Does Venting Knee Joint Capsule Affect Laxity in TKA?

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Disclosures: E.L. Woodard: 3A; Smith and Nephew. C.T. Hebert: 4; Stryker Corporation, Johnson and Johnson. W.C. Gobbell: None. W.M. Mihalko: 1; B Braun, Aesculap Inc. 3B; B Braun, Aesculap, Inc, Medtronic, Inc. 5; Smith & Nephew Inc, B Braun, Aesculap Inc, Stryker Inc. 7; Elsevier, Springer.

Introduction: During both conventional and minimally invasive knee surgery, the knee joint capsule must be incised to allow access to the joint. When this violation occurs the intracapsular pressure is brought to ambient atmospheric pressure, eliminating the pressure gradient that normally contributes to stability of the joint. During knee flexion the joint capsule space is increased while synovial fluid volume remains constant, generating negative pressure within the capsule. The intracapsular volume is maximized at 90 degrees and the pressure generated is the most negative there, stabilizing the knee. Post-surgery the physiologic repair process restores negative pressure of the joint capsule within 7-10 days as granulation tissue bridges the incised capsular tissue. Post-total knee arthroplasty (TKA) rehabilitation regimens commonly involve extensive movements during the first several days of recovery [1]. While exercising the joint at moderate levels is beneficial to promote proper collagen tissue healing and prevent the formation of excess fibrotic tissue [1], aggressive rehabilitation activities undertaken within this initial period of repair may hinder long-term knee stability. If the knee joint is unable to regulate pressure properly, joint laxity can increase, leading to accelerated device wear and/or injury. The goal of this study was to evaluate the biomechanical changes in knee stiffness caused by the loss of negative pressure. Cadaveric TKA knees were tested before and after “venting” the joint capsule and the results were compared. Changes in rotational and varus/valgus laxity following venting were noted relative to the normal, pre-venting specimens. We hypothesize that venting the knee joint capsule will increase joint laxity when compared to the normal condition.

Methods: The specimens utilized in this study were total knee replacement fresh cadaveric specimens of donors who had previously undergone a total knee replacement (Medical Education and Research Institute (Memphis, TN) and Restore Life USA (Johnson City, TN)). IRB approval was obtained to perform the study. Eleven knee specimens (4 Left, 7 Right) were retrieved and all skin, subcutaneous tissue and muscle was removed while carefully retaining all aspects of the knee capsule and surrounding ligaments. The femur and tibia were cut transversely 180mm superior and inferior to the knee joint line, respectively. Each specimen had the femur and tibia potted using urethane epoxy in a coupling that allowed it to be mounted into a custom knee testing machine (Little Rock, AR). Specimens were then mounted with the tibia mounted vertically in the machine and the femoral coupling locked in a neutral position. During normal conditions and after venting, specimens were tested with the tibia at full extension and at 30, 60, and 90 degrees of flexion in relation to the femur. An upward vertical force of 30 N was placed under the tibia to maintain joint contact during all tests. At each flexion angle, a 1.5Nm internal and external rotational torque was applied about the tibial axis while the femur was fixed and the tibia was free to rotate about the joint center in the coronal plane. A 10 Nm varus and valgus torque was also applied to the tibia, while internal-external rotation was unconstrained. A fellowship-trained,
board-certified orthopedic surgeon then made a small horizontal incision with a number 10 scalpel blade on the medial side of the joint to vent any pressure inside the capsule. The deflection in degrees at ±10Nm varus and valgus torque in the coronal plane, referenced from normal neutral position, was recorded to determine the varus and valgus laxity for each test. Likewise, the deflection in degrees at ±1.5Nm internal and external torque in the transverse plane, referenced from the normal neutral position, was recorded to determine rotational laxity. Wilcoxon signed rank tests with Holms-Sidak corrections were used to determine if any statistically significant changes existed between vented capsule and normal conditions. Statistical families were broken by rotation (e.g. external). All statistical analyses were performed using SPSS version 22.0 (IBM-SPSS, Armonk, New York) software. A p-value less than 0.05 was considered significant at the 95% confidence level.

**Results:** Venting the joint capsule consistently increased laxity in all tests (Figures 1 and 2), most notably increasing valgus laxity by 1.3 degree and varus laxity by 1.7 degrees at 90 degrees of flexion. Out of the two, only varus was statistically different from normal (p=0.006). Internal rotation showed a significant (p=0.005) 2.0 degree change in laxity at 30 degrees of flexion, while external rotation laxity increased by 1.7 deg at 90 degrees of flexion.

**Discussion:** Increases in mean varus/valgus laxity and mean rotational laxity were observed at all angles of flexion. This supports the theory that negative pressure of the joint capsule in the intact knee is an important stabilizer in the physiological range of knee flexion. It was expected that the greatest changes in knee laxity following venting of the joint capsule would occur at 90 degrees of flexion, at which joint capsule space is maximum and negative pressure likely contributes most significantly to knee stability. While the increase in both varus and valgus laxity and external rotational laxity were the greatest at 90 degrees, the increase in internal rotational laxity was greatest at 30 degrees of flexion. During internal rotation at 30 degrees of flexion, the primary stabilizer of the intact knee is the posteromedial capsule, whereas at higher angles of flexion the superficial medial collateral ligament (sMCL) plays a more significant role in restricting internal rotation [2]. The greater relative contribution of the capsule to stability at 30 degrees of flexion than at 90 degrees of flexion explains the greater increase in internal rotational laxity caused by venting the capsule at 30 degrees flexion than at 90 degrees flexion. Limits of the study include small sample size (n = 11). A potential confounding variable was the variability of implant manufacturer and design between specimens; different designs possess varying material properties that affect the biomechanical response of the device to applied forces and torques. However, normalizing the data by comparing within subject changes should account for any variability in implant design or surgical technique.

**Significance:** Knowledge of how these surgical techniques affect capsule stiffness in flexion and extension emphasizes the importance of limiting patient rehabilitation activities immediately following total knee arthroplasty and other knee surgery. The results of this study should be considered when implementing a rehabilitation strategy during the 7-10 day period post-TKA in order to optimize surgical outcomes and maximize long-term knee stability.
Figure 1: Rotational Laxity Changes from Normal at Extension and 30 degrees of Flexion
+ Denotes P<0.05 * Denotes significance with Holms-Sidak correction within each family.

Figure 2: Rotational Laxity Changes from Normal at 60 and 90 degrees of Flexion
+ Denotes P<0.05 * Denotes significance with Holms-Sidak correction within each family.