Anterolateral Versus Medial Plating of Distal Extra-articular Tibia Fractures: A Biomechanical Model

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abstract

Both medial and anterolateral plate applications have been described for the treatment of distal tibia fractures, each with distinct advantages and disadvantages. The objective of this study was to compare the biomechanical properties of medial and anterolateral plating constructs used to stabilize simulated varus and valgus fracture patterns of the distal tibia. In 16 synthetic tibia models, a 45° oblique cut was made to model an Orthopedic Trauma Association type 43-A1.2 distal tibia fracture in either a varus or valgus injury pattern. Each fracture was then reduced and plated with a precontoured medial or anterolateral distal tibia plate. The specimens were biomechanically tested in axial and torsional loading, cyclic axial loading, and load to failure. For the varus fracture pattern, medial plating showed less fracture site displacement and rotation and was stiffer in both axial and torsional loading (P<.05). For the valgus fracture pattern, there was no statistically significant difference between medial and anterolateral plating. There were no significant differences between the 2 constructs for either fracture pattern with respect to ultimate load, displacement, or energy absorption in load to failure testing. When used to stabilize varus fracture patterns, medial plates showed superior biomechanical performance compared with anterolateral plates. In this application, the medial plates functioned in anti-glide mode. For valgus fracture patterns, no biomechanical differences between anterolateral and medial plating were observed. In clinical practice, surgeons should take this biomechanical evidence into account when devising a treatment strategy for fixation of distal tibia fractures. [Orthopedics. 2015; 38(9):e760-e765.]
Distal tibia fractures can be challenging to treat because of the complex injury patterns and a tenuous soft tissue envelope, with operative treatment historically associated with significant complications.\(^1\) In an effort to perform an appropriate osseous reconstruction and preserve the soft tissue envelope, multiple surgical approaches and fixation strategies have been proposed.\(^8\) Options for plate osteosynthesis include medial plating and anterolateral plating via a variety of surgical approaches.\(^3,9,10\)

Proponents of medial plating cite the technical ease of the approach, the ability to perform a minimally invasive procedure, and decreased local soft tissue disruption at the fracture site as the primary advantages.\(^3,9,11,12\) However, medial implants can be prominent on the subcutaneous medial face of the tibia and sit directly beneath soft tissues that are often tenuous, sometimes leading to complications, such as wound breakdown.\(^3,10,13\) Anterolateral plating has received increased attention in contemporary tibia fracture care, with cited advantages including more robust soft tissue coverage for the plate and the ability to avoid incisions about the subcutaneous medial tibia.\(^14,15\) Critics of this approach noted that more extensive dissection in the vicinity of critical neurovascular structures makes the approach technically demanding and increases the risk of nerve or vessel injury.\(^3,4,7,9,12\) Small clinical outcomes studies have been conducted and operative techniques are well described, but the biomechanical consequences of these distinct plate applications are not well understood.\(^3,10,13,16,17\) This study compared the biomechanical characteristics of medial versus anterolateral plates applied to various fracture patterns of the distal tibia. The authors hypothesized that medial plating would optimize biomechanics in varus patterns and that lateral plating would optimize biomechanics in valgus patterns.

**Materials and Methods**

**Sample Preparation and Study Groups**

Test samples used were medium-size fourth-generation composite tibia models (Model 3401; Pacific Research Laboratories, Inc, Vashon Island, Washington). A standardized 45° oblique osteotomy was made through each tibia with a custom-made jig to recreate an Orthopaedic Trauma Association type 43-A1.2 fracture.\(^18\) In 8 specimens, the osteotomy was made from proximal and medial to distal and lateral to simulate a varus injury pattern. In the remaining 8 specimens, the osteotomy was made from proximal and lateral to distal and medial to simulate a valgus injury pattern. Each fracture was anatomically reduced and plated with a precontoured distal anterolateral or distal medial locking plate (Zimmer Inc, Warsaw, Indiana). Three 3.5-mm nonlocking bicortical screws were used to secure the plates to the tibial diaphysis. Four 3.5-mm locking screws were used to stabilize the distal segment (Figures 1-2). Nonlocking screws were used for diaphyseal fixation and locking screws were used for metaphyseal short-segment fixation to replicate typical intraoperative techniques. This generated 4 combinations of fracture patterns and plate positions for biomechanical testing. Sample size estimation based on preliminary data showed that 4 specimens per group would be required. Comparable biomechanical studies with composite tibia models used similar group sizes.\(^19,20\) The proximal and distal ends of the specimens were secured in polymethylmethacrylate molds within a custom-made aluminum frame. The same molds were used for all specimens, ensuring identical loading points, alignment, and specimen orientation for all tests.

