BIOMECHANICAL COMPARISON FOR UNSTABLE FEMORAL-SUPRACONDYLAR FRACTURES TREATED WITH RETROGRADE, TRADITIONAL FEMORAL OR TIBIAL LOCKED NAILS

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SUMMARY

Retrograde locked intramedullary nailing has gradually been widely used to treat femoral supracondylar fractures. Because a standard femoral supracondylar nail has unique disadvantages: high price and potentially inducing a femoral shaft stress fracture, it is often replaced by a traditional femoral or tibial locked nail. A biomechanical comparison was therefore made between both traditional locked nails in order to recommend a better one in treating unstable femoral supracondylar fractures.

Fourteen left sawbone femurs were osteotomized in the femoral supracondylar area to simulate an unstable fracture without shortening. Seven specimens were treated with retrograde dynamic traditional femoral locked nails and other seven, retrograde dynamic traditional tibial locked nails. All specimens were tested with a servohydraulic Material Testing System machine to compare the relative stability. Static compression, dynamic cyclic compression, and static compression to failure were investigated. An extensometer was used to measure displacement of fragments.

Displacement between both fragments increased following increment of loads in both nails. The load-displacement curve showed nearly linear up to 1,000N for both nails. The femoral nail had a larger stiffness as compared to the tibial nail at 100 N and 200 N ($p = 0.02$ and $0.04$, respectively) in static compression and at 700-1,000N ($p = 0.01$, in each case) in dynamic cyclic compression; moreover, larger loads in static compression to failure ($p < 0.001$).

INTRODUCTION

Retrograde locked intramedullary nailing has gradually been widely used to treat femoral supracondylar fractures [1]. Technically, insertion of locked screws in the hip area is generally technically demanding. Additionally, the high price of a standard supracondylar nail may greatly restrict its wide use. In the literature, a traditional femoral or tibial locked nail is used to replace a standard supracondylar nail [2]. The end of these nails reaches the level of the lesser trochanter to prevent a stress fracture. Clinically, these nails are normally used as a dynamic mode and locked screws in the upper end of nails are not inserted. Although a high success rate has been reported, such a technique may not be applied in all types of femoral supracondylar fractures. Because a traditional femoral or tibial locked nail has a different contour, individual use in the femoral supracondylar region may create a varied effect biomechanically.

METHODS

Sawbone femurs were used in this study. One was for testing using traditional femoral locked nails and the other one, using traditional tibial locked nails. Transverse osteotomy was made 3 cm proximal to the femoral condyle on two femurs; then, oblique osteotomy (1 cm length) on the proximal fragment was made from the superomedial to inferolateral cortex. Subsequently, 1 cm width of the lateral aspect of the proximal fragment was transversely excised (Figure 1). One oblique femoral locked screw (diameter, 6.4 mm; length, 80 mm) or two transverse tibial locked screws (diameter, 5 mm; length, 50, 60 mm) were inserted in the femoral condyle and the supracondyle. No locked screws were inserted in the upper end of the femur. Specimens were mounted in a uniaxial servohydraulic material testing system machine to compare relative stability of the two types of locked nails. The distal end of the femoral condyle was potted with low-melting alloy in a 6 cm X 10 cm block. The femoral shaft was secured at 7° adduction in the coronal plane and neutral in the sagittal plane.

Static compression testing:

A pre-load 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 0.5 mm/sec increment up to 1,000 N was applied directly onto the femoral head. 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 increased with each 100 N up to 1,000 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 any evidence of failure. Failure was defined as pullout of the fixation screws, fracture displacement greater than 2 mm or permanent implant deformation.

Static compression to failure testing:

All femurs were used for static compression to failure testing. Loads are applied until failure for each individual femur and the ultimate failure strength was obtained. The static compressive strength of each group was obtained from the average failure strength of seven femurs.
RESULTS
In the static compression test, displacement between both fragments increased following increased loads in both nails. The load-displacement curve showed nearly linear up to 1,000 N for both nails (Figure 2). The femoral nail had a larger stiffness as compared to the tibial nail. In the dynamic cyclic compression test, displacement between both fragments increased following increased loads in both nails. The load-displacement curve showed nearly linear up to 1,000 N for both nails (Figure 3). The femoral nail had a larger stiffness as compared to the tibial nail. In the static compression to failure test, the femoral nail failed at 8,663 and the tibial nail failed at 7,547 N. All specimens failed due to transcervical femoral neck fractures. All the shaft and implants were intact.

DISCUSSION
The mechanism of a dynamic intramedullary nail to stabilize a long bone fracture is by way of three-point fixation principle. The axial compressive and rotational stabilities are provided by friction between the nail and the bone. The friction forces between the nail and the bone decide the degree of the stability. Mechanically, the wider is the contact area between the nail and the bone, the bigger are the friction forces. Because the contour of a femoral locked nail is much more similar to the femur as compared to a tibial locked nail, the contact area between the nail and the bone is much wider in the former. Thus, a femoral locked nail should have much better stability as compared to a tibial locked nail in stabilizing the femur. Although in the present study the comparison is statistically significant only at 100 N and 200 N with the static compression test and 700-1,000 N with the dynamic cyclic compression test, more comparisons may be statistically significant as long as testing specimens are increased.

Mechanical testing for fixation stability may use static compression or dynamic cyclic compression and each has achieved individual support. Additionally, rotational stability is considered more crucial than axial compression stability by some orthopedists. In the present study, rotational stability is not compared but static or dynamic cyclic compression has achieved a consistent result. A femoral locked nail is superior to a tibial locked nail in use.

A 12 mm diameter of femoral locked nail has one 6.4 mm proximal diagonal screw and a 12 mm diameter of tibial locked nail has two proximal transverse screws. The biomechanical effect may be affected by these screws due to their close to the fracture site. However, in the present study with static compression to failure, all specimens sustain transcervical femoral neck fractures. The osteotomy site, the nailed sawbone femur, and the nail with screws are completely intact. The femoral neck has tolerated more than 750 kg of static compressive forces then fractures. Thus, once a dynamic femoral or tibial locked nail is used retrogradely in treating a femoral supracondylar fracture, an implant failure should occur uncommonly. On the contrary, implant failure is not uncommon with an antegrade locked nail to treat a femoral supracondylar fracture.

CONCLUSIONS
Clinically, a traditional femoral locked nail may be more suitable to replace a standard femoral supracondylar nail with a retrograde fashion to treat an unstable femoral supracondylar fracture. A tibial locked nail may be considered when a femoral locked nail is inadequate in use because of a short femur.

REFERENCES