TRABECULAR BONE STRAIN CHANGES ASSOCIATED WITH SUBCHONDRAL BONE DEFECTS IN THE TIBIAL PLATEAU

*Anthony Brown, A.N., McKinley, T.O., Bay, B.K.
*+ Orthopaedic Research Laboratory, Department of Orthopaedic Surgery, University of California Davis, 4635 Second Ave., Sacramento, California, 95817.
Phone: (916)734-5745, Fax: (916)734-5750, e-mail: bkbay@ucdavis.edu

**Introduction:** Subchondral bone defects in the proximal tibia are commonly encountered with tibial plateau fractures. Bone defects and grafting treatments affect knee mechanics but the effects are not well understood. Changes in subchondral strain affect cartilage stress which likely contributes to post-traumatic arthritis. Historically, investigators have had to use analytical models to study trabecular mechanics. Texture correlation allows direct measurement of trabecular strain. The purpose of our study was to use this technique to evaluate two hypotheses related to the effects of subchondral trabecular defects. First, subchondral bone defects will increase strains in proximity to the defect. Second, morselized bone graft and PMMA will return strains to near normal levels.

**Methods:** One centimeter sections were cut from the midcoronal articulation of ten cadaver knees. Rough cut sections were frozen onto an aluminum base and milled to a thickness of 6.50 mm +/- 0.02 mm. Milled specimens were potted into aluminum loading platens with polymethylmethacrylate and transferred to our loading apparatus. Texture correlation is dependent on comparing high quality contact digitographs of loaded and unloaded specimens. The specimen and platens were secured to a loading frame designed to fit within a contact radiography unit. Force was determined by a load cell contacting the lower platens. A stepper motor axially loaded the specimens to 0 and 400N. Images were captured on Kodak Industries M film. All specimens were loaded intact and subsequently with three increasing circular bone defects immediately below the subchondral plate in the medial plateau. Defects were 10%, 20%, and 30% of the width of the medial plateau. Loads were repeated in eight knees after filling the large defect with morselized cancellous bone graft and subsequently with PMMA.

Contact digitographs were digitized using a light box and a 1k x 1k 16-bit CCD. Texture correlation measurements were performed with in-house code written in C and running on a Sun SPARCstation. Texture correlation compares digitized radiographs of a sample under load with an unloaded image to determine sub-pixel level displacements and measure strains at high spatial resolution. Strain is calculated from the displacement measurements. Strain components were calculated at 2500 analogous points within the epiphyseal and metaphyseal trabecular bone of the proximal tibia. The points were kept in correspondence by using an automated meshing based on consistently measured anatomical landmarks.

Each specimen was divided into juxtaarticular (within 3 mm of cartilage), epiphysial (between juxtaarticular region and physeal scar), and metaphyseal regions (below the physeal scar). These three regions were divided into inner and outer subregions. Median shear strain values were determined in the corresponding six subregions and were compared to intact samples using one way analysis of variance.

**Results:** Subchondral defects caused significant elevations in strain, especially in the epiphysis (Figure 1). The large defect also caused a large strain elevation in the outer juxtaarticular region (Table 1). Morselized bone graft eased strain elevations in the juxtaarticular region but accentuated strain elevations in the epiphysis and metaphysis. PMMA did not relieve strain concentrations near the jointline but decreased strains in the epiphysis and metaphysis.

**Discussion:** A significant percentage of tibial plateau fractures develop post-traumatic arthritis (PTA). Short term results are excellent, but after 7 years results are less satisfactory. Previous models have shown increasing stiffness in subchondral bone elevates cartilage shear stress. Strain elevations resulting from bony defects may drive an adaptive response leading to stiffened subchondral bone. By direct measurement, we found that intact structures uniformly distribute strain from the joint through the metaphysis. This likely represents the ideal condition for a load bearing bicondylar joint and should be one goal in reconstruction.

**Our results support the first hypothesis in that strain did increase with increasing defect size, but the effect was not strictly proportional. The substantial jump in strain magnitudes associated with the largest defect indicates a threshold phenomenon.**

The second hypothesis was better supported for PMMA than for morselized bone graft. Bone grafting did not ease strain elevations caused by the large defect, and accentuated strains in the epiphysis and metaphysis. PMMA eased epiphyseal and metaphyseal strain elevations, but elevated juxtaarticular strain. This is likely due to the bonding between the PMMA and the surrounding trabeculae, whereas bone graft in the acute phase lacks this bonding capability. PMMA is stiffer than normal trabecular bone, perhaps explaining persistently elevated strain in the outer juxtaarticular region. The ideal graft would have bonding characteristics like PMMA but have a modulus closer to trabecular bone.

<table>
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<th>20%</th>
<th>30%</th>
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**Table 1: Median shear strain values.**

(Statistically significant difference with p < 0.05 from intact in bold)

**Figure 1. Contour plots of maximum shear strain magnitude for one of the samples in intact, 30% defect, bone graft, and PMMA conditions.**


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