Early Weight Bearing After Posterior Malleolar Fractures: An Experimental and Prospective Clinical Study

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The distribution of axial load to the lower end of the tibia at different positions of the ankle joint for the anterior, middle, and posterior part of the joint was studied in both photoelastic models and fractured ankle joints in cadaveric specimens. Synthetic models were used to simulate both normal ankle joints and ankles with fractures of the posterior lip of the tibia. Tests were performed with the ankle at dorsiflexed, neutral-flexed, and plantarflexed positions of the ankle joint. The clinical portion of the study evaluated 15 patients with fracture of the posterior malleolus that comprised 0% to 33% of the articular surface. All patients had open reduction and internal fixation through a posterolateral or posteromedial approach, and were allowed full weight bearing in a cast within 7 days of surgery. In the simulated models, the posterior one fourth of the ankle joint remains unloaded in the majority of the cases. The stresses are greatly increased when the load is doubled and are mainly distributed to the 2 central quadrants. With additional axial load, the fourth quadrant sustained little increase in the load bearing. All patients have had an uneventful recovery. By the second postoperative month, they were able to walk normally and had a painless range of motion of the ankle. By the third month, all patients were able to undertake their daily activities, and all fractures were consolidated. The clinical relevance of this study is early weight bearing, after open reduction internal fixation of posterior malleolar fracture of the ankle joint, facilitates recovery, promotes fracture union, and allows the patient to assume normal activity by the third month after surgery. (The Journal of Foot & Ankle Surgery 42(2):99–104, 2003)

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Isolated fracture of the posterolateral tibial lip is a rather rare lesion. According to Neumaeir Probst et al (1), only 25 cases were seen in 2500 ankle lesions. Surgical restoration is the treatment of choice because “even minimal displacements of joint fragments will result in incongruity between the talus and the ankle mortise, resulting in secondary traumatic arthritis” (2). Two additional studies also emphasized the role of reduction of the posterior malleolus on the outcome after fracture (3,4). On the contrary, Rowley et al (5), in a prospective randomized trial of ankle fractures concluded that, in the early recovery period, there was no difference in the outcome between the surgically and conservatively treated groups. However, this study did not focus on the posterior malleolus.

Weight bearing after surgical reduction is not advocated until 8 to 12 weeks after surgery (2). Harager et al (6) reported that full weight bearing is recommended after open reduction and internal fixation, even in an elderly population. Tropp and Norlin (7) and Egol et al (8), in separate prospective studies, support the use of a functional brace because it provides superior results over plaster. Finally, van Laarhoven et al (9) and Dogra and Rangan (10), in their prospective studies, had equivocal results in those patients who were allowed early weight bearing.

The distribution of axial load forces applied to the lower end of the tibia and its articular surface, during ankle flexion-extension, has been studied by a number of investigators (11–14). Michelson et al (15) stated that there was no difference between the forces on the medial and on the lateral malleoli measured under static or dynamic conditions. Kura et al (16) reported no difference on the contact area of the ankle from unloaded to the loaded position in the medial, central, and lateral zones of the plafond. Unfortunately, there was there no determination of the isolated loading characteristics for the posterior zone in any of these studies.
Hartford et al (17) reported a significant decrease in tibiotalar contact area, with a fracture fragment of more than 33% involvement of the joint, as compared with the control samples. Macko et al (18) reported that the surface area of contact decreased with increasing size of the posterior malleolar fragment. However, neither of these investigations actually measured the forces with varying positions of the joint subjected to axial load.

Useful information for the reaction of bone to stress in loaded joints can be provided by a photoelastic model made of materials with double refractive properties (19–24). The purpose of this investigation was to study the distribution of forces to the tibial plafond at 3 different positions of flexion in a photoelastic model. This investigation also studied the same forces with a simulated fracture of the posterior malleolus. Lastly, we wanted to compare our findings with a small clinical series of patients with a posterior malleolus fracture who were allowed early weight bearing.

Materials and Methods

Laboratory Investigation

The models used in this study were made from 1-cm thick suboxided resin plates of a viscoelastic material. These models were reproduced from drawings of the lateral radiographs of normal ankle joints. To reproduce the fracture of the posterior lip of the tibia, the posterior third of the model was divided and then repaired with a specially constructed 3.5-mm lag screw made from Araldite (Vantico AG, Basel, Switzerland). A rubber sheet representing the articular cartilage was placed between the talus and the tibia. The distal articular surface of the ankle joint was divided in 4 quadrants, each one representing 25% of the articular surface as determined from the lateral radiograph.

