Jones Fracture Fixation

A Biomechanical Comparison of Partially Threaded Screws Versus Tapered Variable Pitch Screws

Justin D. Orr, MD, Richard R. Glisson, BS, and James A. Nunley, MD
Investigation performed at the Department of Orthopaedic Surgery, Duke University Medical Center, Durham, North Carolina

Background: Stabilization of fifth metatarsal Jones fractures with intramedullary screw fixation is the most common method for surgical fixation when operative treatment is indicated. Conventional partially threaded screws of various diameters are routinely used for Jones fracture fixation. Recently, the use of tapered variable pitch screws has become popular, but information regarding their performance in Jones fracture fixation is limited. No previous studies have compared conventional and tapered variable pitch screws in Jones fracture fixation under physiologic cyclic loading conditions.

Purpose: To determine whether biomechanical differences exist between appropriately sized conventional partially threaded screws and tapered variable pitch screws under physiologic cyclic loading conditions with regard to Jones fracture fixation.

Study Design: Controlled laboratory study.

Methods: Simulated Jones fractures were created in 23 matched pairs of fresh-frozen fifth metatarsals. One bone from each pair was stabilized with a conventional partially threaded screw and the contralateral bone with a tapered variable pitch screw. Initial compression, as well as fracture site compression, angulation, and bending stiffness, was compared between groups throughout 1000 physiologic cyclic loads.

Results: Conventional partially threaded screws obtained significantly greater initial compression compared with tapered variable pitch screws. Significantly greater compression was maintained throughout cyclic loading with conventional screw fixation compared with tapered variable pitch screws. Fracture site angulation was significantly greater using tapered variable pitch screws from the tenth load cycle through completion of cyclic loading. Despite a trend toward increased fracture site bending stiffness when using conventional screws, no difference in fixation stiffness was demonstrable between the 2 screw types.

Conclusion: In this cadaveric Jones fracture fixation model, conventional partially threaded screws provided improved fracture site compression and decreased fracture site angulation but offered no advantage in improving fracture site stiffness compared with tapered variable pitch screws. These results provide empirical evidence to guide implant selection decision making for operative fixation of Jones fractures.

Clinical Relevance: While the use of tapered variable pitch screws is a potential alternative for fixation of fifth metatarsal Jones fractures, conventional partially threaded screws may provide better biomechanical stability, the effect of which on fracture healing is unknown.

Keywords: fracture; Jones; intramedullary; metatarsal; screw

The American Journal of Sports Medicine, Vol. XX, No. X DOI: 10.1177/0363546511428870 © 2012 The Author(s)

This fracture has a high tendency to displace, given its anatomic location between the relatively immobile base of the fifth metatarsal and the more mobile distal fragment of the fifth metatarsal shaft. As well, this region of the proximal fifth metatarsal has an inherently diminished osseous blood supply. Therefore, treatment of Jones fractures has been fraught with high rates of delayed union and nonunion, leading to much investigation regarding optimal treatment options. In addition, recent data indicate similar healing characteristics for both zone II and proximal diaphyseal zone III fifth metatarsal fractures, suggesting that all zone II and zone III fractures should be regarded simply as “Jones” fractures.

Historically, indications for operative treatment have included acute fractures in high-performance athletes, open fractures, and delayed union or nonunion after
appropriate nonoperative treatment. While a variety of techniques for operative fixation have been described, each with related technical strengths and weaknesses, currently the most common procedure for Jones fractures when surgical fixation is indicated is intramedullary screw fixation. Fixation with a variety of intramedullary screw types has been adopted; however, use of conventionally threaded cancellous screws with thread diameters ranging from 4.5 mm to 6.5 mm is most common.

