Retrograde Nailing of a Femoral Supracondyle

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abstract

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Because standard femoral supracondylar nails have certain disadvantages, they are often replaced by traditional femoral or tibial locked nails. The purpose of this study was to make a biomechanical comparison between both types of traditional locked nails to determine which technique was more suitable for treating unstable femoral supracondylar fractures. Fourteen left Sawbones femurs (Pacific Research Laboratories, Vashon, Washington) were osteotomized in the femoral supracondylar area. One centimeter of the medial cortex in the proximal fragment was obliquely removed to simulate an unstable fracture without shortening. Seven specimens were treated with traditional retrograde dynamic femoral locked nails, and the other 7 with traditional retrograde dynamic tibial locked nails. All specimens were tested with a servohydraulic materials testing machine to compare their relative stability. Static compression, dynamic cyclic compression, and static compression to failure were tested. An extensometer was used to measure the displacement of fragments. Displacement between the fragments increased following the increment in loads in both nails. The load–displacement curve was nearly linear up to 1000 N for both nails. The femoral nail had a greater stiffness compared with the tibial nail at 100 and 200 N ($P=.02$ and $P=.04$, respectively) in static compression and at 700 to 1000 N ($P=.01$ in each case) in dynamic cyclic compression, as well as larger loads in static compression to failure (8663 vs 7547 N, respectively; $P<.001$). Clinically, a traditional femoral locked nail may be more suitable to replace a standard femoral supracondylar nail in a retrograde fashion to treat an unstable femoral supracondylar fracture.
Retrograde locked intramedullary nailing is widely used to treat femoral supracondylar fractures.1-4 The advantages of this technique are that it (1) may be used as a closed technique, (2) may be used as a load-sharing device, (3) has a shorter lever arm for bending loads compared with plates, and (4) is not affected by the femoral condylar contour during nail insertion.5-7 A high union rate with a low complication rate has been reported in the literature.8,9

A Green-Seligson-Henry nail was the first standard retrograde locked nail used in the treatment of femoral supracondylar fractures.10 Because of their short length, all locked screws can be accurately inserted with a target device. Therefore, an image intensifier may not always be necessary intraoperatively. However, the short length of a Green-Seligson-Henry nail may create a stress riser in the femoral shaft, which can introduce a femoral shaft stress fracture.11 The end of a retrograde locked nail is recommended to reach the level of the lesser trochanter. Accordingly, insertion of locked screws in the upper end of a retrograde locked nail may require the assistance of an image intensifier. In general, insertion of locked screws in the hip area is technically demanding. In addition, the high cost of a standard supracondylar nail may restrict its wide use.

A traditional femoral or tibial locked nail is usually used to replace a standard supracondylar nail.12,13 To prevent a stress fracture, the end of these nails reaches the level of the lesser trochanter. Clinically, these nails are normally used in a dynamic mode, and locked screws are not inserted in the upper end of the nails. Although a high success rate has been reported,14 such a technique may not be applied in all types of femoral supracondylar fractures. Because traditional femoral or tibial locked nails have different contours, their individual use in the femoral supracondylar region may create a varied biomechanical effect. In the current prospective study, the biomechanical effect between both locked nails was compared. As a result of this comparison, it may be possible to recommend which device is better for the treatment of unstable femoral supracondylar fractures.

**Materials and Methods**

Fourteen left Sawbones femurs (Model #3306; Pacific Research Laboratories, Vashon, Washington) were evenly divided into 2 groups15-17: 1 for testing traditional femoral locked nails and 1 for testing traditional tibial locked nails. The femur had a length of 45 cm (from the piriformis fossa to the intercondylar notch).

A transverse osteotomy was made 3 cm proximal to the medial femoral condyle on all 14 femurs; then, an oblique osteotomy (1 cm length) was made on the proximal fragment from the superomedial to the inferolateral cortex. Subsequently, 1 cm width of the lateral aspect of the proximal fragment was transversely excised. The proximal and the distal fragments were reduced, tibial locked nails were inserted in a retrograde fashion. Two transverse tibial locked screws were inserted in the femoral supracondyle. No locked screws were inserted in the upper part of the femur.

