INTRODUCTION:

The stiffness of a fixation construct affects the mechanism and progression by which a fracture heals. Locked plating constructs have improved fixation strength in weak bone, but their relatively high stiffness may suppress interfragmentary motion (IFM) to a level insufficient for optimal promotion of secondary bone healing.[1] This is especially of concern when locked plates are used as bridge plating constructs in absence of interfragmentary compression, whereby fracture healing relies on secondary bone healing by callus formation. Recent case studies on locked plating have supported this concern by describing deficient callus formation and delayed unions or non-unions.[2-3]

To address this concern, Far Cortical Locking (FCL) screws have recently been introduced, which have a reduced mid-shaft diameter to provide unicortical fixation in the far cortex without being rigidly fixed in the near cortex underlying the plate.[4] FCL screws have been shown to reduce the axial stiffness of a locked bridge plating construct by 88% without reducing construct strength, while inducing nearly parallel IFM in a synthetic bone model.[4]

To document FCL performance in human bone, the present study evaluated FCL screws in conjunction with locked bridge plating constructs applied to distal femur fractures in human cadaveric specimens. We hypothesized that FCL screws can decrease construct stiffness while retaining construct strength as compared to standard locked plating constructs.

METHODS:

Twenty-two paired fresh frozen human femora (age 61-93; 8 male, 14 female) were screened for pathology, and bone mineral density was assessed by DEXA scans (Hologic, Bedford, MA). An OTA 33-A3 fracture was simulated by a 1-cm gap osteotomy 6 cm proximal to the intercondylar notch.Fractures were stabilized with periarticular locking constructs in absence of interfragmentary compression, whereby fracture healing relies on secondary bone healing by callus formation. Recent case studies on locked plating have supported this concern by describing deficient callus formation and delayed unions or non-unions.[2-3]

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For quasi-physiological loading, specimens were aligned in a material testing system (Instron 8874, Instron, Canton, MA) to apply load through the centers of the femoral head and intercondylar notch. The proximal and distal ends of the femur were potted with bone cement into custom fixtures. The proximal fixture was hinged to allow for varus/valgus rotation around the femoral head center.

Specimens were loaded once to 1,200 N for pre-conditioning. Subsequently, construct stiffness was measured by loading each femur to 1,200 N in 50 N increments. After each load increment, resulting IFM was measured with digital calipers at the near and far cortex. Stiffness at the near and far cortex was calculated by dividing each load increment by the resulting IFM. The durability of constructs was evaluated by dynamic loading at load magnitudes representative of level walking.[6] Each specimen was loaded for 100,000 cycles at 1,870 N (2.4 times body weight, BW). Subsidence, representing the progressive collapse of the osteotomy gap, was measured in real-time with two miniature electronic motion sensors (pBIRD; Ascension, Burlington, VT) adjacent to the osteotomy gap. Subsidence during cyclic loading in excess of 5 mm was deemed failure by loss of fixation, at which point dynamic loading was terminated. If a specimen survived 100,000 cycles without failure, residual construct strength was measured by quasi-static loading to failure in 500 N increments. Failure was defined as subsidence > 5 mm or catastrophic fracture, whichever occurred first. DEXA t-scores, stiffness and strength was statistically compared between construct groups using paired Student’s T-test at α=0.05.

RESULTS:

DEXA: T-Scores ranged from 2.5 to -3.4 and were not significantly different between FCL (-1.0 ± 1.7) and NCB groups (-1.1 ± 1.7, p = 0.6).

Construct Stiffness: FCL constructs exhibited a biphasic stiffness profile, while NCB constructs demonstrated a linear load-displacement behavior (Figure 2a). FCL constructs had a primary stiffness of 1,150 ± 324 N/mm. For loads above 800 N, the secondary stiffness of FCL constructs increased to 3,671 ± 1,155 N/mm due to near-cortex support. The primary stiffness of FCL constructs was 81% lower than that of NCB constructs (p<0.01). At 1 x BW loading, FCL constructs induced on average over 4 times more IFM than NCB constructs (p<0.01, Figure 2b).

At 1 x BW, IFM in the FCL group was 0.6 mm at both the near and far cortex. In NCB constructs, IFM was smaller at the near cortex (0.1 mm) than at the far cortex (0.2 mm).

Failure Mode: Ten of eleven pairs of femurs failed by distal fixation failure and one pair failed by diaphyseal fracture. Seven pairs survived 100,000 cycles of dynamic loading. In three pairs, both the FCL and NCB femurs failed during dynamic loading after an average of 12,700 and 10,150 cycles, respectively (p=0.16). In one pair, the NCB construct failed during dynamic loading, but the FCL survived 100,000 cycles.

Construct Strength: Of the seven pairs that survived dynamic loading, there was no difference in residual strength between FCL constructs (5,269 ± 1,122 N) and NCB constructs (4,956 ± 1,557 N, p = 0.30).

DISCUSSION: At low post-operative loading, elastic flexion of FCL screws can reduce construct stiffness by 81% compared to standard NCB constructs. FCL constructs had the same durability and strength as NCB constructs. Most importantly, at 1 x BW loading, FCL constructs permitted IFM motion at both the near and far cortex that was within the 0.5-1.0 mm range known to promote secondary bone healing.[8] Therefore, FCL screws enable stiffness reduction of standard locked plating constructs to promote secondary bone healing without decreasing construct strength. Nevertheless, this potential benefit of FCL screws on fracture healing has to be verified in vivo.

REFERENCES:


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