Patellofemoral Contact Mechanics After Quadriceps Tendon Graft Harvest
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Introduction
A minor number of cruciate ligament reconstructions performed in the United States are done using quadriceps tendon allografts. But it remains an important option for patients who have had prior cruciate reconstructions or who have incompetent hamstrings or patellar tendons.

Concern has been raised regarding the effect that the harvest procedure can have on the stress and wear patterns of the patellofemoral joint. It is possible that removal of a bone block from the proximal patella could change the structural properties of the bone and alter contact stresses on the joint. Prior work by Sharkey et al showed no changes in patellofemoral contact stress after harvest of central-third patellar tendon autografts at the distal pole of the patella. However, contact loads at the superior pole of the patella are larger and any effect caused by graft harvest may be magnified [7].

The purpose of this study was to evaluate patellofemoral contact stresses and quadriceps tendon strain in three phases of the central-third quadriceps tendon and bone block harvest procedure: 1) Normal intact extensor mechanism, 2) Post graft harvest, and 3) Post donor site closure.

Methods
Cadaveric specimens (n=5) were procured through our institutions willd body program after institutional review board approval of our study. Specimens were dissected using a combination of sharp and blunt techniques to remove the soft tissues with care to preserve all knee ligaments, retinacula, and capsule. The muscular tissue of the quadriceps was separated from the tendon which had been transected at a point 15cm proximal to the superior pole of the patella [7]. The tendons of the vastus lateralis, vastus medialis, vastus intermedius and rectus femoris, semitendinosus, and biceps femoris were separated into 6 distinct bundles [8]. A series of locked running stitches using #5 nonabsorbable suture was woven through each of these bundles for load application. The proximal stump of the femur was secured to a base plate. Sutures connected to the hamstrings were secured in line with the femur to prevent the leg from extending beyond 90 degrees of flexion. Thirty five pounds of force were distributed between the four bundles of the quadriceps with 13 1/3 pounds on the medialis, 3 1/3 pounds on the rectus, 5 pounds on the intermedius and 13 1/3 pounds on the laterals according to a crosssectional distribution technique[1].

One arm of a Tekscan KScan sensor [6, 9] (Tekscan, South Boston, MA) was inserted into the patellofemoral joint under the superior pole of the patella. Two differentiable variable reluctance transducers (Microstrain, Burlington, VT) were secured to the medial and lateral bands of the remaining quadriceps tendon and were connected to the data acquisition equipment.

Peak contact stress, contact area, center of force, and quadriceps tendon strain data were collected during three phases of testing. The first was under normal circumstances before harvest of the graft; the second was after graft harvest [10], and the third was after closure of the soft tissue harvest site using #2 sutures. ANOVA statistics were used to compare the phases of testing for significant changes with significance set at p ≤ 0.05.

Results
The results of this study are shown in Table 1. There was no significant change in contact stress (p=0.725), Contact Area (p=0.692), or position of the center of force in the transverse (p=0.282) or axial directions (p=0.462) during the phases of testing. There was also no significant change in strain in the medialis (p=0.440) or lateralis (p=0.990) bands of the remaining quadriceps tendon.

Discussion
The results of this study show that there were no significant changes in the contact mechanics of the patellofemoral joint or quadriceps tendon after harvesting a quadriceps tendon graft with its associated bone block or after repairing the soft tissue defect that had been caused by the harvest procedure. Regarding the hard tissue, the rigidity of the subchondral bone is enough to sustain and distribute the load in the proximal patella after removal of the central bone block without changing the peak contact pressure or contact area in the patellofemoral joint. Regarding the soft tissue, disruption of the middle third of the quadriceps tendon at its distal extent did not change the force vectors enough to change either the peak contact pressure or the position of the center of force at the patellofemoral joint. Nor was there a significant increase in the strain measured in the medial or lateral bands of tendon that remained after harvest.

The orientation of collagen fibers and the layers of the tissue have been shown to be highly variable[8] in the quadriceps tendon near its insertion at the patella. Disruption of the central third could have preferentially changed the influence of the vastus lateralis or vastus medialis on the orientation or bias of the patella in the trochlea thus changing the contact pressures in the joint. This was not found to be the case in this study.

Our results agree with analogous research done after patellar tendon harvest by Sharkey et al which also showed that there was no change in the contact mechanics of the patellofemoral joint after harvest of a bone block from the distal patella[7].

There were some limitations in this study. The magnitude of forces modeled in this study are lower than those seen during more vigorous activities. Higher forces may disclose changes that were not seen in our study. The distribution of forces between the separate tendons of the quadriceps muscles modeled only one balanced physiologic state and do not represent the range of activities that may be experienced in vivo. The anatomy of the layered quadriceps tendon is highly variable and our methods did not capture individual bundles of the remaining quadriceps tendon.

Significance
Patellofemoral pain is a significant cause of disability which could be exacerbated by surgical procedures that alter the contact mechanics at this joint. This study measures changes that occur in this location as a result of quadriceps tendon graft harvest.

BIBLIOGRAPHY