Fracture Motion in Distal Tibial Rodding: Effect of Obliquity, Load, and Locking Screw Pattern

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Objective: *To conduct a biomechanical study on composite synthetic tibia bone models under physiologic torsional loading conditions to evaluate the relationship between fracture obliquity and locking screws configuration of distal metaphyseal tibial fracture model fixed by intramedullary (IM) nail fixation.*

Material and Method: *The biomechanics of six different locking screws configurations in an IM nail used to fix various distal metaphyseal tibial fracture obliquities were evaluated. The Sawbones were osteotomized following reaming of the medullary canal 2 mm over the respective nail diameter. Specimens were tested in internal and external rotation at 0.25 degrees/second to 7 Nm followed by a hold at 7 Nm for two seconds. The testing was conducted under two compressive loading conditions, 20 N and 500 N, to determine if a constant compressive load affects interfragmentary motion during torsion. The influence of screw configurations on construct stability was investigated at fracture obliquities ranging from 0° to 60° including a spiral obliquity (spiral configuration and obliquity of 45° by definition).*

Results: *During both internal and external rotation, significant differences were observed in interfragmentary motion between the two compressive loading levels (20 N and 500 N). For internal rotation testing, there are significant differences in interfragmentary displacement for fracture obliquities less than or equal to 40° when the degree of interlocking is diminished. For obliquities between 0° and 30°, which could be classified as a transverse and short oblique fracture pattern, significant rotatory changes become present as the degree of interlocking is decreased. Similar results are found in external rotation, however, stability appears to be compromised with obliquities of 50° or less.*

Conclusion: *Our study examined interfragmentary motion during pure compressive loading to determine the optimal interlocking pattern for distal metaphyseal fractures of various obliquities. The appropriate fixation configuration should be selected to apply adequate fracture stabilization for all physiologic loading modalities. Although increasing fracture obliquities provide increased stability during torsional loading, stability is adversely affected for increasing fracture obliquity at greater than 30° and certainly by 40° of fracture obliquity during pure compression. The data confirmed that not just the interlocking pattern but also the fracture configuration and compressive load level contribute to overall construct stability when physiologic torsional loads were applied. Interfragmentary displacement was significantly increased, in compression loading mode, when a progressive fracture obliquity degree was tested.*

Keywords: *Distal metaphyseal tibial fracture, Intramedullary nail, Biomechanic, Proximal interlocking screw, Distal interlocking screw, Fracture obliquity, Screw configuration*

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Intramedullary (IM) nailing has become the preferred procedure for management of most displaced diaphyseal tibia fractures because of its low incidence of complications and excellent clinical outcomes[1-5]. Over time, implant design and screw locking options have advanced with a longer working range for fixation because of the additional distal and proximal screw interlocking options. Consequently, the indications for use of IM nails have been extended to include extra-articular proximal and distal metaphyseal tibia fractures[6-9]. Some studies have successfully demonstrated that interlocking nailing could be used in treating fractures of the distal tibia[10-12]. However, as the indications for IM fixation have been expanded through the proximal and distal metaphyseal regions, increased rates of secondary loss of reduction with following malalignment have been reported[13-19].

Fractures in the distal metaphyseal tibia managed with IM nail fixation provides less stability as a result of the anatomic pattern of the distal tibia. The metaphyseal flare of the medullary canal lessens the contact between the nail and the endosteal surface.

Advances in nail design, most notably the presence of more distal locking options with multiplanar

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fixation, have also improved the biomechanics of IM nailing for distal tibia fractures. In addition to the fracture site region, fracture patterns and patterns of locking screw configurations may play a role in distal fragment stabilization or lack of. Fracture obliquity has been shown to influence fracture stability in external fixation models, but no such work being done with IM nailing[24].

The purpose of the present study is to evaluate the relationship between fracture obliquity and locking screws configuration of distal metaphyseal tibial fractures on interfragmentary motion under physiologic compressive loading in a tibial model.

