,12] will lead to a poor clinical result. Both the lateral and the antiglide plating systems can achieve an anatomical reduction. Maintenance of the anatomical reduction until union should lead to a good clinical result based on published criteria[5,11].

We think advantages of fixation with the antiglide plate are the enhanced strength and stiffness; therefore, it is better able to maintain the reduction until union occurs. In relatively weaker bone, both the lateral plate without a lag screw across the site of the fracture and the antiglide plate failed when the bone could not withstand the forces to which it was subjected. However, the location of the screws that pulled out differed, thus providing an explanation for the increased stability using the antiglide plate. Two bicortical screws in the proximal part of the cortex that were used with the antiglide plate had better purchase in the bone than the two screws in the cancellous bone of the distal part of the fibular metaphysis that were used with the lateral plate.

The fibulae with stronger bone showed different modes of failure. The antiglide plates deformed as the moment was transmitted through the firmly fixed screws. The lateral plates held the distal fragment securely enough to create a

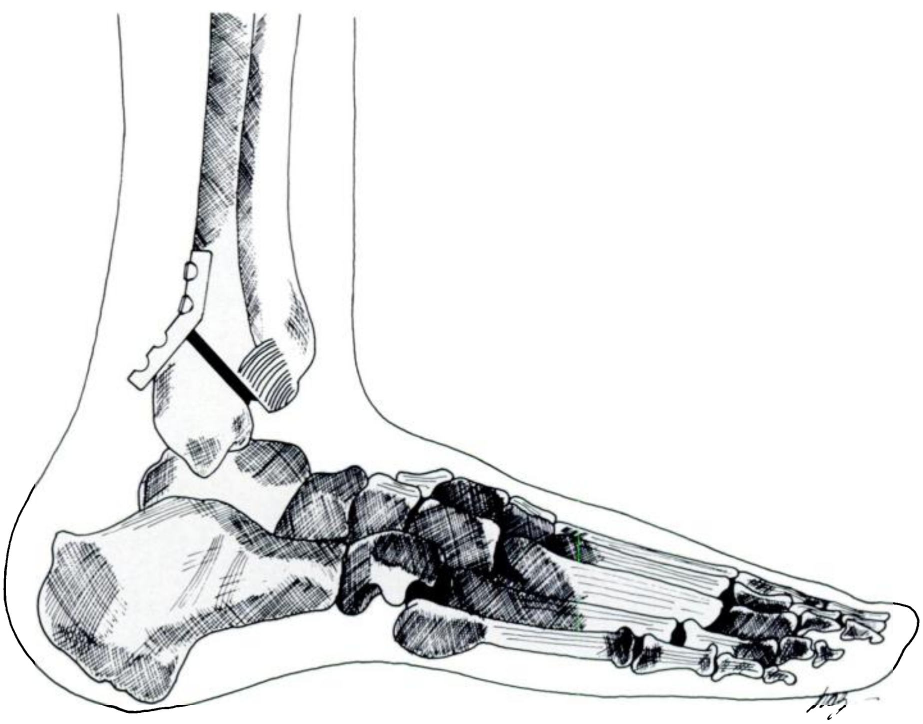

FIG. 7-B

Type-IV failure. In strong bone, the screws in the proximal fragment do not pull out, but rather the plate bends at the site of the most distal screw in the proximal fragment.

posteriorly directed force on the proximal screws, which vertically fractured the proximal part of the shaft through the line of the screw-holes. Again, analysis of the pattern of failure yields insight into the biomechanical difference of fixation with the two plating systems. Fixation with the lateral plate failed because the bone failed, while fixation with the antiglide plate failed strictly due to failure of the plate.

The superiority of the antiglide plating system, without a lag screw across the site of the fracture, over the lateral plating system was most evident at low and middle ranges of bone strengths and less evident for the stronger bones. Thus, the antiglide plating system is particularly advantageous for use in patients who have osteoporosis of any etiology.

There are two major goals of surgery for an intra-articular fracture: anatomical restoration of the normal anatomy and achievement of rigid stability to allow for early functional recovery. In our study the forces that normally are encountered during the period of recovery after fixation of this type of fracture were examined. Axial loading is not seen clinically, as patients who have this type of fracture are kept non-weight-bearing until union. Also, when these fractures redisplace after early reduction, the initial deformity is recreated. The improved fixation of the lateral malleolus with the antiglide plate would be better able to resist displacement of the fracture should the clinician choose to institute early motion. This may facilitate rehabilitation in patients who have this common injury.