While expedited return to activity with intramedullary screw fixation of Jones fractures has been reported in high-demand athletic populations, failure of operative fixation leading to poor fracture healing has also been well described. Several authors have reported on the biomechanics of intramedullary screw fixation of Jones fractures in an effort to optimize surgical fixation for these difficult fractures. With regard to the use of conventional partially threaded cancellous screws in the treatment of Jones fractures, debate exists whether increased screw diameter results in improved biomechanical fracture stability; however, there is evidence that increased screw diameter leads to improved torsional rigidity and pullout strength but at the risk of possible intraoperative canal "blowout" fractures. Recently, the use of intramedullary tapered variable pitch screws has gained popularity for the treatment of Jones fractures, and promising results have been demonstrated clinically. To our knowledge, only 1 biomechanical study compared the use of tapered variable pitch screws to partially threaded cancellous (conventional) screws for this application. The study demonstrated increased pullout resistance with use of conventional screws but did not demonstrate improved bending stiffness compared with tapered variable pitch screws. This study was limited in that it was a single load-to-failure study and did not compare fracture site compression, angulation, or bending stiffness during cyclic loading.

We understand that the importance and degree of fracture site stability with regard to Jones fracture healing is currently unknown. Therefore, this study was designed to directly compare conventional partially threaded screws and tapered variable pitch screws with regard to fracture site compression, angulation, and bending stiffness throughout simulated physiologic cyclic loading in a cadaveric Jones fracture model to determine if biomechanical differences exist. The resulting data on fracture site compression, angulation, and stiffness throughout simulated physiologic cyclic loading provide surgeons with empirical evidence to guide their implant selection decision-making processes when electing for operative fixation of Jones fractures.

MATERIALS

Anatomic Specimens

Twenty-three matched pairs of fifth metatarsals were dissected from fresh-frozen cadaveric feet and were stripped of all soft tissue. The average age of the metatarsal donors was 57 years (range, 32-80 years; 14 men and 9 women). Each metatarsal was radiographed in the anteroposterior (AP) and lateral planes with the bone in contact with the radiograph cassette to minimize magnification. To account for confounding differences in bone quality related to donor age or gender, all bones were scanned using dual-energy x-ray absorptiometry (DEXA) to quantify bone mineral density with a Lunar PIXImus small-animal densitometer (Lunar Corporation, Madison, Wisconsin). Quality assurance testing was performed using a phantom with a known bone mineral density.

Radiographic Measurements

All radiographic imaging was performed using digital imaging software. A metallic marker of known length was placed at the bottom of each cassette in order to calculate a magnification ratio. The length of each metatarsal, from the anticipated fixation screw entry point near the tip of the tuberosity to the most distal aspect of the head, was measured from the AP radiograph. Seventy percent of this length was calculated, and the radiograph was marked at this distance from the proximal tuberosity (Figure 1). This length approximates the straight portion of the fifth metatarsal diaphysis proximal to the distal lateral curvature. Three different medullary canal diameter measurements were determined. On the AP radiograph, the narrowest inner cortical diameter (I.D.) and the narrowest outer cortical diameter (O.D.) were determined within the proximal 70% of the bone. Finally, the narrowest O.D. was also determined on the lateral radiograph within the same straight portion of the metatarsal (Figure 2). All 4 of the aforementioned measurements were used in selecting the optimal screw size for each bone.

Screw Selection

Screws used included stainless steel 4.5-mm and 6.5-mm partially threaded cancellous screws (Synthes, Monument, Colorado); titanium 5.0-mm partially threaded cancellous screws (DePuy ACE Medical Co, Warsaw, Indiana); and titanium Acutrak 4/5 and Acutrak Plus tapered, fully threaded variable pitch titanium screws (Acumed, Hillsboro, Oregon). The Acutrak 4/5 screw has a leading thread diameter of 4.0 mm and a trailing thread diameter of 5.0 mm, and the Acutrak Plus screw has a leading thread diameter of 5.0 mm and a trailing thread diameter of 6.5 mm. At the time of our testing, the manufacturer did not produce a screw intermediate in size to the Acutrak 4/5 and Acutrak Plus screws.