Material and Method

The biomechanics of six different locking screws configurations (Fig. 1), in an IM nail used to fix various distal metaphyseal tibial fracture obliquities were evaluated using a composite synthetic tibia bone model.

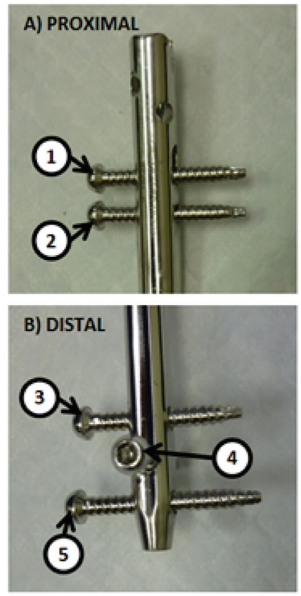
Implantation procedure

Fourth Generation Composites Tibias (Sawbones Part Number: 3402, Pacific Research Laboratories, Inc., Vashon Island, WA) were used to maintain consistency and eliminate the variability of cadaveric bones. The Sawbones were osteotomized following reaming of the medullary canal 2 mm over the respective nail diameter. Distal cuts, located 7 cm proximal to the distal edge of distal tibial articular surface, were made at various obliquities measured from horizontal in the coronal plane: 0°, 30°, 40°, 50°, and 60°. Cuts were made using a band saw with the specimens mounted in a custom fixture ensuring consistent planar alignment of the cuts between specimens. A spiral cut pattern oriented 45 degrees from horizontal was created in one specimen using a Dremel rotary hand tool. The Sawbones were then instrumented using a reamed stainless steel IM nail measuring 10x360 mm (M/DN; Zimmer, Warsaw, IN). The nail was inserted according to standard tibial IM technique. The osteotomized fracture ends were then perfectly apposed so there was no gap in the fracture ends present. Two screws were inserted at the proximal interlocking holes and three screws at the distal interlocking holes as shown in Fig. 1.

Mechanical testing

Biomechanical testing was conducted on an Instron ElectroPuls E10000 (Instron Corporation, Norwood, MA). The proximal and distal ends of the specimens were held in polymethylmethacrylate (PMMA) molds secured in an aluminum frame. The same PMMA molds were used for all specimens, ensuring identical loading points and specimen orientation for all tests. Loads were applied through a loading arm with a ball end attached to the machine actuator. The ball engaged a spherical depression in the proximal fixture located at the center of the tibial plateau. On the distal end, specimens were attached to the base of the test machine using a similar ball and socket joint with the loading point aligned with the center of inferior articular surface. The mechanical testing set-up was shown in Fig. 2A.

Specimens were loaded in axial compression at a rate of 0.05 mm/second to 1,000 N followed by a hold at 1,000 N for two seconds. The maximum load of 1,000 N was selected to simulate compressive loading present during ambulation. Throughout testing custom trackers with infrared emitters, rigidly attached to the proximal and distal segments, were monitored with a 3D Creator motion tracking system (Boulder Innovation Group, Boulder CO) (Fig. 2B). Preliminary testing showed the position and rotational accuracies of the trackers to be within ±0.1 mm and ±0.2 degrees, respectively. A custom MATLAB program was used



Configuration 1: All screws
Configuration 2: Screw 3 removed
Configuration 3: Screw 4 removed
Configuration 4: Screws 2 & 4 removed
Configuration 5: Screws 2, 3 & 4 removed
Configuration 6: Screws 1, 2, 3 & 4 removed

Fig. 1 Screws employed in various proximal (A) and distal (B) tibial nail locking configurations.