**Mechanical Testing**

Biomechanical testing was conducted on an Instron ElectroPuls E10000 machine (Instron Corporation, Norwood, Massachusetts) with a capacity of 10 kN for axial and 100 Nm for torsional loading, with accuracy to 30 μm and 0.5° for axial and rotatory loading conditions, respectively. Loads were applied through an arm with a stainless steel ball end attached to the machine actuator (Figure 3). The ball engaged a spherical depression machined into the proximal fixture located 10 mm medial and 10 mm posterior to the medial intercondylar tubercle. On the distal end, specimens were attached to the base of the test machine with a similar ball-and-socket joint, with the loading point aligned with the center of the tibial plafond. The proximal and distal loading points were chosen to model anatomic loading with axial compression of the tibia during gait, as previously described.\(^20-22\) Specimens were first preloaded to 50 N and then loaded at 0.1 mm/s to 700 N. The process was repeated, and the average of 3 trials was calculated for the final reported value.

Torsional loads were applied to the specimens via vertical loading arms attached to the test machine actuator on the proximal end and base on the distal end and offset from the axis of rotation of the machine. These loading arms engaged horizontal rods connected to the fixtures on the proximal and distal ends. During testing, specimens were rotated through an axis with a proximal loading point at the center of the tibial plateau and a distal loading point through the center of the tibial plafond, incorporating the same ball-and-socket joints used in the axial loading tests. During torsional testing, an axial compressive load of 20 N was maintained to ensure rotation about the described loading axis. Internal and external rotation tests were performed by rotating at 0.5°/s to 7 Nm. The average of 3 trials was calculated for the final reported value.

Next, specimens were cyclically loaded in axial compression from 100 N to 1400 N at 2 Hz for 5000 cycles with the same loading points used in the initial compression tests. The loading levels and number of cycles were selected to approximate the loads seen during the initial postoperative period.\(^23\) After cyclic test-
ing, specimens were loaded to failure at a displacement rate of 0.1 mm/s. Testing to failure was videorecorded to aid in mode of failure analysis.

**Data Evaluation and Statistical Analysis**

For all calculations, average deformations and rotations resulting from testing intact specimens were subtracted from the values obtained during testing of the fractured specimens that had been stabilized. By subtracting the compliance of the test setup and the intact specimen, the authors estimated displacements and rotations at the fracture site.

Compressive stiffness and torsional stiffness were calculated as the average of 3 trials from the initial quasi-static axial compression and torsional tests. Compressive stiffness was calculated by determining the slope of the linear portion of the load vs displacement curve. Torsional stiffness was defined as the slope of the linear portion of the torque vs rotation curve. Fracture site displacement and rotation were defined as the average displacement at 700 N and rotation at 7 Nm of the 3 trials conducted on each specimen.

Creep, defined as the difference in maximum displacement between the 5000th cycle and the third cycle, and permanent deformation were recorded for each specimen after cyclic compressive testing. Ultimate load, displacement to failure, and energy absorption were calculated from load to failure tests. Energy absorption was calculated as the area under the load vs displacement curve to the maximum load point. Mann-Whitney U tests were used to compare the 2 plating constructs in each fracture pattern. The level of statistical significance was set at $P \leq 0.05$.

