Finite Element Analysis of Donor Site Fracture Risk After Medial Femoral Condyle Flap Harvest: Implications for Optimal Harvest Site and Flap Size

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INTRODUCTION:

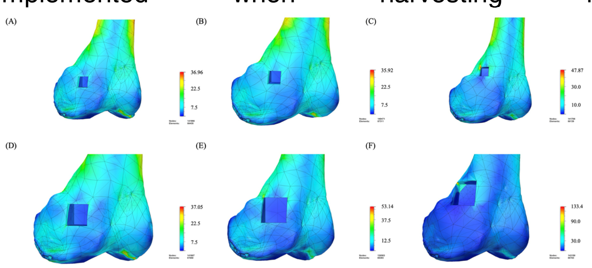
The medial femoral condyle (MFC) bone flap has become a versatile option used in an increasing array of procedures. However, because of varying sizes of bone flap harvested, postoperative activity modification is needed and concern for distal femur fracture exists. While past biomechanical studies have examined risk of fracture following MFC harvest in a single impulse load, no studies have examined the effect of cyclic loading on risk of femur fracture. This study aimed to evaluate the risk of fracture with standard weight-bearing after routine medial femoral condyle (MFC) harvest with varying harvest size and location using finite element analysis.

METHODS:

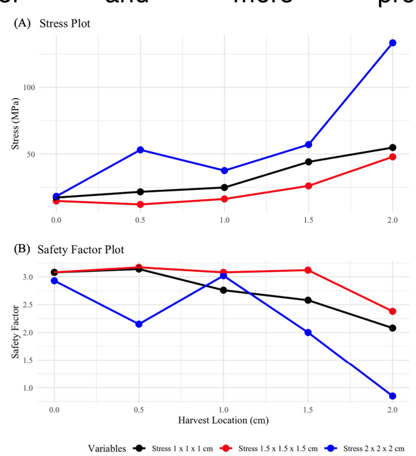
A finite element analysis (FEA) model developed from CT scans of healthy subjects evaluated the potential impact of MFC harvest on donor femur strength. Donor flaps were modeled as cubes of corticocancellous defects within the descending genicular angiosome (DGA) along the medial femoral condyle. Stress, strain, and safety factors were recorded during simulated single-leg stance, as a function of harvest size and location within the DGA. S-N curves were further used to determine the respective number of cycles to failure due to fatigue.

RESULTS: Among the 15 simulated harvest size and location combinations, the smallest (1 cm x 1cm x 1 cm) corticocancellous flap centered 0.5 cm proximal to the medial epicondyle demonstrated the most favorable stress (12.2 MPa), strain (0.002), safety factor (3.17), and fatigue (>10^6 cycles) profiles during single-leg stance. Larger and more proximally harvested flaps resulted in an increased risk of fracture. The largest (2 cm x 2 cm x 1.5 cm) and most proximally based flap (2 cm proximal) resulted in a precipitous increase in stress (133.4 MPa) and fatigue (10 cycles to failure) profile.

DISCUSSION AND CONCLUSION: Our results suggest that small corticocancellous flaps centered 0.5 cm proximal to the medial epicondyle are the most favorable for harvest, resulting in physiologically tolerable stress and strain values on the donor femur during single-leg stance. Our findings suggest that caution and weight-bearing restrictions should be implemented when harvesting larger and more proximally based flaps.



Stress map at the distal femur after MFC harvest for 1 cm x 1 cm x 1 cm at the (A) distal medial epicondyle, (B) 10 mm proximal, and (C) 20 mm proximal and for 2 cm x 2 cm x 2 cm at the (D) distal medial epicondyle, (E) 10 mm proximal, and (F) 20 mm proximal. Moving the excision site proximally from the distal medial epicondyle to 10 cm proximal and 20 cm proximal moves the indicated point of greatest stress indicated from the lateral condyle to the proximal posterior corner of the harvest site. Of note, the scale for the heat map of stress (MPa) varies for each simulation and is demonstrated in the lower right corner of the image.



Maximum stress (A) and safety factor (B) versus harvest location. Cortical stress values rise as the harvested bone flap increases in size or is taken more proximally along the medial femoral condyle. Safety factor sharply declines at the largest and most proximally based harvest parameters tested.