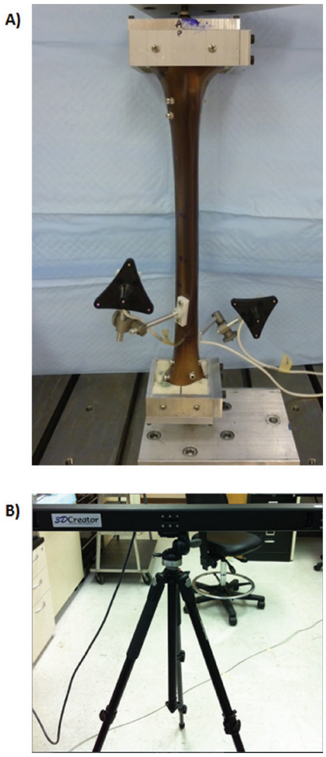


Fig. 2 (A) Experimental set-up used for mechanical testing. Motion trackers were rigidly attached on the Sawbone tibia proximal and distal to the osteotomy site. (B) 3D Creator motion capture system.

to analyze the motion tracking data and determine interfragmentary motion of the specimens at 1,000 N compressive load. Interfragmentary displacement was determined by calculating the vector magnitude of the individual displacement components (superior-inferior, medial-lateral, anterior-posterior), while interfragmentary rotation was defined as the rotation of the distal segment about the long axis of the proximal segment. Three trials were performed for each of the six screw locking configurations shown in Fig. 1, resulting in a total of 18 tests on each specimen (6 synthetic tibia bone model specimens).

Statistical analysis

Comparisons of interfragmentary motions were made 1) between configurations at the various fracture obliquities, and 2) between fracture obliquities for the various screw configurations. For each fracture obliquity, a mixed-effects regression model was fit to estimate the effect of the six screw configurations on the two outcome measures, interfragmentary displacement and rotation. The estimated marginal means and 95% confidence intervals were produced from these models, and pairwise comparisons between the configurations were made with a 95% family-wise confidence level assuming equal variance across the conditions. Next, the analyses were transposed to compare the effects of different obliquities within each configuration.

Due to the large number of statistically significant comparisons between the various fracture obliquities and screw configurations, thresholds were established to limit the presentation of significant findings to only clinically meaningful data. Both a magnitude threshold and difference threshold were defined to achieve this goal. For a comparison between two fracture obliquities or screw configurations to be valid, the magnitude of at least one of the interfragmentary displacements compared needed to be greater than the magnitude threshold (1 mm or 2 mm). Furthermore, the difference between the interfragmentary displacements being compared was required to be at least the value of the difference threshold (1 mm or 2 mm). Results were presented for all combinations of the various magnitude and difference threshold values.

In addition to the thresholds defined for interfragmentary displacement, rotational thresholds (magnitude and difference) were established for comparisons of interfragmentary rotation. It was decided that rotations involving 2 mm of displacement on the outer surface of the tibia would be clinically meaningful. This displacement value and the average tibial outer radius at the location of the cut were used to calculate a rotation threshold of 8° using the arc length formula for a circle (arc length = radius x angle in radians). At least one of the rotations being compared needed to be at least 8° to meet the rotational magnitude threshold. Moreover, the difference between the rotations being compared must be greater than the rotational difference threshold of 4°. Four degrees of rotation corresponds to a difference of approximately 1 mm displacement on the outer surface of the tibia.

Results

Interfragmentary displacement and rotation mean and standard deviation values for the three trials conducted on each specimen for each configuration are presented in Table 1. Compression testing resulted in no significant interfragmentary rotations, with all rotations being less than two degrees.

Significant configuration comparisons for various fracture obliquities at designated interfragmentary displacement thresholds were presented in Table 2 (p-value of less than 0.001).

Table 1. Interfragmentary displacements and rotations at 1,000 N compressive load (mean ± SD)