**RESULTS**

In the varus fracture pattern, medial plating was biomechanically superior to anterolateral plating under all testing conditions: fracture site displacement ($0.1 \pm 0.0$ vs $0.6 \pm 0.5$ mm, $P = 0.029$); compressive stiffness ($6211 \pm 3147$ vs $1290 \pm 652$ N/mm, $P = 0.029$); fracture site external rotation ($1.4^\circ \pm 0.4^\circ$ vs $5.1^\circ \pm 0.7^\circ$, $P = 0.029$); torsional stiffness in external rotation ($2.7 \pm 1.3$ vs $1.2 \pm 0.1$ Nm/°, $P = 0.029$); fracture site internal rotation ($0.6^\circ \pm 0.1^\circ$ vs $1.5^\circ \pm 0.5^\circ$, $P = 0.029$); and torsional stiffness in internal rotation ($2.7 \pm 1.3$ vs $1.2 \pm 0.1$ Nm/°, $P = 0.029$) (Table). The valgus fracture pattern showed no significant biomechanical differences between the medial and anterolateral plates: fracture site displacement ($0.2 \pm 0.1$ vs $0.2 \pm 0.1$ mm, $P = 0.686$); compressive stiffness ($2690 \pm 1325$ vs $3793 \pm 1621$ N/mm, $P = 0.686$); fracture site external rotation ($2.0^\circ \pm 0.8^\circ$ vs $1.9^\circ \pm 0.2$ Nm/°, $P = 0.686$); fracture site internal rotation ($4.5^\circ \pm 1.4^\circ$ vs $4.3^\circ \pm 0.5^\circ$, $P = 0.686$); and torsional stiffness in internal rotation ($1.3^\circ \pm 0.3$ vs $1.5^\circ \pm 0.2$ Nm/°, $P = 0.486$).

No significant difference was found in cyclic creep between medial and anterolateral plates in either fracture pattern.
pattern (varus, 0.0±0.1 vs 0.0±0.3 mm, \(P=0.686\); valgus, 0.1±0.1 vs 0.1±0.1 mm, \(P=0.886\)). For the varus fracture pattern, no significant difference in permanent deformation between medial and anterolateral plates was observed after cyclic loading (1.0±0.3 vs 0.9±0.3 mm, \(P=0.886\)). However, significantly more permanent deformation was seen for the valgus fracture pattern with the medial vs the anterolateral plate (1.6±0.5 vs 0.9±0.1 mm, \(P=0.029\)).

For both the varus and valgus fracture patterns, no significant differences were found between medial and anterolateral plates in ultimate load (varus, 3853±255 vs 4187±91 N, \(P=0.057\); valgus, 4096±442 vs 4557±594 N, \(P=0.343\)); displacement to failure (varus, 6.8±2.0 vs 4.8±1.5 mm, \(P=0.200\); valgus, 4.1±0.8 vs 4.4±0.9 mm, \(P=0.486\)); or energy absorption to failure (varus, 22.6±6.3 vs 16.0±5.6 Nm, \(P=0.114\); valgus, 14.7±1.2 vs 19.2±5.3 Nm, \(P=0.343\)). Medial plating for the varus fracture pattern showed a trend toward statistical significance for increased ultimate load, but statistical significance was not achieved.

In load to failure testing, all medially plated specimens failed by crack propagation through the distal screw holes. Four of the anterolaterally plated specimens failed via permanent deformation at the fracture site, 3 failed by crack propagation through the distal screw holes, and 1 failed via fracture adjacent to the proximal screws.

**DISCUSSION**

Obtaining and maintaining appropriate reduction until fracture healing and avoiding complications are the goals of distal tibia fracture care. In the current study, for a simulated varus fracture pattern, medial plate fixation provided a more stable biomechanical construct in both axial and torsional loading compared with an anterolateral plate. In a simulated valgus fracture pattern, no difference was found between the 2 constructs. The finding that medial plating was biomechanically optimal in a simulated varus fracture pattern was consistent with the authors’ hypothesis and corroborated expert opinion that the initial deformity should help to guide plate location. However, anterolateral plating did not seem to confer a biomechanical advantage in a simulated valgus fracture pattern. This finding was contrary to the authors’ hypothesis and may be explained by the fact that the simulated valgus fracture exited in a direct lateral location on the distal tibia, whereas the plate position on the distal fragment was anterolateral, not functioning in true anti-glide mode.