The models were then stabilized on a specially constructed apparatus, holding the tibia on a vertical position and allowing the talus to be fixed in a neutral position, plantarflexion, and dorsiflexion. The models were loaded with 55 kg and 105 kg in 3 different positions of the ankle joint (neutral position, dorsiflexion, and plantarflexion). The loads were vertical in a line parallel to the longitudinal axis of the tibia. Each value was determined 3 times. Nine loading sequences were performed for both the fractured and the nonfractured models.

After loading of the model, the photoelastic fringe patterns were observed as a series of successive multicolored bands. Each band represented a different degree of birefringence, corresponding to the realized stress in the test model (22). The isochromatics were plotted on a scale from 0 to 90 in 10-unit increments and converted to a whole number. The numbers indicate the relative magnitude of the stress.

Clinical Investigation

From 1981 to 1996, 15 patients with fracture of the posterior malleolus representing one fourth to one third of the articular surface were admitted for treatment. The size of the fracture of the posterior margin of the tibia comprised more than one fourth and less than one third of the articular joint space. All of them underwent open reduction internal fixation by the senior author (G.P.) through a posterolateral or posteromedial approach. A walking cast was then applied, and the patients were allowed to bear weight on the injured extremity to tolerance after the first postoperative week.

The criteria used for clinical assessment were pain, swelling, range of motion and stiffness, walking distance with or without use of a walking stick, and return to work and/or to previous level of activities. The patients were assessed clinically and radiographically after the removal of plaster (2 months after surgery), 3 months after surgery, and 24 months after surgery.

Results

Laboratory Investigation

In the normal joint in neutral position with 55-kg load, the first quadrant, representing the most anterior part of the joint, is partially loaded (Fig. 1). In the second and third quadrant of tibia, the isochromatic value was 2. The fourth quadrant, representing the most posterior part of the joint, remains dark with an isochromatic value of 0. When the joint is loaded with 105 kg, the first quadrant becomes completely unloaded (Fig. 2). The load to the second and third quadrants increased, with an isochromatic value of 5. The load also extended to the anterior half of the fourth quadrant, and showed an isochromatic value of 1.

With the joint model placed in dorsiflexion and loads of 55 kg and 105 kg were applied, both the second and third quadrants had isochromatic values of 2.5 and 5, respectively. With the 55-kg force, the first and fourth quadrant did not absorb load, but had minimal load with the 105-kg force. With the normal joint placed in plantar flexion, the anterior 3 quadrants had an isochromatic value of 3 after a 55-kg load was applied. When a 105-kg load was applied, the isochromatic value increased to 6. In both load applications, the posterior or fourth quadrant remained unloaded.

A simulated fracture of the posterior one third of the tibia was created in the models and was followed up with precise reduction and screw fixation (Fig. 3). The fractured model with the joint in neutral position had loads of both 55 kg and 105 kg applied. The anterior quadrant was partly loaded only during the larger load. The second and third quadrant
had isochromatic values of 3 and 6, respectively, whereas the fourth quadrant remained dark (unloaded).

With the simulated-fracture model in dorsiflexion, the isochromatic values in the second and third quadrant with both loads were 3.5 and 7, respectively, whereas the first and fourth quadrants were partly loaded. With the joint in plantar-flexion, both loads produced isochromatic values in the first, second, and third quadrants of 4 and 7, respectively, whereas the fourth quadrant remained dark (unloaded).

Clinical Investigation

Four patients were men and 11 were women, with an average age 48.8 years (range, 14 to 73 years). The left ankle was involved in 8 patients, and the right ankle was involved in 7. Four patients sustained a fracture of the fibula distal to the joint line and fracture of the medial malleolus, 8 patients sustained a fracture of the medial malleolus and an oblique fracture of the fibula at the joint line, 2 patients had fracture of the fibula proximal to the joint line and a fracture of the medial malleolus, and 1 patient sustained a fracture of the upper one third of the fibula and rupture of the syndesmosis.

All patients had an uneventful postoperative recovery. At the time of the initial postoperative evaluation (2 months after surgery), the 4 patients with fibular fractures below the joint line had no pain and had a complete return to activity. There were no changes in the clinical course in subsequent visits.

The 8 patients with the oblique fracture of the fibula at the joint line, 7 presented with a normal ankle joint, whereas 1 complained of mild pain during walking and occasional swelling at 2 months after surgery. At 3 months after surgery, all patients with this fracture pattern had a normal ankle.

At the time of initial evaluation of the remaining 3 patients with fibular fractures above the level of the ankle joint, all had to use a walking stick for almost a month and complained of postural swelling after walking or in the evening. These complaints dissipated by the second evaluation (3 months after surgery) and none were using a walking stick (Fig. 4). By the third month, all patients were able to undertake their daily activities, and all fractures were consolidated.