Obliquity (degree)	Configuration	Displacement (mm)	Rotation (degree)
0	1	0.2±0.1	0.3±0.1
0	2	0.2±0.0	0.1±0.0
0	3	0.2±0.0	0.2±0.0
0	4	0.1±0.0	0.0±0.0
0	5	0.1±0.0	0.0±0.0
0	6	0.0±0.0	0.0±0.0
30	1	0.2±0.0	-0.3±0.0
30	2	0.1±0.0	-0.2±0.0
30	3	0.2±0.0	-0.3±0.0
30	4	0.1±0.0	-0.4±0.1
30	5	0.2±0.0	-0.4±0.1
30	6	0.1±0.0	-0.2±0.1
40	1	0.1±0.0	0.0±0.0
40	2	0.1±0.0	0.0±0.0
40	3	0.1±0.0	-0.1±0.0
40	4	0.7±0.2	-1.6±0.7
40	5	0.7±0.1	-0.8±0.3
40	6	1.7±0.0	-1.1±0.4
50	1	0.1±0.0	-0.1±0.0
50	2	0.2±0.0	-0.2±0.0
50	3	0.2±0.0	-0.1±0.0
50	4	1.2±0.2	-1.4±0.6
50	5	1.8±0.1	-0.9±0.5
50	6	2.1±0.1	-0.8±0.2
60	1	0.1±0.0	0.0±0.0
60	2	0.4±0.1	0.1±0.1
60	3	0.2±0.0	0.0±0.0
60	4	3.1±0.2	-0.9±0.3
60	5	3.6±0.1	-0.6±0.3
60	6	4.0±0.1	-0.6±0.2
Spiral	1	0.4±0.1	-0.3±0.3
Spiral	2	0.3±0.0	0.0±0.2
Spiral	3	0.5±0.0	0.3±0.2
Spiral	4	1.1±0.1	1.5±0.3
Spiral	5	1.6±0.3	1.3±0.4
Spiral	6	1.7±0.5	1.0±0.7

Magnitude threshold: 1 mm, difference threshold: 1 mm

For a fracture obliquity of 40°, configuration 6 contained significant greater interfragmentary displacement compared to all other configurations. For a fracture obliquity of 50°, configurations 4, 5, and 6 displayed interfragmentary displacements that were significantly larger than configuration 1. Configurations 5 and 6 had significant greater values than configuration 2, and configurations 4, 5, and 6, were significantly greater than configuration 3. For a fracture obliquity of 60°, configurations 4, 5, and 6 were significantly larger than configurations 1, 2 and 3. For a spiral fracture, configurations 5 and 6 were significantly greater than configurations 1, 2, and 3.

Magnitude threshold: 1 mm, difference threshold: 2 mm

For a fracture obliquity of 60°, configurations 4, 5, and 6 displayed significant greater interfragmentary displacement compared to configurations 1, 2, and 3.

Magnitude threshold: 2 mm, difference threshold: 1 mm

For a fracture obliquity of 50°, configuration 6 displayed significant greater interfragmentary displacement compared to configurations 1, 2, and 3. For a fracture obliquity of 60°, configurations 4, 5, and 6 were significantly larger than configurations 1, 2, and 3.

Magnitude threshold: 2 mm, difference threshold: 2 mm

For a fracture obliquity of 60°, configuration 4, 5, and 6 showed significant greater interfragmentary displacement compared to configurations 1, 2, and 3.

Comparisons among fracture obliquities were also made. Significant fracture obliquity comparisons for various screw configurations at designated interfragmentary displacement thresholds are presented in Table 3.

Table 2. Significant configuration comparisons organized by fracture obliquity

Fracture obliquity	Significant configuration comparisons
Magnitude threshold: 1 mm, difference threshold: 1 mm	
40 degrees	6-1, 6-2, 6-3, 6-4, 6-5
50 degrees	4-1, 5-1, 6-1, 5-2, 6-2, 4-3, 5-3, 6-3
60 degrees	4-1, 5-1, 6-1, 4-2, 5-2, 6-2, 4-3, 5-3, 6-3
Spiral	5-1, 6-1, 5-2, 6-2, 5-3, 6-3
Magnitude threshold: 1 mm, difference threshold: 2 mm	
60 degrees	4-1, 5-1, 6-1, 4-2, 5-2, 6-2, 4-3, 5-3, 6-3
Magnitude threshold: 2 mm, difference threshold: 1 mm	
50 degrees	6-1, 6-2, 6-3
60 degrees	4-1, 5-1, 6-1, 4-2, 5-2, 6-2, 4-3, 5-3, 6-3
Magnitude threshold: 2 mm, difference threshold: 2 mm	
60 degrees	4-1, 5-1, 6-1, 4-2, 5-2, 6-2, 4-3, 5-3, 6-3