![Figure 1: Illustration of the testing protocol. A transverse osteotomy was made 3 cm proximal to the medial femoral condyle on all 14 left femurs; then, an oblique osteotomy (1 cm length) was made on the proximal fragment from the superomedial to the inferolateral cortex. Subsequently, 1 cm width of the lateral aspect of the proximal fragment was transversely excised. After the proximal and the distal fragments were reduced, tibial locked nails were inserted in a retrograde fashion. Two transverse tibial locked screws were inserted in the femoral supracondyle. No locked screws were inserted in the upper part of the femur.](image-url)
The femoral condyle was potted with low-melting alloy in a 6×10-cm block. The femoral shaft was secured at 7° of adduction in the coronal plane and neutral in the sagittal plane. Thus, the mechanical axis was vertical to the ground. A metal cup that matched the femoral head was used for compression of the femur. An extensometer (MTS Systems Corporation) was placed with a vertical contact on the surface of the femoral shaft between both fragments medially to measure the displacement.

**Static Compression Testing**

A preload of 20 N was applied on the femoral head, which minimized the gap between the metal cup and the femoral head. A vertical compressive loading with a 0.5-mm per second increment up to 1000 N was applied directly to the femoral head. The applied load was recorded simultaneously with Testar II software (MTS Systems Corporation). The full range of displacement was set within 20 mm. The data acquisition was 1 data/0.01 mm.

**Dynamic Cyclic Compression Testing**

Using load control, loads were increased with each 100 N up to 1000 N applied to each construct with 500 cycles at a rate of 2 Hz. After each cycle increment, the reading of the displacement was obtained, and specimens were evaluated for evidence of failure. Failure was defined as pullout of the fixation screws, fracture displacement >2 mm, or permanent implant deformation.

**Static Compression-to-failure Testing**

Loads were applied until failure for each femur, and the ultimate failure strength was obtained. The static compressive strength of each group was obtained from the average failure strength of the 7 femurs in each group.

All data were compared using a paired Student’s t test. A P value of .05 indicated statistical significance.

**RESULTS**

All 14 specimens completed all 3 tests. In the static compression test, displacement between both fragments increased following increased loads in both nails. The load–displacement curve was nearly linear up to 1000 N for both nails (Figure 4). The femo-
ral nail had a greater stiffness compared with the tibial nail at 100 and 200 N \((P=.02\) and \(P=.04\), respectively). However, other comparisons were not statistically significantly different (Table).

In the dynamic cyclic compression test, displacement between both fragments increased following increased loads in both nails. The load–displacement curve was nearly linear up to 1000 N for both nails (Figure 5). The femoral nail had a greater stiffness compared with the tibial nail at 400, 700, 800, 900, and 1000 N \((P=.04, P=.01, P=.01,\) and \(P=.001\), respectively). However, other comparisons were not statistically significantly different (Table).

In the static compression-to-failure test, the femoral nail failed at 8663±224 N, and the tibial nail failed at 7547±221 N \((P<.001)\) (Table). All specimens failed due to transcervical femoral neck fractures (Figure 6). All shafts and implants were intact.

**DISCUSSION**

Factors that favor fracture healing are minimal gap, adequate stability, and sufficient nutrition supply.\(^\text{18}\) By using dynamic intramedullary nailing to treat long-bone fractures, the gap between both fragments can be minimized.\(^\text{19,20}\) With a closed technique or minimized dissection of soft tissues, the periosteal vascularity can be preserved and nutrition supply can be well maintained.\(^\text{10,14}\) If local stability can be suf-

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### Table

**Displacement of Fragments Following Increased Compressive Loads**\(^a\)

<table>
<thead>
<tr>
<th>Load, N</th>
<th>Static Compression, mm</th>
<th>Dynamic Cyclic Compression, mm</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Femoral Nail (n=7)</td>
<td>Tibial Nail (n=7)</td>
</tr>
<tr>
<td>100</td>
<td>0.013±0.002</td>
<td>0.016±0.002</td>
</tr>
<tr>
<td>200</td>
<td>0.027±0.002</td>
<td>0.030±0.002</td>
</tr>
<tr>
<td>300</td>
<td>0.041±0.003</td>
<td>0.045±0.004</td>
</tr>
<tr>
<td>400</td>
<td>0.057±0.005</td>
<td>0.059±0.004</td>
</tr>
<tr>
<td>500</td>
<td>0.070±0.007</td>
<td>0.073±0.005</td>
</tr>
<tr>
<td>600</td>
<td>0.083±0.008</td>
<td>0.087±0.005</td>
</tr>
<tr>
<td>700</td>
<td>0.095±0.009</td>
<td>0.099±0.004</td>
</tr>
<tr>
<td>800</td>
<td>0.106±0.009</td>
<td>0.112±0.005</td>
</tr>
<tr>
<td>900</td>
<td>0.116±0.011</td>
<td>0.124±0.004</td>
</tr>
<tr>
<td>1000</td>
<td>0.126±0.010</td>
<td>0.135±0.005</td>
</tr>
<tr>
<td>Failure load</td>
<td>8663±224</td>
<td>7547±221</td>
</tr>
</tbody>
</table>

\(^a\)Data expressed as mean±standard deviation.\(^b\)Statistical significance.
ficiently provided, fracture healing is normally predictable. The current study biomechanically compared a traditional retrograde femoral locked nail and a traditional retrograde tibial locked nail to identify the more relatively stable device.