To maximize screw size, an objective, standardized screw selection method was established to grossly match the sizes of the screws to the sizes of the metatarsals. With use of a computer randomization program, 1 member of each matched metatarsal pair was randomly selected to receive a conventional partially threaded screw. Partially threaded screw diameters were assigned as follows: individual metatarsals with narrowest I.D. < 4.0 mm received a 4.5-mm screw; I.D. = 4.0 to 4.5 mm, a 5.0-mm screw; and

---

1References 2, 3, 10, 13, 14, 17, 20, 21, 28.
2References 8, 11, 15, 16, 19, 20, 25, 29.
3References 8, 11, 16, 19, 22, 25, 29.
4References 2, 3, 10, 13, 14, 17, 20, 21, 28.
I.D. > 4.5 mm, a 6.5-mm screw. The O.D. as determined on AP and lateral radiographs was used to ensure that the outer diameter of the screw would not lead to canal “blow-out” fractures. This algorithm, based on radiographic measurements, was followed consistently throughout testing. Ten metatarsals were stabilized with 5.0-mm conventional screws, and 13 metatarsals were stabilized with 6.5-mm conventional screws. No metatarsals met criteria for use of 4.5-mm conventional screws. The contralateral metatarsal of each pair received an appropriately sized tapered variable pitch screw (Acutrak 4/5 or Acutrak Plus); bones with I.D. < 4.5-mm received an Acutrak 4/5 screw, and bones with I.D. ≥ 4.5 mm received an Acutrak Plus screw. Using this screw selection method, 3 metatarsals were stabilized with Acutrak 4/5 screws, and 20 metatarsals were stabilized with Acutrak Plus screws.

In both conventional screw and tapered variable pitch screw groups, screw length was approximately 70% of the length of the metatarsal. This screw length allowed for a standardized method that ensured the screw was not too long, preventing lateral fracture site gapping, but long enough that threads in the conventional screws were distal to the fracture site.

Jones Fracture Creation

The surface of each metatarsal was degreased using an acetone-soaked gauze sponge. A 1.6-mm Kirschner wire was then inserted transversely through the center of the metatarsal head and clamped in a vise, stabilizing the bone during preparation for intramedullary screw insertion. The medullary canals were prepared according to the recommendations of the manufacturers of the respective screws. In each case, the guide wire was removed but the pilot drill bit was left in the bone after drilling the canal. The projecting drill bit shank was inserted into the chuck of a drill press that was previously adjusted to ensure that the axis of the drill chuck was perpendicular to the drill press table. A stainless steel tube, 2.5-cm diameter and 2.5-cm long, was coated with Vaseline and positioned upright on the drill press table, and the chuck was lowered until the center of the head of the metatarsal was centered in the tube. Polymethylmethacrylate (PMMA) dental cement (Fastray, H. J. Bosworth Co, Skokie, Illinois) was mixed and poured into the tube, and the metatarsal was lowered into the tube until the stop was reached. After the PMMA hardened, the drill bit was removed and the stainless steel tube was slipped off. The resulting cylindrical block of PMMA encasing the metatarsal head was clamped in a machinist’s vise such that the bone’s longitudinal axis was horizontal. The vise was placed against the guide fence of a band saw, and the metatarsal was passed through the saw blade to produce a cut simulating a Jones fracture. The vise was then repositioned, and a second cut was made parallel to and 2.0 mm distal to the first, resulting in removal of a total of 4.0 mm of bone at the fracture site after accounting for the 1.0-mm saw kerfs. Figure 3 illustrates the osteotomized proximal fifth metatarsal, simulating a true zone II fracture.

Jones Fracture Fixation

A testing apparatus was fabricated that incorporated a load cell (Model 3185-50, Eaton Corporation, Troy, Michigan) modified by extending the sensing arms and terminating them with parallel thin stainless steel plates. The apparatus was oriented such that the plates could be interposed between the proximal and distal fragments of the metatarsal to monitor compression as the fixation screw was tightened and during subsequent cyclic loading. The sum of the thickness of the plates and the 1.0-mm gap between them was 4.0 mm, which corresponded to the amount of bone removed during creation of the simulated fracture. A threaded rod was placed transversely through a hole drilled through the center of the PMMA cylinder encasing the metatarsal head. The rod was attached to
a yoke, which was in turn connected to the actuator of a servohydraulic materials testing machine (Model 1321, Instron Corp, Norwood, Massachusetts). The fracture site load cell was positioned such that the cut surface of the distal fragment was flush against 1 of the load cell plates with the fragment oriented horizontally. The proximal metatarsal fragment was then aligned with the distal fragment, and the screw was inserted through the proximal fragment and into the distal fragment, passing through slots machined in the plates (Figure 3).

