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A Biomechanical Comparison of Periprosthetic Femoral Fracture Fixation in Normal and Osteoporotic Cadaveric Bone

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Abstract: Several techniques are described for fixation of Vancouver B1 femoral shaft fractures after total hip arthroplasty. Twenty-four femurs were scanned by dual x-ray absorptiometry scanned and matched for bone mineral density. Femurs were implanted with a cemented simulated total hip prosthesis with a simulated periprosthetic femur fracture distal to the stem. Fractures were fixed with Synthes (Paoli, Pa) 12-hole curved plates and 4 different constructs proximally. Each construct was loaded to failure in axial compression. Constructs with locking and nonlocking screws demonstrated equivalent loads at failure and were superior in load at failure compared with cables. Cable constructs failed proximally. No proximal failures occurred in specimens fixed with screws and cables. A combination of locked or nonlocked screws and supplemental cable fixation is recommended for the treatment of Vancouver B1 periprosthetic femur fractures. **Keywords:** periprosthetic, Vancouver B1 fracture, cadaver, biomechanics, fixation.

Periprosthetic fractures complicate approximately 0.4% of primary total hip arthroplasties (THAs) and 2.1% of revision THAs [1-3]. Risk factors include osteoporosis, rheumatoid arthritis, revision surgery, stress shielding, stress risers, cortical perforation, and component loosening. Frequently, treatment of such fractures is complicated by osteoporosis and poor quality of the remaining bone. The ultimate goals in the management of periprosthetic fractures are to provide the patient with fracture union, a stable prosthesis, and a functional limb suitable for ambulation.

Management is based upon fracture location and implant stability. *Vancouver B1 periprosthetic femur fractures* are defined as fractures occurring at or near the distal tip of a well-fixed prosthesis [4]. These fractures are associated with a high complication rate because of their instability and suboptimal fixation methods. Surgical treatment has included open reduction and internal fixation with different combinations of plates, strut allografts, cables, and screws. Many variations exist. The most common is an Ogden-type construct with a plate secured with cables proximally and screws distally [5].

The biomechanics of traditional fixation devices used for periprosthetic fractures at the hip have been well studied [6-11]. They have also been evaluated in clinical practice [12-20].

Locking plates have been introduced for the treatment of complex fractures [21]. Although they are frequently used in trauma cases, there are few studies examining their use in periprosthetic fractures. One study examined locked plates compared with conventional cable plates in osteoporotic cadaveric bone [9]. Another biomechanical study compared locked and conventional plating in a sawbones model [22]. To our knowledge, there is no study examining locked plates in both normal and osteoporotic cadaveric bones. The purpose of this study was to evaluate 4 periprosthetic femoral shaft fracture fixation techniques to determine load to failure and mode of failure. We hypothesized that locked plating provides increased biomechanical stability in normal and osteoporotic bones.

Materials and Methods

Institutional review board approval was obtained. Twenty-four embalmed human femurs were stripped

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Table 1. Construct Configuration and Distribution

Construct	Proximal Fixation	Distal Fixation	Fracture Gap, cm	No. of Specimens
A	3 unicortical 5.0-mm locking screws	4 standard 4.5-mm bicortical screws	2	6
B	3 cables, 3 unicortical 5.0-mm locking screws	4 standard 4.5-mm bicortical screws	2	6
C	3 cables, 3 unicortical 4.5-mm standard screws	4 standard 4.5-mm bicortical screws	2	6
D	3 cables	4 standard 4.5-mm bicortical screws	2	6