At the time of final evaluation (2 years after injury), none of the patients in any of the groups had any complaints and were able to resume their respective preinjury activity levels. There were no radiographic signs of arthrosis in any patient.
Discussion

According to Fessler (19), the arrangement of the stress trajectories in the photoelastic model is similar to that of the trabeculae in the actual bone. Furthermore, the photoelastic model may provide information concerning the stress distribution in bones and in joints. Forty-one years later, Hirokawa et al (26) used the photoelastic coating method to analyze the stress-strain relationship of the anterior cruciate ligament. Maquet et al (20) have investigated the distribution of forces on a normal knee joint, with the load applied to various positions of the joint. They concluded that the stresses of a photoelastic model are symmetrically distributed if the weight is centrally applied to the weight-bearing surface. If the applied load is shifted laterally, the distribution of the stress becomes totally modified. They also showed that the obliquity of the bearing surface does not modify the distribution characteristics. These investigations support our use of a photoelastic model to determine the stress distribution with various loads to the distal end of the tibia.

In this study, the fringe isoclines are parallel to the

FIGURE 3 Fracture of the posterior lip of the tibia and the medial malleolus.

FIGURE 4 Three-month postoperative radiograph after open reduction and internal fixation. The fracture remained undisplaced, despite early weight bearing, and is fully consolidated.
longitudinal axis of the tibia, and indicate the direction of the main compressive stresses. These lines are independent of their magnitude (19). Lines perpendicular to these indicate the direction of the main tensile stresses. The areas in which the fringe lines become denser indicate the concentration and magnitude of the load. The isochromatic patterns, in all of the parts of these experiments are almost the same, although their distribution is not regular depending on the position of the ankle joint. It is obvious that the main stresses are exerted on the second and third central quadrants, whereas the first quadrant is only partly loaded. The fourth quarter remains dark in the majority of the trials, which means that is not loaded. In a few trials, it becomes partially loaded. The stresses are greatly increased (denser lines), when the load is increased to 105 kg and are mainly distributed to the second and third quadrants, whereas the fourth quadrant continues to be unloaded except when the ankle is dorsiflexed.

This qualitative photoelastic study of the distal epiphysis of the tibia allows us to extrapolate that the main load bearing areas are the central 2 quadrants. The first one is partly loaded, whereas the fourth one is almost unloaded, even when it is loaded to 105 kg. Clinically, this could allow for weight bearing in patients with a surgically repaired posterior malleolus fracture, as long as the ankle is in neutral position. Compressive forces are observed along the fracture line in the simulated model, but are attributed to the lag screw.

The clinical portion of this investigation examines the effect of early weight bearing on the posterior malleolus after open reduction. Some authors (2,3,18) suggest that even minimal displacement may lead to post traumatic arthrosis. Hartford et al (17) and Macko et al (18) investigated the contribution of the posterior malleolus on the contact area of the ankle joint. Both studies support the concept that, with increased size of the fracture, the joint contact area is diminished. Kura et al (16), measuring the surface contact area of the ankle joint, found that the contact area did not change significantly from an unloaded condition to one with a 667-N load in the medial, central, and lateral zones. Michelson et al (14) suggested that there was no difference between the forces measured under static or dynamic conditions.

Many authors support the concept that fractures of the ankle do well after surgical intervention and early weight bearing, either in a plaster cast or in a walking brace (5–8). Based on the results of the photoelastic model experiments, we evaluated a series of patients with fractures of the posterior margin of the tibia that comprise up to one third of the articular surface. We wanted to see if immediate weight bearing was possible after open reduction and internal fixation without displacement.

Our 15 patients were allowed to bear as much weight as tolerated with the help of crutches and the protection of a walking cast. Although our clinical series was small, the results were very promising. Patients obtained full function of the affected leg, and were able to bear weight on both legs during the recovery period. The plaster cast maintains the ankle in neutral position and protects the posterior malleolus from axial load.

Although our series was small and the photoelastic experiments were somewhat qualitative, the results indicate that it may be possible to permit earlier weight bearing than was previously thought. It would have been ideal to evaluate a series of patients who had surgical repair of isolated posterior malleolar fractures, but this is not clinically feasible because these fractures are quite uncommon. Because our bench testing divided the ankle into quadrants, we could not determine the loading characteristics of the area that would correspond to fracture fragments that were larger than one fourth of the surface but smaller than one third of the surface. Furthermore, it would have been preferable to institute a more formal clinical evaluation system, but we were mainly interested in looking at displacement of the posterior malleolus. Because we did not observe any such displacement, we concluded that weight bearing was an acceptable postoperative activity. Similarly, we could not determine if there was any associated risk of displacement with varying size of the posterior malleolar fragment.

References