Rotation of the distal fragment was constrained by the attached yoke during screw insertion, and rotation of the proximal fragment was controlled by a projecting 1.6-mm Kirschner wire temporarily inserted into the tuberosity. The compressive force at the fracture site was displayed on a monitor during insertion, and in the case of the conventional screws, screw advancement was halted and the initial compressive force recorded when the head was seated and the force reached a plateau. In the case of the tapered variable pitch screws, advancement was halted and the initial compressive force was recorded when the trailing end of the screw was flush with the bone surface.

The trailing end of the screw was covered with modeling clay to isolate it from the embedding material, and a three-sided aluminum dam was placed around the proximal fragment of the construct. PMMA was then poured into the compartment and allowed to harden, rigidly fixing the proximal fragment to the testing device (Figure 4).

Cyclic Loading

A cyclically applied load of 0 N to 12.01 N was then applied to the metatarsal head in the sagittal plane (plantar to dorsal) over 1000 cycles. The peak applied load of 12.01 N is one-half of the load to which the head of the fifth metatarsal is subjected during the push-off phase of gait in normal ambulation. Load cycles 1, 2, 3, 4, 5, 10, 50, 100, 200, 400, 600, 800, and 1000 were linear ramps at 0.1 mm per second, while all other loads were sinusoidal at a frequency of 0.5 Hz. Applied load, fracture site compression, and displacement data were recorded at a sampling rate of 50 Hz throughout the cyclic loading. The metatarsal head was returned to its starting position after each load cycle, and testing was stopped if gross failure occurred, defined for the purpose of the study as interfragmentary angulation exceeding 10° in the sagittal plane.

Data Analysis

Verification of Similarity Between Left and Right Members of Matched Pairs. Bone mineral density and the 4 radiographic diameter measurements were tabulated for metatarsals that received the conventional screws and the contralateral bones that received the tapered variable pitch screws. The values were compared in a pairwise fashion using 2-tailed Student t tests to ascertain that these parameters did not vary appreciably between members of each matched pair. The significance level for these and all other statistical tests was set at $P = .05$.

Compression. The mean (n = 23) initial fracture site compression (N) achieved by each screw category (conventional and tapered variable pitch) was compared using a Wilcoxon matched-pairs signed rank test. The mean fracture site compression was graphed immediately after return of the metatarsal head to its starting position after load cycles 1, 2, 3, 4, 5, 10, 50, 100, 200, 400, 600, 800, and 1000, and a 2-way repeated measures analysis of variance (ANOVA) was used to determine whether a statistically significant difference in ability to maintain fracture site compression existed during cyclic loading. When indicated, Tukey post hoc tests were used to detect significant differences in compression at each evaluated load cycle increment. The null hypothesis was that there was no difference in mean compression between the 2 screw types.
Table 1: Fracture Site Compression, Angulation, and Bending Stiffness at Each of the 13 Cyclic Loading Increments