Table 3. Significant obliquity comparisons organized by configuration

Configuration	Significant obliquity comparisons
Magnitude threshold: 1 mm, difference threshold: 1 mm	
4	50-0, 60-0, Spiral-0, 50-30, 60-30, 60-40, 60-50, 60-Spiral
5	50-0, 60-0, Spiral-0, 50-30, 60-30, Spiral-30, 50-40, 60-40, 60-50, 60-Spiral
6	40-0, 50-0, 60-0, Spiral-0, 40-30, 50-30, 60-30, Spiral-30, 60-40, 60-50, 60-Spiral
Magnitude threshold: 1 mm, difference threshold: 2 mm	
4	60-0, 60-30, 60-40, 60-Spiral
5	60-0, 60-30, 60-40, 60-Spiral
6	50-0, 60-0, 50-30, 60-30, 60-40, 60-Spiral
Magnitude threshold: 2 mm, difference threshold: 1 mm	
4	60-0, 60-30, 60-40, 60-50, 60-Spiral
5	60-0, 60-30, 60-40, 60-50, 60-Spiral
6	50-0, 60-0, 50-30, 60-30, 60-40, 60-50, 60-Spiral
Magnitude threshold: 2 mm, difference threshold: 2 mm	
4	60-0, 60-30, 60-40, 60-Spiral
5	60-0, 60-30, 60-40, 60-Spiral
6	50-0, 60-0, 50-30, 60-30, 60-40, 60-Spiral

Magnitude threshold: 1 mm, difference threshold: 1 mm

For configuration 4, a fracture obliquity of 60° contained significant greater interfragmentary displacement compared to all other fracture obliquities. A fracture obliquity of 50° displayed significant more interfragmentary displacement than fracture obliquities of 0° and 30°. A spiral fracture obliquity showed significant more interfragmentary displacement than a fracture obliquity of 0°.

For configuration 5, a fracture obliquity of 60° displayed significant greater interfragmentary displacement compared to all other fracture obliquities. A fracture obliquity of 50° showed significant larger displacement than fracture obliquities of 0°, 30°, and 40°. Interfragmentary displacement for a spiral fracture obliquity was significantly greater than fracture obliquities of 0° and 30°.

For configuration 6, a fracture obliquity of 60° contained significant greater interfragmentary displacement compared to all other fracture obliquities. Interfragmentary displacement for a fracture obliquity of 40° was significantly larger than that seen in fracture obliquities of 0° and 30°. Both a fracture obliquity of 50° and a spiral fracture obliquity displayed significant more interfragmentary displacement than fracture obliquities of 0° and 30°.

Magnitude threshold: 1 mm, difference threshold: 2 mm

For configurations 4 and 5, a fracture obliquity of 60° contained significant greater interfragmentary displacement compared to fracture obliquities of 0°, 30°, 40°, and spiral. For configuration 6, a fracture obliquity of 60° had significant greater interfragmentary displacement compared to fracture obliquities of 0°, 30°, 40°, and spiral. A fracture obliquity of 50° showed significant more interfragmentary displacement than fracture obliquities of 0° and 30°.

Magnitude threshold: 2 mm, difference threshold: 1 mm

For configurations 4 and 5, a fracture obliquity of 60° showed significant greater interfragmentary displacement compared to all other fracture obliquities. For configuration 6, a fracture obliquity of 60° contained significant greater interfragmentary displacement compared to all other fracture obliquities. A fracture obliquity of 50° showed significant more interfragmentary displacement than fracture obliquities of 0° and 30°.

Magnitude threshold: 2 mm, difference threshold: 2 mm

For configurations 4 and 5, a fracture obliquity of 60° displayed significant greater interfragmentary displacement compared to fracture obliquities of 0°, 30°, 40°, and spiral. For configuration 6, a fracture obliquity of 60° contained significant greater interfragmentary displacement compared to fracture obliquities of 0°, 30°, 40°, and spiral. A fracture obliquity of 50° displayed significant more interfragmentary displacement than fracture obliquities of 0° and 30°.