Insertion of a lag screw through the antiglide plate and across the site of fracture did not alter the strength of fixation. When sufficient torque was generated to cause failure of the more proximal screws or bending of the plate, or both, the lag screw in essentially cancellous bone also pulled out easily. However, this screw did help obtain anatomical reduction of the fracture and it should be used, if possible.

References

1. BRUNNER, C. F.: Personal communication, Dec. 2, 1982.
2. BRUNNER, C. F., and WEBER, B. G.: Special Techniques in Internal Fixation, p. 125. New York, Springer, 1982.
3. DE SOUZA, L. J.; GUSTILO, R. B.; and MEYER, T. J.: Results of Operative Treatment of Displaced External Rotation-Abduction Fractures of the Ankle. J. Bone and Joint Surg., **67-A:** 1066-1074, Sept. 1985.
4. HUGHES, J. L.; WEBER, H.; WILLENEGGER, H.; and KUNER, E. H.: Evaluation of Ankle Fractures. Non-operative and Operative Treatment. Clin. Orthop., **138:** 111-119, 1979.
5. JOY, GREGORY; PATZAKIS, M. J.; and HARVEY, J. P., JR.: Precise Evaluation of the Reduction of Severe Ankle Fractures. Technique and Correlation with End Results. J. Bone and Joint Surg., **56-A:** 979-993, July 1974.
6. LAUGE-HANSEN, N.: Fractures of the Ankle. II. Combined Experimental-Surgical and Experimental-Roentgenologic Investigations. Arch. Surg., **60:** 957-985, 1950.
7. LEEDS, H. C., and EHRLICH, M. G.: Instability of the Distal Tibiofibular Syndesmosis after Bimalleolar and Trimalleolar Ankle Fractures. J. Bone and Joint Surg., **66-A:** 490-503, April 1984.
8. MITCHELL, W. G.; SHAFTAN, G. W.; and SCLAFANI, S. J. A.: Mandatory Open Reduction. Its Role in Displaced Ankle Fractures. J. Trauma, **19:** 602-615, 1979.
9. MÜLLER, M. E.; ALLGÖWER, M.; SCHNEIDER, R.; and WILLENEGGER, H.: Manual of Internal Fixation. Ed. 2, pp. 282-295. New York, Springer, 1979.
10. PANKOVICH, A. M.: Fractures of the Fibula at the Distal Tibiofibular Syndesmosis. Clin. Orthop., **143:** 138-147, 1979.
11. PETTRONE, E. A.; GAIL, MITCHELL; PEE, DAVID; FITZPATRICK, THOMAS; and VAN HERPE, L. B.: Quantitative Criteria for Prediction of the Results after Displaced Fracture of the Ankle. J. Bone and Joint Surg., **65-A:** 667-677, June 1983.
12. PHILLIPS, W. A.; SCHWARTZ, H. S.; KELLER, C. S.; WOODWARD, H. R.; RUDD, W. S.; SPIEGEL, F. G.; and LAROS, G. S.: A Prospective, Randomized Study of the Management of Severe Ankle Fractures. J. Bone and Joint Surg., **67-A:** 67-78, Jan. 1985.
13. RAMSEY, P. L., and HAMILTON, WILLIAM: Changes in Tibiotalar Area of Contact Caused by Lateral Talar Shift. J. Bone and Joint Surg., **58-A:** 356-357, April 1976.
14. SEGAL, DAVID: Displaced Ankle Fractures Treated Surgically and Postoperative Management. *In* Instructional Course Lectures, The American Academy of Orthopaedic Surgeons. Vol. 28, pp. 79-88. St. Louis, C. V. Mosby, 1979.
15. WEBER, B. G.: Personal communication, Dec. 17, 1983.
16. WILSON, F. C.: Fractures and Dislocations of the Ankle. *In* Fractures in Adults, edited by C. A. Rockwood, Jr., and D. P. Green. Vol. 2, pp. 1665-1701. Philadelphia, J. B. Lippincott, 1984.
17. YABLON, I. G.; HELLER, F. G.; and SHOUSE, LEROY: The Key Role of the Lateral Malleolus in Displaced Fractures of the Ankle. J. Bone and Joint Surg., **59-A:** 169-173, March 1977.
18. YDE, JOHANNES, and KRISTENSEN, K. D.: Ankle Fractures. Supination-Eversion Fractures of Stage IV. Primary and Late Results of Operative and Non-operative Treatment. Acta Orthop. Scandinavica, **51:** 981-990, 1980.