The mechanism of a dynamic intramedullary nail to stabilize a long-bone fracture is by way of a 3-point fixation principle.\textsuperscript{21,22} The axial compressive and rotational stabilities are provided by friction between the nail and the bone.\textsuperscript{23-25} The friction forces between the nail and the bone decide the degree of stability. Mechanically, the wider the contact area between the nail and the bone, the bigger the friction forces.\textsuperscript{26} Because the contour of a femoral locked nail is more similar to the femur than to a tibial locked nail, the contact area between the nail and the bone is wider in the femur.\textsuperscript{27,28} Thus, a femoral locked nail should have greater success than a tibial locked nail in stabilizing the femur. Although in the current study the comparison is only statistically significant at 100 and 200 N with the static compression test and 700 to 1000 N with the dynamic cyclic compression test, other comparisons may be statistically significant if the testing specimens are increased.

In the current study, a tibial locked nail did not match snugly to the femur in a retrograde fashion.\textsuperscript{27} As a result, the fragment surface was revised to reduce the fracture. In such cases, the bone contact between the proximal and distal fragments may not be complete, which may reduce the testing stability. Clinically, a femoral locked nail is more commonly used in treating a femoral supracondylar fracture than a tibial locked nail.\textsuperscript{12,14} The current study confirmed this was a better choice.

When human beings ambulate, the knee sustains 3 to 5 times the body weight of stresses by axial compression, bending, and torsion.\textsuperscript{29,30} In the current study, a traditional femoral locked nail showed a better axial compressive and bending stability compared with a traditional tibial locked nail. Clinically, the fracture surface is normally rugged.\textsuperscript{31} After fracture fragments are reduced and compressed by axial compressive forces, the fracture surface is interlocked, and rotational stability increases. An unlocked intramedullary nail has been successfully used in the treatment of middle shaft noncomminuted long-bone fractures.\textsuperscript{32}

Mechanical testing for fixation stability may use static or dynamic cyclic compression, and each has achieved individual support.\textsuperscript{33-35} In the current study, static and dynamic cyclic compressions achieved consistent results. A femoral locked nail was superior to a tibial locked nail.

A 12-mm-diameter femoral locked nail has a 6.4-mm proximal diagonal screw, and a 12-mm-diameter tibial locked nail has 2 proximal transverse screws. The biomechanical effect may be affected by these screws due to their close proximity to the fracture site.\textsuperscript{36} However, in the current study, all specimens sustained transcervical femoral neck fractures when undergoing static compression to failure. The osteotomy site, the nailed sawbone femur, and the nail with screws were completely intact. The femoral neck tolerated >750 kg of static compressive forces before fracturing. Thus, once a dynamic femoral or tibial locked nail is used in a retrograde fashion to treat a femoral supracondylar fracture, an implant failure should be unlikely to occur. In contrast, implant failure is not uncommon when an antegrade locked nail is used to treat a femoral supracondylar fracture.\textsuperscript{37}

Variations exist in estimating numbers of steps in daily activity.\textsuperscript{38,39} In the current study, 500 cycles were used to test dynamic cyclic compression when compressive forces were increased.\textsuperscript{40} Clinically, under protected weight bearing, the number of steps may not greatly affect the fixation stability.\textsuperscript{41,42}

A limitation of the current study is the small number of specimens, which may have affected the results of the statistical comparisons.\textsuperscript{35,39} All data showed that a femoral locked nail had better stability than a tibial locked nail. However, a small number of comparisons showed statistical significance. If the sample sizes were increased, more comparisons may have achieved statistical significance.

**Conclusion**

Because no previous reports have compared the 2 types of locked nails in treating femoral supracondylar fractures either biomechanically or clinically, the data of the current study cannot be compared with other findings. However, experimentally and theoretically, a femoral locked nail has a better stability than a tibial locked nail. The former should be preferentially considered when a femoral supracondylar fracture with an adequate indication is treated. The latter may be considered when a femoral locked nail is unsuitable for use, such as a short femur without an adequate length of femoral locked nails.

**References**