Discussion

Locked IM nailing is a standard method for treatment of displaced tibial shaft fractures[1-5]. The treatment of distal metaphyseal tibial fractures remains a challenging problem in modern fracture care. To exploit the benefits of IM nailing even in distal fractures, various modifications in the implants have been introduced. These changes include the number

Table 4. Interfragmentary displacements and rotations of 50 degrees fracture obliquity with 12 mm and 10.5 mm reaming at 1,000 N compressive load (mean ± SD)

Ream size (mm)	Configuration	Displacement (mm)	Rotation (degree)
12	1	0.1±0.0	-0.1±0.0
12	2	0.2±0.0	-0.2±0.0
12	3	0.2±0.0	-0.1±0.0
12	4	1.2±0.2	-1.4±0.6
12	5	1.8±0.1	-0.9±0.5
12	6	2.1±0.1	-0.8±0.2
10.5	1	0.1±0.0	-0.1±0.0
10.5	2	0.1±0.0	-0.2±0.1
10.5	3	0.1±0.0	-0.2±0.0
10.5	4	0.4±0.1	-0.7±0.5
10.5	5	0.5±0.1	-0.4±0.3
10.5	6	0.9±0.0	-0.3±0.2

and location of the locking holes in the nail. As a result of the ability to have distal locking in a multiplanar manner, IM nails have been successfully used for fixation of fractures in the distal metaphysis of the tibia[9,10,12,20].

With the growing use of these new generation nails in the treatment of fractures extending into the metaphysis, there has been a growing number of reported complications such as delayed healing, non-union, and angulatory or rotational malunion[7,8]. Im and Tae[7] and Janssen et al[8] concluded that plate and screws fixation could restore alignment better than IM nailing for the treatment of distal tibial fractures.

Modern tibial nail designs have interlocking holes that enable distal placement of screws to within 5 mm of the tip of the nail. Multiplanar patterns to a very distal extension are commonly found in these third generation nails.

Distal locking screws have less cortical purchase in metaphyseal bone, and control of the IM nail position in the distal tibial canal as well as control of the fracture fragments, depends on these screws. There is increased stress on the screws to maintain fracture alignment[21]. The locking screws are important in increasing torsional rigidity and compressive strength of the nail-screw construct. Because the metaphyseal flare of the distal tibia causes a widening of the IM canal as compared to the diaphysis, sufficient nail-bone contact is not provided, thus the interface between nail, bone, and locking screw number and configuration become an important variable in overall construct stability.

In the present study, the IM canal was reamed up to a diameter of 12 mm (2 mm greater than nail diameter) for all specimens to create similar bone/nail interfaces. The present study was designed to investigate the relationship between fracture obliquity and screw configuration at proximal and distal interlocking holes following tibial stabilization with IM nail fixation. The influence of screw configurations on construct stability was investigated at fracture obliquities ranging from 0° to 60° of obliquity including a spiral obliquity (spiral configuration and obliquity of 45° by definition).

Based on this model, our primary findings were organized by fracture obliquity. The data confirmed that not just the interlocking pattern but also the fracture configuration, contributed to overall construct stability when physiologic load was applied. In all these fracture constructs fracture ends were absolutely opposed, so a gap could not be attributed as a cause for this fracture migration. Our data was further stratified for significance by looking at a minimum fracture migration magnitude with applied load (either 1 mm or 2 mm), and an absolute threshold of displacement difference between two groups (either 1 mm or 2 mm).

For a magnitude threshold of 1mm and difference threshold of 1 mm, there were significant differences in interfragmentary displacement for fracture obliquities greater than or equal to 40° when the degree of interlocking was diminished. For a magnitude threshold of 1mm and difference threshold of 2 mm, significant findings were only present in fracture obliquities greater than or equal to 60°. Interfragmentary displacement was significantly increased, in compression loading mode, when a progressive fracture obliquity degree was tested. For a magnitude threshold of 2 mm and difference threshold of 1 mm, significant findings were present in fracture obliquities greater than or equal to 50°. For a magnitude threshold of 2 mm and difference threshold of 2 mm, only significant finding was present in fracture obliquity 60°. Fracture obliquities of 30° or less were adequately stabilized under compressive loading with an IM tibial nail with all screw configurations tested in the present study. As seen for the data from configuration 4, they were also inherently stable with dynamic proximal interlocking.