<table>
<thead>
<tr>
<th>Cycle No.</th>
<th>Conventional Screws</th>
<th>Tapered Variable Pitch Screws</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Compression, N</td>
<td>Angulation, deg</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>91.4 (47.6)b</td>
<td>1.3 (1.2)</td>
</tr>
<tr>
<td>2</td>
<td>91.1 (47.9)b</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>3</td>
<td>90.9 (48.1)b</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>4</td>
<td>90.8 (48.3)b</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>5</td>
<td>90.7 (48.4)b</td>
<td>1.4 (1.3)</td>
</tr>
<tr>
<td>10</td>
<td>90.6 (48.8)b</td>
<td>1.5 (1.5)c</td>
</tr>
<tr>
<td>50</td>
<td>90.4 (49.5)b</td>
<td>1.6 (1.6)c</td>
</tr>
<tr>
<td>100</td>
<td>90.5 (49.7)b</td>
<td>1.7 (1.7)c</td>
</tr>
<tr>
<td>200</td>
<td>90.9 (50.2)b</td>
<td>1.7 (1.8)c</td>
</tr>
<tr>
<td>400</td>
<td>91.1 (50.8)b</td>
<td>1.8 (2.0)c</td>
</tr>
<tr>
<td>600</td>
<td>91.2 (51.2)b</td>
<td>1.8 (2.1)c</td>
</tr>
<tr>
<td>800</td>
<td>91.2 (51.3)b</td>
<td>1.8 (2.1)c</td>
</tr>
<tr>
<td>1000</td>
<td>90.9 (51.8)b</td>
<td>1.9 (2.1)c</td>
</tr>
<tr>
<td></td>
<td>57.1 (31.0)b</td>
<td>1.7 (1.8)</td>
</tr>
<tr>
<td></td>
<td>56.6 (31.6)b</td>
<td>1.8 (2.0)</td>
</tr>
<tr>
<td></td>
<td>56.2 (32.0)b</td>
<td>1.9 (2.1)</td>
</tr>
<tr>
<td></td>
<td>55.9 (32.3)b</td>
<td>1.9 (2.2)</td>
</tr>
<tr>
<td></td>
<td>55.8 (32.7)b</td>
<td>2.0 (2.2)</td>
</tr>
<tr>
<td></td>
<td>55.4 (33.0)b</td>
<td>2.1 (2.3)c</td>
</tr>
<tr>
<td></td>
<td>54.5 (34.3)b</td>
<td>2.2 (2.5)c</td>
</tr>
<tr>
<td></td>
<td>54.0 (34.8)b</td>
<td>2.4 (2.6)c</td>
</tr>
<tr>
<td></td>
<td>53.6 (34.9)b</td>
<td>2.5 (2.7)c</td>
</tr>
<tr>
<td></td>
<td>53.3 (36.9)b</td>
<td>2.7 (2.8)c</td>
</tr>
<tr>
<td></td>
<td>53.3 (37.6)b</td>
<td>2.8 (3.0)c</td>
</tr>
<tr>
<td></td>
<td>53.2 (38.3)b</td>
<td>2.9 (3.0)c</td>
</tr>
<tr>
<td></td>
<td>53.0 (38.7)b</td>
<td>3.0 (3.1)c</td>
</tr>
</tbody>
</table>

aMeans, with standard deviations in parentheses.
bP < .001, comparing conventional and tapered screws at each cycle point.
cP < .05, comparing conventional and tapered screws at each cycle point.

Results:

Mean bone mineral density in the partially threaded cancellous (conventional) screw group was 0.357 g/cm³ compared with 0.351 g/cm³ in the tapered variable pitch screw group (P > .05). As well, no significant differences were noted (P > .05) between the 2 experimental groups for any of the metatarsal diameter or length measurements. Five pairs of metatarsals that were initially destined for inclusion in this study had to be excluded because no fracture site compression was achieved in the bone that received the tapered variable pitch screw. In all 5 instances, the contralateral conventional screws did obtain adequate initial compression. These 5 pairs were excluded from testing and are not represented in the 23 pairs for which results are presented. Table 1 presents fracture site mean compression, mean angulation, and mean stiffness results with associated standard deviations at each of the 13 cyclic loading increments.

Angulation. Fracture site angulation (degrees) at 12.01 N of load was calculated at each of the examined cyclic loading increments from the corresponding head displacement and the distance from the fracture site to the point of load application. The mean angulation (n = 23) at each increment for each screw category was graphed, and a 2-way repeated measures ANOVA with Tukey post hoc tests was used to detect significant differences in angulation at each evaluated load cycle increment. The null hypothesis was that there was no difference in angulation between the 2 screw types.