of surrounding muscle and soft tissue. Dual x-ray absorptiometry (DEXA) scans were performed on each femur so that they could be matched by bone mineral density (BMD). The femoral head was removed, and the canal was reamed. A straight metal carriage bolt measuring 10 cm with a 0.95-cm diameter was cemented into the femoral canal to simulate a femoral stem. A 45° oblique osteotomy, angled away (superolateral to inferomedial) from the lateral cortex, was performed 2 cm distal to the stem and cement mantle. The fracture was fixed, leaving a 2 cm gap between proximal and distal fragments. This gap eliminates the compressive effect of the fragments, effectively isolating the proximal fixation during testing and simulating a "worst-case" scenario with a comminuted fracture with no cortical apposition. Cement was injected and impacted with a calibrated restrictor handle retrograde to a level 2 cm distal to the stem and was controlled with a foam cement restrictor. The femoral condyles were removed, and the distal femur was potted in dental stone 2 cm below the end of the plate. Table 1 describes the 4 testing groups. Synthes (Paoli, Pa) 12-hole 4.5-mm broad curved periprosthetic locking plates were used for each femur and were applied according to the technique guide. Synthes 1.7-mm cables were tensioned to 294 N.

Biomechanical testing was performed on an Instron Mechanical Testing System (Instron Bi-Axial Servo-Hydraulic Testing Machine Model no. 8874; Instron, Norwood, Mass) using a technique similar to that described by Stoffel et al [23] and Kose et al [24]. Specimens in each group, 3 male and 3 female cadaver specimens (n = 6), were tested in axial compression with a 2 cm fracture gap. The femurs were matched by BMD after DEXA scan with a range from 0.43 to 1.09 g/cm^2. The constructs were mounted with the femoral shaft colinear to the axis of loading. The potted femur was semiconstrained at proximal and distal ends to allow the femoral shaft to bend into varus or valgus as the construct was axially loaded. The constructs were loaded through the simulated proximal femoral stem to failure at 0.5 cm/s (Fig. 1). Compressive axial load, displacement, cable slippage, and closure of the fracture gap were measured. *Failure* was defined as screw pullout, closure of the osteotomy, fracture, or permanent deformation of the plate. Force displacement curves were generated for each, and load at failure was determined based on these curves.

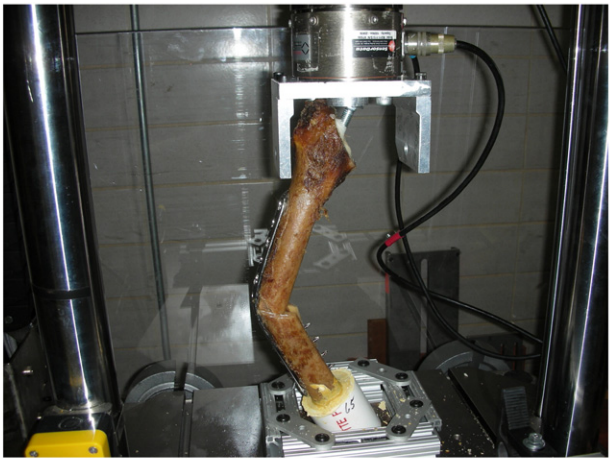

Fig. 1. Axial loading of cadaveric femur with proximal locking screw construct.

Statistical Analysis

Statistical analysis of the data was conducted through SPSS for Windows version 16 (SPSS, Chicago, Ill). One-way analysis of variance and post hoc least significant difference were performed on the load to failure data to determine differences.

Results

One-way analysis of variance showed a statistically significant difference among groups for load at failure (P = .002). Bone mineral density (P = .91) and T score (0.92) among the groups was not statistically different. The loads at failure of each of the constructs are shown in Table 2. The 4 groups vary in proximal fixation only with all groups fixed distally with bicortical screws. Post hoc testing with least significant difference found statistically significant differences between cables alone and the other 3 fixation forms. Fig. 2 is a graphic representation of the 4 fixation types with standard deviations. The cables alone were the least resistant to failure compared with the other 3 fixation constructs.

Group A—Unicortical Locking Screws (n = 6)

The average load to failure was 1085 N. One osteoporotic female femur specimen with a BMD of 0.43 g/cm^2 failed proximally with screw pullout and fracture of the lateral femoral cortex at 544.7 N. There were no distal failures. All other specimens failed with permanent varus deformation of the plate. Post hoc