Increasing fracture obliquity beyond 30° caused fracture instability as interlocking was decreased below two distal locking screws and one proximal locking screw set in a non-static mode. This data also showed that with proximal interlocking in a dynamic mode, with fracture obliquities 40 degrees and greater, there was resultant increase in shear at the distal tibial fracture site. This resulted in significant instability certainly by a fracture obliquity of 50 degrees.

It should be noted that no significant differences were seen between configurations 2 and 3, which involved different distal interlocking screw orientations (two parallel and two perpendicular distal screws) for all fracture obliquity patterns tested. This result was similar to those seen in the study by Chen et al, which demonstrated no statistical difference in nail stability between the two screw patterns in anterior, posterior, medial, or lateral directions, or torsional loading(22).

Mohammed et al, found that there was a high incidence of non-union in distal metaphyseal tibia fractures treated with IM nailing when only one distal locking screw was used. Therefore, they recommended two distal locking screws be used for these distal metaphyseal tibial fractures(23). This author did not factor in fracture obliquity as it related to end outcome. The successful implantation of a locked tibial nail for fixation of these distal tibial fractures relies on a clear understanding of both proximal and distal interlocking screw configurations for the particular fracture pattern that is present. When an oblique fracture is axially loaded, the force of opposition from the distal fragment will be distributed in both horizontal and vertical directions. Our data suggested that when treating a distal metaphyseal tibia fracture with IM nail fixation, the fracture obliquity and screw configuration significantly influence the construct stability and should be factored in to the decision-making in selecting the most advantageous fixation.

Lowenberg et al(24) also reported the fracture angulation introduces two elements: incomplete opposition to the axial load and the introduction of an unopposed horizontal component of force. After the summation of the vector forces, a resultant shear force is realized. Shear force is that which results parallel to the plane of opposition causing the contact surfaces to slide against each other. Shearing force is the culprit of instability in an oblique fracture and is exacerbated with increasing fracture angulation. Loading an oblique fracture will introduce an unopposed tangential component(24).

We recognized some limitations to our study. We used Sawbone tibial models instead of cadaveric models to ensure consistency and reproducibility. Cadaver bones are impractical as a testing material when comparing multiple tests with added variables due to the difficulty of obtaining bones of equivalent bone mineral density and strength for the consistency of the tests. There were no soft tissue or muscle restraints on the Sawbones and load was applied in a single vector. In addition to compressive loading, other loading conditions (torsion, bending) should be considered when selecting the appropriate fixation method.

In conclusion, our study demonstrated that optimizing the available screw configurations can minimize fracture site motion and shear in distal tibial fractures with larger fracture obliquities. To our knowledge, this represents the first study to correlate fracture obliquity and IM nail locking configuration to fracture displacement with an applied physiologic loading. The value of 1,000 N equates to normal physiologic load with walking for an average adult male. Our data showed that once fracture obliquity at the distal tibia exceeded 30 degrees and reached 40 degrees, and even with absolute fracture fragment opposition, shear becomes a major force in resultant fracture displacement. This also confirmed that the degree of instability of the bone/interlocking nail construct increased with increasing fracture obliquity. The data also showed that reducing proximal fixation from two screws to one (with the remaining proximal screw placed in a dynamic mode) even destabilized these distal fractures to a greater degree with fractures of higher obliquity. This data mirrored work done by the previous study reflecting the influence of fracture obliquity on construct stability in limbs stabilized with external fixation(24). Finally, combining the present data with the research already available on the optimum environment for fracture healing may allow optimum placement of interlocking screws not, only to provide stability, but also specifically to induce changes in strain at the fracture site. Further clinical studies are necessary to clarify the nature and the clinical significance of this effect.