Bending Stiffness. Bending stiffness (N/m/degree angulation) was calculated from the region of the load displacement curve between 9 N and 12 N of applied load for each examined cyclic load interval and was expressed as N/m of bending moment per degree of angulation. The mean stiffness (n = 23) at each increment for each screw category was graphed, and a 2-way repeated measures ANOVA with Tukey post hoc tests was used to detect significant differences in bending stiffness at each evaluated load cycle increment. The null hypothesis was that there was no difference in stiffness between the 2 screw types.

## Results

### Compression

The mean initial compression (N) at the fracture site obtained by the conventional screws was significantly greater than that of the tapered variable pitch screws (P = .029). The mean compression achieved by the conventional screws was 92.1 N (SD, 46.5 N). The mean compression achieved by the tapered variable pitch screws was 59.4 N (SD, 27.4 N). A statistically significant interaction effect between screw type and number of bending load cycles existed (P = .031). Post hoc testing indicated that the mean fracture site compression was significantly greater for the conventional screws compared with the tapered variable pitch screws at each of the 13 evaluated cyclic load increments (P < .001 at all loading increments). The cyclic loading compression results are summarized in Figure 5, which demonstrates relatively little loss of compression throughout cyclic loading for both groups.

### Angulation

There was a significant interaction effect between screw type and number of bending load cycles with regard to fracture site angulation (P = .004). The mean angulation (degrees) at the fracture site in metatarsals fixed with the tapered variable pitch screws exceeded that of conventional screw fixation at every evaluated time point beginning at load cycle 10 and continuing through load cycle...
The angulation results are summarized in Figure 6, which demonstrates a relatively linear change in angulation during cyclic loading for both groups and a more rapid angulation increase for the tapered variable pitch screw constructs as cyclic loading progressed.

Bending Stiffness

The mean bending stiffness (N·m/degree angulation) of the fracture site did not differ significantly between screw types at any of the individually examined load cycle increments. The stiffness results are summarized in Figure 7, which demonstrates relatively constant bending stiffness throughout cyclic loading for both groups. Although we were unable to demonstrate a significant difference in stiffness during cyclic loading with the number of specimens available, Figure 7 demonstrates a consistent trend toward improved bending stiffness characteristics with conventional screw fixation.

**DISCUSSION**

The goal of this study was to directly compare conventional partially threaded and tapered variable pitch screws with regard to fracture site compression, angulation, and bending stiffness throughout cyclic loading in a cadaveric Jones fracture model. This study represents the largest number of tested cadaveric metatarsal pairs to date for this purpose. We also utilized a unique biomechanical testing method never previously used to monitor Jones fracture site compression, angulation, and stiffness throughout cyclic loading, and these findings should be of particular interest to all clinicians who treat this fracture.

The use of tapered variable pitch screws for treatment of Jones fractures has gained recent popularity. These screws obtain interfragmentary compression by means of a thread pitch differential between the leading and trailing ends of the screw. The biomechanical characteristics of this screw type have been evaluated previously in cadaveric scaphoid, vertebral cancellous, and femoral cancellous bones, as well as in synthetic foam. Until recently, there had been no studies in which these screws were compared with conventional screws for Jones fracture fixation. McPeake et al reported a 100% union rate in zone II and zone III proximal fifth metatarsal fractures fixed with the tapered variable pitch screws and autogenous bone grafting. This series prompted a cadaveric biomechanical study comparing tapered variable pitch screws to 6.5-mm conventional partially threaded cancellous screws for the
treatment of Jones fractures. Using a single load-to-failure model, this study demonstrated superior pull-out strength for conventional screws but no difference with regard to bending rigidity. In contrast, our study used a cyclic loading model with an applied force that better approximates weightbearing. Therefore, we believe the current study reflects a more clinically applicable scenario.