The study findings differed from previous reports. A recent biomechanical study by Yenna et al tested medial vs

### Table

**Displacement, Rotation, and Stiffness in Axial (Compressive) and Torsional Loading**

<table>
<thead>
<tr>
<th>Cut and Plate</th>
<th>Compression</th>
<th>External Rotation</th>
<th>Internal Rotation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fracture Site Displacement, mm</td>
<td>Stiffness, N/mm</td>
<td>Fracture Site Rotation, °</td>
</tr>
<tr>
<td>Varus</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Anterolateral</td>
<td>0.6±0.5a</td>
<td>1290±652a</td>
<td>5.1±0.7a</td>
</tr>
<tr>
<td>Medial</td>
<td>0.1±0.0a</td>
<td>621±3147a</td>
<td>1.4±0.4a</td>
</tr>
<tr>
<td>Valgus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anterolateral</td>
<td>0.2±0.1</td>
<td>3793±1621</td>
<td>3.3±0.3</td>
</tr>
<tr>
<td>Medial</td>
<td>0.2±0.1</td>
<td>2690±1325</td>
<td>2.6±0.8</td>
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*aStatistically significant difference between medial and anterolateral plates, \(P<0.05\).*
anterolateral plates in stabilizing distal tibia fractures and found no difference between them in compressive and torsional stiffness. This study created pie-shaped fracture wedges with 20° obliquity of opposite orientations to model varus and valgus comminution. The specimens were tested with the wedge in place and then removed to model a comminuted fracture. Data from all fracture patterns were averaged to compare anterolateral and medial plating. In combining the data from all fracture patterns, the authors could not assess differences that may have been observed between each plate for a specific fracture pattern. Additionally, in creating a segmental defect to model comminution, the authors compared the biomechanics of anterolateral vs medial plates in bridge mode. Although this is valuable information, the current findings are distinct and important because the study modeled an oblique fracture pattern in which axial load generates a shear force that is best counteracted by anti-glide plating.

**Limitations**

This study had several important limitations. To minimize variability among specimens, the authors used synthetic bone models that may not precisely replicate the environment seen in vivo with a postoperative tibia fracture. 25-29 To isolate the role of plate placement and tibia fracture patterns, the model also omitted such potentially important structures as the fibula, ligaments, and muscular attachments as well as the proximal and distal loading surfaces of the knee and ankle joints. Another potential limitation was the use of a simple fracture pattern in the sagittal plane which may not exactly replicate fracture patterns encountered in clinical practice. Despite the limitations, the use of modern fourth-generation composite models is also a strength of this experimental setup because these materials closely resembled human bone in biomechanical fracture fixation testing. 29 Use of a standard operative technique with identically sized hardware and a simple fracture pattern allowed for a consistent reduction with which to isolate the effect of fracture obliquity on the 2 plating constructs. The authors believe that the fracture models reasonably approximate common varus and valgus patterns and simulate the conditions in which the differences between medial and anterolateral plating are relevant.

**Conclusions**

The surgical care of extra-articular distal tibia fractures is controversial. Treatment options include nonoperative management, intramedullary nailing, and plate fixation. This study showed the biomechanical advantage of medial plating for varus fracture patterns. In valgus fracture, no difference was found between anterolateral and medial plating. Based on these findings, it is recommended that surgeons consider the fracture pattern and deformity when deciding between anterolateral and medial plating. Future research is needed to explore the clinical differences between medial and anterolateral plating of the distal tibia, and particular attention should be paid to the influence of a varus vs valgus injury pattern on outcome.

**References**


20. Yenna ZC, Bhadra AK, Ojike NI, et al. Anterolateral and medial locking plate stiffness...