What is already known on this topic?

To our knowledge, this represents the first study to correlate fracture obliquity and IM nail locking configuration to fracture displacement with an applied physiologic loading. The value of 1,000 N equates to normal physiologic load with walking for an average adult male.

What this study adds?

This biomechanical study establishes that when treating a distal metaphyseal tibia fracture with IM nail fixation, the fracture obliquity and screw configuration significantly influence the construct stability and should be factored in for decision-making in selecting the most advantageous fixation. Our results demonstrated that optimizing the available screw configurations can minimize fracture site motion and shear in distal tibial fractures with larger fracture obliquities.

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Potential conflicts of interest

None.

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การเคลื่อนไหวในตำแหน่ง distal tibia ภายหลังการใส่ nail: ปัจจัยที่มีผลต่อการเคลื่อนไหวในแง่ของมุมในการหัก น้ำหนัก และรูปแบบในการใส่สกรู

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ภูมิหลัง: *เพื่อประเมินความสัมพันธ์ระหว่างมุมในการหักและรูปแบบในการใส่สกรูว่ามีผลต่อ การเคลื่อนไหวในตำแหน่ง distal tibia ในขณะที่มีน้ำหนักแบบ physiologic กระทำต่อกระดูกที่ใส่ nail*

วัสดุและวิธีการ: *กำหนดรูปแบบการใส่ locking screw 6 รูปแบบ ในกระดูก distal tibia ที่หักในมุมต่าง ๆ โดยใช้กระดูกเทียมที่ ream โพรงกระดูกให้กว้างกว่า nail 2 มิลลิเมตร จากนั้นนำไปทดสอบโดยใส่น้ำหนักแบบ axial compression ทั้งแบบ internal rotation และแบบ external rotation ที่ 0.25 องศา/วินาที ด้วยแรง 7 นิวตันเมตร เป็นเวลา 2 วินาที การทดสอบนี้ดำเนินภายใต้แรงกดที่ 20 นิวตัน และ 500 นิวตัน ตามลำดับ โดยประเมินรูปแบบของการใส่สกรูกับความมั่นคงในกระดูกที่หักในมุมต่าง ๆ กัน ตั้งแต่ 0 องศา ถึง 60 องศา*

ผลการศึกษา: *พบว่าเกิดการเคลื่อนเพิ่มขึ้นอย่างมีนัยสำคัญเมื่อมุมที่หักเพิ่มขึ้นขณะทำการทดสอบทั้งแบบ internal และ external rotation ที่แรงกด 20 นิวตัน และ500 นิวตัน สำหรับการทดสอบแบบ internal rotation พบว่าเกิดการเคลื่อนที่ของรอยหักอย่างมีนัยสำคัญ เมื่อมุมที่หักน้อยกว่าหรือเท่ากับ 40 องศา ในกรณีที่ใส่สกรู interlocking น้อยลง เมื่อมุมที่หักอยู่ระหว่าง 0 และ 30 องศา จะเกิดการหมุนที่รอยหักอย่างมีนัยสำคัญเมื่อใส่สกรู interlocking น้อยลง ซึ่งผลลัพธ์ออกมาในลักษณะคล้ายกันเมื่อทดสอบแบบ external rotation*

สรุป: *การใส่รูปแบบ interlocking screw ที่เหมาะสมจะสามารถช่วยลดการเคลื่อนไหว และแรงเฉือนในตำแหน่งกระดูก distal tibia ที่หัก ในมุมที่หักขนาดใหญ่ พบว่ามีการเคลื่อนบริเวณรอยต่อที่หักของกระดูกเพิ่มขึ้นอย่างมีนัยสำคัญเมื่อมุมในการหักเพิ่มมากขึ้นในแรงที่กระทำแบบ compression จากข้อมูลที่ได้สรุปว่าทั้งรูปแบบการใส่สกรู และมุมในการหักมีผลต่อความมั่นคงแข็งแรงระหว่างที่มีแรงกระทำแบบ physiologic compressive*