In this cadaveric Jones fracture model, our data demonstrate that initial fracture site compression, as well as maintenance of compression throughout cyclic loading, was greater in the conventional partially threaded screw group. As well, we noted a progressive, statistically significant increase in fracture site angulation associated with use of tapered variable pitch screws compared with conventional screw constructs; this angulation began only after the tenth cycle and continued until the completion of cyclic loading. Despite a trend toward increased bending stiffness with conventional screws, we were unable to demonstrate a significant biomechanical advantage over tapered variable pitch screws with regard to this parameter. It is noteworthy that fracture site stiffness is typically measured in the latter region of the load displacement curve in this cadaveric model and therefore reflects resistance to further angulation after loosening has occurred at the bone–implant interface. Therefore, we believe that among the 3 parameters measured, bending stiffness is probably the least clinically relevant biomechanical parameter tested. Although compared with conventional screws tapered variable pitch screws may provide adequate stabilization for fracture healing clinically, these results indicate significantly decreased fracture site compression and increased fracture site angulation with their use. While we cannot definitively state whether the increased fracture site compression or decreased fracture site angulation afforded by use of conventional partially threaded screws would necessarily result in superior clinical outcomes with regard to Jones fracture fixation, these results should be of interest to surgeons who treat these fractures.

There are several strengths of this study. First, with 23 matched metatarsals, this is the largest cadaveric Jones fracture study to date. As well, it represents the first study to specifically compare these 2 screw types for Jones fracture fixation stability throughout a cyclically applied mechanical challenge. Prior studies have largely used single load-to-failure models, the results of which can be difficult to interpret clinically. Second, all specimen preparation and testing was performed by the same surgeon, avoiding the potential for variability in the quality of individual specimens. Finally, the cyclically applied force we selected approximates half of the normal physiologic load during gait, representing what might occur if one walked on a surgically repaired Jones fracture prior to adequate bone healing. While no in vitro study can perfectly simulate in vivo conditions, we believe our model is a reasonably accurate estimation of physiologic loading.

We acknowledge several limitations in the current study. As has been mentioned in previous Jones fracture biomechanical studies, poor bone density might lead to inferior screw fixation performance. To offset this criticism, we performed DEXA scanning of all paired metatarsals before testing. Although we did not perform multivariate analyses comparing bone density and biomechanical properties, we showed no significant difference in bone density between the 2 screw groups. While to our knowledge no normative values for metatarsal bone mineral density have been published, a recent study compared metatarsals before and after periods of prolonged nonweightbearing in young, healthy subjects and demonstrated normal values ranging from 0.473 to 0.488 g/cm³. These data suggest that our donor metatarsals might have some unknown degree of osteopenia. However, a previous study failed to show a correlation between bone density and bending stiffness or pull-out strength with use of 5.0-mm and 6.5-mm conventional screws in a cadaveric Jones fracture single load-to-failure model. Second, as part of our model, a 4.0-mm section of bone was removed at the site of the simulated Jones fracture to accommodate the force transducer. While this likely had little effect on the conventional screw group, it might have had a negative effect on the tapered variable pitch screw group by reducing the number of threads engaging the inner cortical bone proximally. Also, for standardization purposes, we elected to create only true zone II proximal fifth metatarsal fractures; however, we recognize that similar nonunion rates exist for zone III fractures, prompting some to consider all zone II and zone III proximal fifth metatarsal fractures alike. We also acknowledge that while 1000 loading cycles is more physiologic than a single load-to-failure model, it does not represent a large number of cycles.

Finally, as we indicated previously, this study addresses only in vitro biomechanical stability as it relates to 2 different screw fixation techniques; therefore, one cannot draw conclusions based on these results regarding in vivo fracture healing. While we cannot infer actual improvement in Jones fracture healing potential based on the results of the current investigation, this study does provide empirical evidence indicating improved fracture site compression and decreased fracture site angulation with use of conventional partially threaded screws compared with tapered variable pitch screws. These results should be considered when selecting implants for operative fixation of Jones fractures. Further prospective comparative studies are warranted to determine if actual clinical differences exist in vivo with regard to Jones fracture fixation using conventional versus tapered variable pitch screws.

REFERENCES


For reprints and permission queries, please visit SAGE's Web site at http://www.sagepub.com/journalsPermissions.nav